Article

An Integrated Study of the Spatiotemporal Characteristics of the Impact of China's Digital Economy on the Upgrading of the Sports Industry

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Abstract: As the digital economy becomes a key driver of global economic growth, China's sports industry is currently undergoing a profound digital and intelligent transformation. Using Stata 18.0 software, this study conducts a comprehensive spatial autocorrelation analysis across 15 provincial-level regions in China from 2020 to 2024. It aims to systematically identify the complex integration patterns between the digital economy and the sports industry, providing robust empirical evidence and a solid theoretical foundation for effective policymaking. The empirical findings demonstrate that, first, the digital economy substantially advances sports industry upgrading and elevates its position in global value chains through technological integration, factor reorganization, and business-model innovation. Crucially, this positive impact exhibits a non-linear pattern of increasing marginal returns over time. Second, the effect displays marked spatiotemporal differentiation across the country. Spatially, the impact is significantly stronger in eastern China, forming high-value clusters in the Yangtze River Delta, Pearl River Delta, and Beijing-Tianjin-Hebei region. Temporally, it follows a clear diffusion path from core city polarization to broader surrounding areas via technology spillovers, capital flows, and model replication, although absolute regional disparities persist. Based on these comprehensive findings, this paper recommends implementing differentiated regional development strategies, establishing a unified national market for data factors to facilitate secure resource circulation, and strengthening cross-departmental collaborative governance to form a joint force for high-quality industrial transformation.

Keywords: digital economy; sports industry; spatiotemporal analysis; spatial econometrics; industrial upgrading

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1. Introduction

1.1. Research Background

The digital economy has become a key driver of global economic growth and industrial transformation [1]. Under China's 14th Five-Year Plan for Digital Economy Development, integrating digital technologies with the real economy is prioritized to empower traditional sectors. Although China's sports industry is expanding, it still faces challenges such as a suboptimal supply structure, uneven regional development, and gaps in digital application. Traditional models rely heavily on physical venues and manufacturing, leaving them constrained by geography and resource inefficiency.

Emerging digital forms—including smart venues, online fitness, digital events, and sports data services—offer solutions to these bottlenecks. Furthermore, the 14th Five-Year Plan for Sports Development emphasizes digital transformation in key sports sectors, shifting the focus of upgrading from quantitative growth to structural optimization and technological empowerment. Incorporating temporal evolution and spatial differences into a unified analytical framework, this paper examines the mechanisms, spatial effects,

and regional heterogeneity of the digital economy's impact on sports industry upgrading, aiming to inform high-quality development and policy refinement.

1.2. Research Significance

Existing research primarily examines the digital economy's impact on general manufacturing, services, or overall industrial structures, with limited attention to the distinctive features of the sports industry. As sports integrate traditional offline activities and emerging digital applications, its upgrading process exhibits unique patterns of integration and spatial variation [1]. This study bridges the digital economy, sports industry upgrading, and spatiotemporal analysis to broaden the theoretical understanding of digital empowerment in the sports sector.

The influence of the digital economy on sports industry upgrading shows pronounced regional variation: eastern China benefits from advanced infrastructure and strong consumption capacity, while central and western regions confront challenges related to infrastructure development and resource transformation efficiency [2]. Investigating these spatial disparities offers practical insights for local governments to design region-specific digital-sports policies and supports sports enterprises in optimizing online-offline integration strategies. Collectively, this research enhances understanding of how digital technologies improve sports resource allocation and promote balanced regional development.

1.3. Review of Chinese and International Literature

Extensive research explores the digital economy across three main dimensions:

1. Concept and Meaning: The digital economy is widely understood as a data-driven economic form in which digital knowledge and information serve as key production factors, modern networks function as essential carriers, and information and communication technology applications drive productivity gains and structural optimization [2].

2. Development Characteristics: Development has evolved beyond initial information technology applications toward deeper integration of digital and physical systems. This progression depends critically on infrastructure, human capital, technological capability, and underlying economic conditions [3]. Studies highlight pronounced regional disparities, spatial interdependencies, and operational features characterized by intelligence and networked coordination.

3. Integration of Digital and Real Economies: Digital technologies transform traditional industries through technology diffusion, platform-based connectivity, and reallocation of production factors. This integration reshapes endogenous growth drivers and strengthens regional coordination, while generating spatially heterogeneous outcomes [4].

Sports industry upgrading is defined as a transition from broad-scale growth toward an intensive, high-value-added model, propelled by technological innovation and value chain enhancement [5]. Fueled by rising household demand for sports-related goods and services, this upgrading proceeds along three principal pathways:

1. Accelerated digital and intelligent transformation—including smart venues, online fitness platforms, and virtual sporting events;
2. Deep cross-sector integration with health, tourism, and cultural sectors;
3. A strategic shift toward harmonizing economic returns with broader social benefits.

Policy frameworks such as Healthy China and the Outline for Building a Leading Sports Nation provide strategic guidance for this transformation, though challenges—including gaps in core technologies and incomplete realization of consumer demand—remain [6].

Formally defined at the 2016 G20 Summit, the digital economy reshapes industrial structures through workforce restructuring—generating technology-intensive roles while reducing reliance on routine tasks—and supporting green transformation by optimizing resource allocation and improving operational efficiency [7].

To measure the digital economy, scholars employ two primary methodological approaches:

Index Construction & Weighting Methods: Composite index systems are constructed and evaluated using techniques such as entropy-weighted TOPSIS, principal component analysis, or alignment with authoritative frameworks—including national readiness indices and digital economy measurement standards—across dimensions like infrastructure, digital industrialization, and industrial digitalization [2].

Statistical Satellite Accounts & Input-Output Models: National and provincial measurement frameworks are developed using growth accounting, satellite accounting methodologies, and multi-regional input-output tables to quantify scale, total factor productivity, and interregional factor linkages [8].

While existing literature provides a solid foundation regarding the conceptualization of the digital economy, digital-real integration, and general industrial upgrading, direct empirical and theoretical studies examining the digital economy's impact on sports industry structure remain limited. Most prior work focuses on traditional manufacturing or broad service sectors [9]. The precise mechanisms through which digital technologies reshape production processes, consumption patterns, and resource allocation within the sports sector require deeper theoretical articulation and empirical validation. Addressing these gaps, this paper investigates these underlying mechanisms and proposes policy recommendations aligned with China's regional development contexts and industrial characteristics.

1.4. Research Object and Methods

1.4.1. Research Object

This study examines the spatiotemporal characteristics of how the digital economy influences sports industry upgrading across China. Provincial-level administrative units serve as the fundamental spatial units for regional economic policy implementation; provincial panel data therefore effectively capture macro-level patterns, interprovincial disparities, and spatial interaction mechanisms, offering empirical insights into the digital economy's contribution to high-quality development of the sports industry [4].

1.4.2. Research Methods

1. Literature Review: Systematically reviews academic literature and policy documents on the digital economy, sports industry upgrading, and spatial econometrics to identify key findings, clarify research gaps, construct the theoretical framework, and inform methodology selection.
2. Comparative Analysis: Examines regional variations across eastern, central, and western China and tracks temporal dynamics to assess spatial disparities, stage-specific characteristics, and potential spatial heterogeneity.
3. Mathematical Statistics: Applies descriptive statistics—including mean, standard deviation, minimum, and maximum—to organize and evaluate indicator data, enabling preliminary assessment of distributional features, regional disparities, and evolutionary trends.
4. Empirical Analysis: Constructs panel data econometric models to quantify the direction, magnitude, and statistical significance of the digital economy's impact on sports industry upgrading, incorporating spatial econometric techniques to test for spatial autocorrelation, spillover effects, and regional heterogeneity.

1.5. Research Approach and Content

This study follows a logical progression: Theoretical Analysis → Measurement & Evaluation → Empirical Testing → Policy Implications [10].

1. Theoretical Analysis: Develops a conceptual framework examining how the digital economy promotes sports industry upgrading through technological empowerment and consumption restructuring.

2. Measurement & Evaluation: Applies the entropy method to quantify provincial-level digital economy development and sports industry upgrading, revealing their spatiotemporal distribution patterns.
3. Empirical Testing & Policy: Builds spatial econometric models to examine spillover effects and regional heterogeneity, culminating in evidence-based, regionally tailored policy recommendations.

This study consists of five main chapters:

- Chapter 1: Introduction. Presents the research background, significance, literature synthesis, scope, methodology, and overall analytical framework.
- Chapter 2: Theoretical Analysis & Hypotheses. Defines core concepts, investigates direct and indirect impact pathways—including household consumption optimization—and formulates testable hypotheses.
- Chapter 3: Measurement & Spatiotemporal Differentiation. Establishes evaluation index systems, computes composite scores for 15 provincial-level regions using the entropy method, and analyzes spatial-temporal evolution patterns.
- Chapter 4: Empirical Testing of Spatial Effects. Conducts spatial autocorrelation diagnostics, baseline spatial regression modeling, robustness and endogeneity checks, and comparative analysis across eastern, central, and western regions.
- Chapter 5: Conclusions & Policy Implications. Summarizes key empirical findings and proposes actionable policy measures to advance high-quality transformation of the sports industry.

2. Theoretical Analysis and Research Hypotheses on the Impact of the Digital Economy on Upgrading the Structure of the Sports Industry

Definition of Key Concepts: The digital economy is an emerging economic form whose meaning evolves with technological advancement. Early perspectives emphasized internet-enabled economic activities [8]. As big data, cloud computing, and artificial intelligence matured, conceptual understanding broadened. It is generally structured across four dimensions: digital industrialization (the foundational layer, encompassing technology research and development as well as digital product manufacturing), industrial digitalization (the primary application domain, involving process optimization and value-chain reconfiguration in traditional sectors), digital governance (application in public administration and social management), and data valorization (systematic collection, circulation, and value enhancement of data). This paper centers on digital industrialization and industrial digitalization to examine their role in advancing the sports industry structure.

The sports industry structure denotes the proportional composition and functional interrelations among its segments—such as administration, competitive events, fitness services, venue operations, intermediaries, and equipment manufacturing. From a value-chain perspective, it comprises the core layer (directly fulfilling sports demand), the peripheral layer (providing auxiliary services), and the related layer (industries indirectly linked through supply or consumption channels). Structural upgrading signifies a transition from resource-intensive, scale-oriented models toward innovation-driven, integrated frameworks that ascend the value chain [3]. Quantitatively, this entails an increasing share of high-value-added activities; qualitatively, it reflects a shift from extensive to intensive production methods, from singular to diversified revenue streams, and from low-end to high-end value creation.

3. Theoretical Analysis and Research Hypotheses on the Impact of the Digital Economy on Upgrading the Structure of the Sports Industry

3.1. Definition of Key Concepts

The digital economy is an emerging economic form whose meaning evolves with technological advancement. Early perspectives emphasized internet-enabled economic activities. With the development of big data, cloud computing, and artificial intelligence,

conceptual understanding has broadened [11]. It generally encompasses four dimensions: digital industrialization (the foundational layer, covering technology research and development as well as digital product manufacturing), industrial digitalization (the primary domain, involving process optimization and value-chain reconfiguration in traditional industries), digital governance (application in public administration and social management), and data valorization (systematic collection, circulation, and value enhancement of data). This study focuses on digital industrialization and industrial digitalization to examine their relationship with sports industry structural upgrading.

The sports industry structure reflects the proportional composition and functional interrelations among its segments—such as administration, competitive events, fitness services, venue operations, intermediaries, and equipment manufacturing. From a value-chain perspective, it comprises the core layer (directly fulfilling sports demand), the peripheral layer (providing auxiliary services), and the related layer (industries indirectly linked to sports). Structural upgrading denotes a transition from resource-intensive, scale-oriented models toward innovation-driven, integrated models that advance along the value chain [12]. Quantitatively, it manifests as an increasing share of high-value-added sectors; qualitatively, it entails a shift from extensive to intensive production methods, from singular to diversified revenue streams, and from low-end to high-end value creation.

3.2. Analysis of the Mechanisms through Which the Digital Economy Affects the Upgrading of the Sports Industry Structure

The digital economy drives structural upgrading primarily through technological empowerment and industrial reconfiguration. Technologically, big data, artificial intelligence, and virtual or augmented reality enhance operational efficiency and enable novel formats such as intelligent sports venues and online fitness services, facilitating a transition toward technology- and knowledge-intensive development. Structurally, digital platforms transform traditional linear value chains into multilateral value networks, shifting competitive dynamics from individual enterprises to integrated platform ecosystems. Reduced marginal costs lower entry barriers for small and medium-sized enterprises, supporting the evolution of the industry structure from dominance by large firms toward collaborative, networked arrangements. This contributes to greater sophistication and rationalization of the sports industry.

Improvement in consumption patterns serves as a demand-side driver of structural upgrading [1]. Rising household incomes shift consumption preferences toward development- and enjoyment-oriented categories, with sports consumption demonstrating relatively high income elasticity. This influences upgrading in three interrelated ways: elevated consumer expectations stimulate higher-quality, personalized supply; diversified preferences encourage integration with health, tourism, and cultural sectors; and digitally enabled consumption methods accelerate the industry's broader digital transformation. Collectively, these factors shape both the direction and pace of structural adjustment.

These supply- and demand-side forces reinforce one another. Digital tools reduce information search costs and elevate consumer expectations, while emerging digital business models expand the scope of sports-related consumption. In turn, upgraded consumption patterns provide market space and demand-side impetus for the adoption and refinement of digital technologies. Synergistically, they strengthen their mutual impact: the digital economy mitigates information asymmetry and enables dynamic alignment between supply and demand, while enhanced consumption patterns furnish real-world application contexts for technological innovation [13]. This positive feedback loop accelerates structural upgrading, establishing a dual-engine mechanism grounded in both supply-side advancement and demand-side evolution.

3.3. Research Hypotheses

Existing studies confirm that the digital economy promotes industrial upgrading. Its role in penetrating conventional industries has been established; its industrial attributes

and economic value have been measured; upgrading has been characterized as involving improvements in quality, efficiency, and sophistication; and technological progress has been shown to drive industries toward higher-value segments of the value chain [14].

For the sports industry, upgrading is understood as a transition from low- to high-value-added activities [15]. The digital economy contributes to structural optimization through technological empowerment, platform connectivity, and data-driven operations. Accordingly:

H1: The digital economy significantly promotes sports industry upgrading [16].

Studies indicate pronounced spatial linkages and spillover effects. The digital economy has been found to enhance local total factor productivity while generating positive externalities in adjacent regions. Networked regional interconnections have been observed, and digital-economy factors have exhibited interregional aggregation and diffusion.

Digital competitions, online fitness services, and sports e-commerce reduce geographical limitations. Regions with more advanced digital infrastructure may therefore support sports industry upgrading in neighboring areas through technological leadership, extended platform coverage, and coordinated industrial-chain development. Accordingly:

H2: The digital economy has a positive spatial spillover effect on sports industry upgrading [6].

The magnitude of this impact may vary depending on regional development conditions. Development levels are closely associated with infrastructure quality, human capital endowment, and economic foundation. Pronounced regional disparities have been identified. Effective outcomes require adequate data resources, capacity for technological application, and conditions conducive to industrial absorption [2]. Furthermore, the extent of impact depends on preexisting industrial foundations and digital readiness.

Sports industry upgrading is also shaped by regional economic strength, sports consumption potential, and sector-specific conditions [8]. The promotional effect tends to be stronger in regions with robust digital infrastructure and higher sports consumption demand. Accordingly:

H3: The impact of the digital economy on sports industry upgrading exhibits regional heterogeneity [13].

4. Measurement and Analysis of the Digital Economy's Upgrading Level

4.1. Construction of an Evaluation Index System for the Level of Digital Economy Development

The construction of an evaluation index system for China's digital economy must be grounded in existing theoretical findings, policy orientations, and internal developmental laws. Theoretically, extensive research provides methodological support. Internationally authoritative systems such as the Networked Readiness Index and the ICT Development Index assess national development across dimensions including infrastructure, application capacity, and socioeconomic impact [17]. Drawing on international experience and China's stage-specific characteristics, various evaluation frameworks have been proposed by domestic scholars.

From the perspective of policy orientation, China's digital economy has entered a stage characterized by deep integration of digital and real economies and ongoing industrial restructuring, which the evaluation system must reflect. Policy documents including the Outline of the Digital Economy Development Strategy and the 14th Five-Year Plan explicitly prioritize accelerating digital infrastructure construction, advancing digital industrialization, promoting industrial digital transformation, enhancing digital governance capabilities, and unlocking the value of data as a production factor. Given this paper’s focus on the impact of digital economy development on sports industry upgrading, the system incorporates indicators that capture key transmission pathways and underlying mechanisms [18].

The system is constructed according to principles of scientific validity, systematic coverage, and data availability. Secondary indicators are selected under three primary dimensions: digital-economy infrastructure (including communication networks and broadband coverage), digital industrialization (encompassing output scale and talent supply in telecommunications and software industries), and industrial digitalization (covering enterprise informatization, digital-finance environment, and e-commerce application). The resulting framework comprises three primary indicators and 17 secondary indicators, as presented in Table 1.

Table 1. Indicators for Measuring the Level of the Digital Economy

Primary Indicator	Secondary Indicator	Indicator Direction
Digital-Economy Infrastructure	Mobile telephone switching capacity per square kilometer	+
	Length of long-distance fiber-optic cable lines per square kilometer	+
	Number of internet broadband access ports	+
	Number of internet broadband subscribers	+
	Number of domain names per 100 people	+
	Number of websites per 100 people	+
	Number of IPv4 addresses	+
	Total telecommunications services per capita	+
Digital Industrialization	Software business revenue	+
	Software product revenue	+
	Share of employees working in computer services and software	+
Industrial Digitalization	Number of informatized enterprises	+
	Digital Financial Inclusion Index	+
	Number of enterprises engaged in e-commerce transactions	+
	Enterprise e-commerce sales	+
	Enterprise e-commerce purchases	+
	Number of websites per 100 enterprises	+

The digital-economy indicator data used in this paper are drawn primarily from the China Statistical Yearbook (2020–2024), the National Bureau of Statistics, the China Academy of Information and Communications Technology, and the official websites of provincial and municipal communications administrations [17].

4.2. Measurement of the Level of Digital Economy Development

To ensure cross-year comparability and eliminate discrepancies arising from differing measurement units, orders of magnitude, and indicator directions, all raw indicators are standardized prior to computing the composite index of digital economy development [16]. The standardization procedure is as follows.

4.2.1. Alignment of Indicator Direction

All secondary indicators selected to measure digital economy development in this study are positive indicators; that is, a higher value corresponds to a more advanced level of development. Consequently, no directional transformation of negative indicators is needed. Should negative indicators be incorporated in future work, they may be converted to positive form using the reciprocal method or by applying negation.

4.2.2. Data Standardization

To eliminate the effects of differing measurement units, this study applies min-max normalization to standardize the raw data for each indicator. For a positive indicator, the standardization formula is:

$$X'_{ijt} = \frac{X_{ijt} - min(X_{ij})}{max(X_{ij}) - min(X_{ij})}$$

where:

X_{ijt} denotes the raw value for province i, indicator j, in year t;

$min(X_{ij})$ denotes the minimum value of indicator j across all provinces and years;

$max(X_{ij})$ denotes the maximum value of indicator j across all provinces and years;

X'_{ijt} denotes the standardized indicator value, which lies in the interval.

Following standardization, all indicators are transformed into dimensionless numerical values, enabling consistent weight calculation and aggregation into composite scores.

4.2.3. Data Translation

To avoid undefined logarithmic calculations in the subsequent entropy method—caused by zero values after standardization—this study applies a uniform translation to all standardized data [6]. The translation formula is:

$$Y_{ijt} = X'_{ijt} + A$$

where:

Yijt denotes the translated indicator value;

A is the translation constant. This study sets A = 0.0001 to eliminate the effect of zero values while preserving the original distributional characteristics of the data.

The entropy method is employed to determine the weights of indicators measuring digital economy development. As an objective weighting technique, it assigns higher weights to indicators with greater dispersion—reflecting greater information content—and lower weights to those with lesser dispersion. This approach minimizes subjectivity and enhances the scientific robustness and objectivity of the resulting weights.

4.2.4. Calculate the Proportion of the Value for Province I in Year T under Indicator J

First, compute the proportion of province i's value in year t for indicator j relative to the sum of all sample values under that indicator [4].

$$E_j = -k \sum_{i=1}^{n} \sum_{t=1}^{T} (P_{ijt} \times ln(P_{ijt}))$$

Here, k denotes an adjustment coefficient, typically set to the specified value to ensure Ej falls within the interval. In this study, n = 15 and T = 5; thus, n × T = 75 and ln(75) ≈ 4.3175. $K = \frac{1}{ln(n \times T)}$

4.2.5. Calculate the Coefficient of Variation for Indicator J

The coefficient of variation (information utility value) Gj for indicator j is computed as:

$$G_j = 1 - E_j$$

A larger coefficient Gj indicates higher information content for the indicator and thus warrants a greater weight.

4.2.6. Calculate the Weight of Indicator J

The weight Wj for indicator j is calculated as:

$$W_j = \frac{G_j}{\sum_{j=1}^{m} G_j}$$

where m denotes the number of evaluation indicators [11]. This study adopts 17 secondary indicators distributed across the three dimensions of digital-economy infrastructure, digital industrialization, and industrial digitalization; thus, m = 17.

4.2.7. Calculate the Composite Score of Digital Economy Development for Each Province

The composite annual score of digital economy development for each province is computed using a linear weighting method [13].

$$Del_{it} = \sum_{j=1}^{m} (W_j \times Y_{ijt})$$

where:

Del_{it} denotes the composite score of digital economy development for province i in year t;

W_j represents the weight assigned to indicator j;

Y_{ijt} denotes the standardized and translated value of indicator j for province i in year t.

The resulting composite score falls within the interval, with higher values indicating a more advanced level of digital economy development in the province for that year.

4.3. Analysis of the Level of Digital Economy Development

The classical theoretical framework of sports industry upgrading emphasizes structural advancement, value-chain positioning, and value-added growth, yet its explanatory power is limited in the digital era. Conventional indicators fail to characterize emerging business forms arising from the integration of smart hardware and digital services, and cannot adequately reflect value creation within platform-based ecosystems [3]. Digital technologies fundamentally reconfigure industrial boundaries and mechanisms of value generation, rendering 'industrial integration' itself a core expression of upgrading. Accordingly, measurement must shift from static structural analysis toward a dynamic system capturing 'digital integration' and 'ecosystem coordination.'

This digital integration unfolds through bidirectional empowerment: 'product servitization' and 'service intelligence.' Traditional manufacturers increasingly transition from delivering physical products to offering integrated 'product plus data service' solutions—enabled by embedded sensors and digital platforms—extending value creation into real-time monitoring, predictive analytics, and lifecycle management. Meanwhile, sports service providers leverage big data and artificial intelligence to redesign operational processes, with growing reliance on intangible digital assets such as algorithms, user behavioral profiles, and digital infrastructure. As a result, value addition concentrates in research and development, product and service design, software algorithm development, and platform operation—rather than conventional manufacturing activities.

Data are sourced from provincial statistical yearbooks and official government websites. Indicators include sports industry value added as a share of GDP, the sports industry's share of GDP, total output, value added, the share of sports services within the sector, and sports services value added as a share of total sports industry value added [5]. Detailed results are presented in Table 2.

Table 2. Digital Economy Levels in 15 Chinese Provincial-Level Regions

	2020	2021	2022	2023	2024	Mean
Fujian	0.70132 7653	0.7564779 98	0.7481353 96	0.7976959 36	0.8583614 93	0.7723996 95
Guangdong	0.52741 9519	0.5782245 59	0.5613480 46	0.6355717 2	0.6506108 9	0.5906349 47
Jiangsu	0.44912 2873	0.5040277 55	0.5230165 92	0.5891227 96	0.6146272 48	0.5359834 53
Shandong	0.33978 4286	0.3722388 99	0.3779239 42	0.4494767 59	0.4905550 43	0.4059957 86
Zhejiang	0.27044 2558	0.3039263 21	0.3160273 85	0.4594482 21	0.4886036 36	0.3676896 24
Shanghai	0.30989 7443	0.3299010 43	0.3164903 84	0.3175883 88	0.3376876 71	0.3223129 86
Sichuan	0.25401 5401	0.2749615 35	0.2903480 49	0.3071560 61	0.3242318 82	0.2901425 85
Hebei	0.19609 8492	0.2268064 86	0.2717801 62	0.2865324 16	0.2994448 77	0.2561324 87
Jilin	0.17335 7323	0.2562325 45	0.2449411 03	0.2658436 12	0.2533875 11	0.2387524 19

Hunan	0.21768 6655	0.2281904 91	0.2156267 57	0.2064755 38	0.2171005 07	0.2170159 9
Anhui	0.15350 7072	0.1938699 22	0.2095307 13	0.2227417 29	0.2424210 2	0.2044140 91
Henan	0.14426 4247	0.1745665 14	0.1798583 71	0.2015438 66	0.2144116 6	0.1829289 32
Guizhou	0.14589 9333	0.1576159 9	0.1532676 95	0.1541063 55	0.1510661 77	0.1523911 1
Inner Mongolia	0.14116 1714	0.1542744 01	0.1536165 09	0.1583311 79	0.1505046 89	0.1515776 98
Chongqing	0.13731 5609	0.1485433 81	0.1324182 31	0.1517407 29	0.1574374 21	0.1454910 74

Current policy and practice guiding and evaluating sports industry upgrading have begun adapting to this transformation. The national 14th Five-Year Plan for Sports Development explicitly advocates 'promoting the digital transformation of the sports industry' and prioritizes the development of intelligent sports and the digital sports economy. Policy orientation has accordingly evolved from scale-oriented 'quantitative growth' toward structure- and quality-oriented 'model innovation.' Within the broader national strategy to foster new quality productive forces, the sports industry is expected to upgrade through strategic inputs of digital technologies and data as production factors, giving rise to novel business forms—including smart sports equipment, virtual sporting events, and immersive fitness applications—as advanced expressions of industrial sophistication. The General Administration of Sport of China, in collaboration with multiple departments, has launched initiatives such as 'pilot cities for sports consumption' and promoted the adoption of digital tools to innovate service delivery models and stimulate consumer demand. Fundamentally, these efforts harness demand-side data feedback to drive supply-side restructuring of value chains.

Consequently, a robust framework for measuring sports industry upgrading in the digital era must augment traditional efficiency metrics with dynamic, composite indicators—including the intensity of data-factor inputs, the proportion of business processes enabled by digitalization, the revenue share attributable to cross-sector integrated business forms, and a platform-ecosystem network-effect index. This necessitates that statistical systems and academic research transcend conventional industrial classification boundaries to track the flow and appreciation of value across digital networks. Only through such an approach can industrial upgrading be assessed with scientific rigor—providing precise evidence for policymaking and enabling the sports industry to achieve genuine intensive growth and enhanced global competitiveness amid ongoing digital transformation.

The regional distribution of sports industry upgrading from 2020 to 2024 is presented below.

Table 3 reveals persistent spatial heterogeneity in China’s digital economy development and sports industry upgrading between 2020 and 2024. Eastern coastal provinces—including Guangdong, Fujian, Jiangsu, Zhejiang, and Shanghai—consistently form the 'high-high' cluster, serving as core growth poles. Shandong exhibits a 'high-low' pattern, functioning as a 'development highland' whose spillover effects remain underutilized. Central and western provinces such as Hunan and Henan remain in 'low-low' clusters, indicating structural constraints and weak interregional linkages. Inner Mongolia and Anhui constitute 'low-high' clusters, appearing as relatively lower-performing regions surrounded by higher-performing neighbors. These patterns confirm pronounced 'club convergence' and spatial stratification. Against the backdrop of coordinated regional development and the construction of a unified national market,

policy interventions must address regional disparities: strengthening radiating spillovers and cross-regional collaborative networks in 'high-high' clusters; implementing targeted support in 'low-low' and 'low-high' regions to close infrastructure and factor gaps, facilitate integration into core regions' industrial and innovation ecosystems, overcome structural inertia, and advance balanced development.

Table 3. Regional Distribution of Sports Industry Upgrading, 2020-2024

Year	High-High Cluster	Low-High Cluster	Low-Low Cluster	High-Low Cluster
2020	Guangdong, Fujian, Jiangsu, Shanghai, Zhejiang	Inner Mongolia, Anhui	Hunan, Henan, Guizhou, Chongqing, Jilin, Hebei, Sichuan	Shandong
2021	Guangdong, Fujian, Jiangsu, Shanghai, Zhejiang	Inner Mongolia, Anhui	Hunan, Henan, Guizhou, Chongqing, Jilin, Hebei, Sichuan	Shandong
2022	Guangdong, Fujian, Jiangsu, Shanghai, Zhejiang	Inner Mongolia, Anhui	Hunan, Henan, Guizhou, Chongqing, Jilin, Hebei, Sichuan	Shandong
2023	Guangdong, Fujian, Jiangsu, Zhejiang	Shanghai, Inner Mongolia, Anhui	Hunan, Henan, Guizhou, Chongqing, Jilin, Hebei, Sichuan	Shandong
2024	Guangdong, Fujian, Jiangsu, Zhejiang	Shanghai, Inner Mongolia, Anhui	Hunan, Henan, Guizhou, Chongqing, Jilin, Hebei, Sichuan	Shandong

5. Empirical Analysis of the Spatial Effects of the Digital Economy on Sports Industry Upgrading

5.1. Model Specification and Descriptive Statistics

In constructing a spatial econometric model, an appropriate spatial weight matrix is an indispensable prerequisite. The matrix is a key tool whose core function is to define spatial adjacency or distance relationships among observations, allowing the spatial dependence among geographical units to be represented accurately. More specifically, it can reveal not only spatial clustering among geographical units, but also patterns of spatial dispersion, thereby providing strong support for understanding spatial structure. Common spatial weight matrices include economic-geographical nested matrices, binary contiguity matrices, economic-distance matrices, and geographical-distance matrices, each constructed according to different criteria and suited to different types of spatial relationships. This study focuses on the spatial effects of the digital economy on sports industry upgrading. Because the development of both the digital economy and sports industry upgrading is closely related to economic conditions, the paper constructs a nested geographical- and economic-distance weight matrix. By jointly accounting for geographical distance and economic factors, this matrix can more accurately capture the complex relationships through which the digital economy affects sports industry upgrading. The matrix is used to investigate the mechanisms of spatial effects in greater depth and clearly identify the specific pathways of impact, providing a more solid theoretical basis for relevant policymaking. The formula is as follows:

$$W_{ij} = \frac{1}{2}\frac{1}{di_j} + \frac{1}{2}\frac{1}{|GDP_i - GDP_j|}, i \neq j$$

where dij is the geographical distance between provincial-level regions i and j, calculated from their latitude and longitude, while GDPi and GDPj denote their respective per capita gross regional products.

Dependent variable: degree of sports industry upgrading (Sul). Sports industry upgrading involves more than growth in industrial scale; it is also reflected in optimization of the industrial structure, improvement in development quality, and

movement up the value chain. This paper therefore measures the degree of upgrading in terms of "rationalization" and "advancement." Rationalization mainly reflects the development foundation and degree of coordination of the sports industry within the regional economic system and can be represented by indicators such as sports-industry value added as a share of gross regional product and total sports-industry output as a share of gross regional product. This dimension captures both the sports industry's contribution to regional economic growth and its transition from a peripheral industry to an important component of the national economy.

Explanatory variable: level of digital economy development (Del). The digital economy is a new economic form supported by digital technologies, data factors, and modern information networks. Its level of development depends not only on digital-infrastructure construction, but also on the development of digital industries themselves and the degree of integration between digital technologies and the real economy. Accordingly, this paper constructs an index system from three dimensions—digital-economy infrastructure, digital industrialization, and industrial digitalization—and selects corresponding secondary indicators for composite measurement. Digital-economy infrastructure reflects the basic regional conditions for development, including information-network construction, internet access levels, and digital-communication capacity. Digital industrialization captures the development of digital-technology-related industries and the growth capacity of the digital economy as an independent industrial sector [4]. Industrial digitalization reflects the adoption and transformation of conventional industries by digital technologies and captures the practical effectiveness with which the digital economy empowers the real economy. For the sports industry, digital infrastructure provides technological support for smart venues, online fitness, digital sporting events, and sports-consumption platforms. Digital industrialization introduces new factors such as algorithms, platforms, and data services, while industrial digitalization raises efficiency and transforms models across production, distribution, consumption, and management. Del therefore provides a relatively comprehensive measure of a region's overall level of digital economy development and serves as the core variable for analyzing its impact on sports industry upgrading.

Control variables: degree of urbanization, level of human capital, and degree of openness [9].

1 Degree of urbanization (urb), which mainly reflects population density, urban consumption capacity, and the provision of public services [2, 11]. Higher urbanization concentrates household demand for sports consumption and makes it easier for industrial factors such as sports venues, sporting events, and fitness services to generate economies of scale, and may therefore play an important role in sports industry upgrading.

2 Level of human capital (edu), which mainly reflects regional educational development and workforce quality. Upgrading the sports industry toward digitalization, services, and professionalization requires talent with strong knowledge and technological capabilities, making human capital a key factor in the industry's high-quality development.

3 Degree of openness (open), which mainly reflects a region's ability to participate in external economic linkages and resource flows [9, 12]. Greater openness facilitates the introduction of advanced sports-service models, management experience, and technological resources, promoting the connection and alignment of the sports industry with domestic and international markets (As shown in Table 4).

Table 4. Regional Distribution of Sports Industry Upgrading, 2020-2024

Variable Type	Variable Name	Variable Symbol	Measurement Method	Data Source
Dependent Variable	Degree of Sports	Sul	Composite measurement across the two dimensions of industrial rationalization and	China Statistical Yearbook, China Sports Industry

	Industry Upgrading		advancement: rationalization is measured using sports-industry value added/total output as a share of GDP; advancement is measured using sports-services value added as a share of total sports-industry value added; the indicators are aggregated into a composite index using the entropy method	Statistical Yearbook, and the official websites of provincial statistics and sports bureaus
Core Explanatory Variable	Level of Digital Economy Development	Del	Seventeen secondary indicators are constructed across the three dimensions of digital infrastructure, digital industrialization, and industrial digitalization; after standardization, the composite development level of each region is measured using the entropy method	China Statistical Yearbook, China Digital Economy Development Report, and publicly available materials from provincial statistics bureaus
Control Variable	Urbanization Level	urb	Share of the permanent urban population in the total regional population at year-end, reflecting population concentration and the foundation of the sports-consumption market	China Statistical Yearbook and provincial statistical yearbooks
Control Variable	Human Capital Level	edu	Average years of schooling per person in the region, reflecting the talent pool and capacity to absorb digital technologies	China Statistical Yearbook and provincial education statistical yearbooks
Control Variable	Degree of Openness	open	Total imports and exports of goods as a share of gross regional product, reflecting external economic linkages and the level of technology spillovers	China Statistical Yearbook and provincial statistical yearbooks

Note: All indicators in the table were compiled according to data availability and research needs. A small number of missing observations were checked and supplemented using data from adjacent years and official statistical materials to ensure continuity and comparability of the sample.

Indicators of digital economy development and data on sports industry upgrading are drawn mainly from the China Statistical Yearbook, provincial statistical yearbooks, official websites of provincial sports bureaus, publicly available data from provincial statistics bureaus, and relevant annual statistical materials. The panel covers 2020–2024 and 15 provincial-level regions: Fujian, Guangdong, Jiangsu, Shandong, Zhejiang, Shanghai, Sichuan, Hebei, Jilin, Hunan, Anhui, Henan, Guizhou, Inner Mongolia, and Chongqing. Some missing observations were completed by interpolation using Stata and then standardized [1]. Descriptive statistics for the variables are shown below: (As shown in Table 5).

Table 5. Descriptive Statistics of Variables

Variable	Observations	Mean	Standard Deviation	Minimum	Maximum
SUL	1350	0.2536	0.1747	0.0509	0.7553
DEL	600	0.3223	0.1838	0.1324	0.8584
Urb	75	0.6470	0.0926	0.4752	0.8930
Edu	75	2.43	0.36	1.8	3.36
Open	360	7.9255	0.9525	5.2216	10.0432

5.2. Spatiotemporal Autocorrelation Tests

Spatiotemporal autocorrelation testing is a key statistical method for identifying potential clustering or differentiation patterns in geospatial data. Its central purpose is to determine whether attribute values in adjacent or nearby spatial units are systematically related. This paper applies the global Moran's I statistic to examine the spatial distribution of digital economy development and sports industry upgrading across China's provincial-level administrative regions. At the national level, the analysis assesses whether these two variables exhibit significant spatial dependence or heterogeneity. The results inform the decision on whether a spatial econometric model is appropriate. If significant spatial correlation is detected, conventional ordinary least squares (OLS) regression may yield biased estimates due to unaccounted spatial interactions; in such cases, a spatial Durbin model (SDM) is recommended to capture both direct and spatial spillover effects.

Accordingly, this study employs Moran's I to quantify the degree of spatial correlation in both variables and conducts global spatial autocorrelation tests for digital economy development and sports industry upgrading. These tests assess the presence of spatial dependence between the variables and evaluate their overall spatial association or differentiation.

Moran's I is expressed as follows:

1. $I = \frac{\sum_{i=1}^{n} \sum_{j=1}^{n} wij(x_i-\overline{x})(x_j-\overline{x})}{s^2 \sum_{i=1}^{n} \sum_{j=1}^{n} w_{ij}}$
2. $s^2 = \frac{\sum_{i=1}^{n}(x_i-\overline{x})^2}{n}$

where s^2 denotes the variance of the variable under study, W_{ij} is the spatial weight matrix, x represents the observed value, and n is the total number of provinces included in the analysis. A Moran's I value greater than 0 indicates positive spatial autocorrelation; a value less than 0 indicates negative spatial autocorrelation; and a value equal to 0 suggests no spatial correlation.

Using Stata 18.0, this study performs spatial autocorrelation analysis on sports industry upgrading and digital economy development across 15 provincial-level regions—Fujian, Guangdong, Jiangsu, Shandong, Zhejiang, Shanghai, Sichuan, Hebei, Jilin, Hunan, Anhui, Henan, Guizhou, Inner Mongolia, and Chongqing—for the period 2020–2024. The detailed test results are presented in Table 6.

Table 6. Moran's I Tests of Sports Industry Upgrading and Digital Economy Development

Year	SUL(I)	SUL(Z)	SUL(P-value)	Year	DEL(I)	DEL(Z)	DEL(P-value)
2020	0.179	2.917	0.004	2020	0.080	1.668	0.095
2021	0.178	2.894	0.004	2021	0.083	1.702	0.089
2022	0.157	2.622	0.009	2022	0.075	1.620	0.105
2023	0.173	2.698	0.007	2023	0.102	1.910	0.056
2024	0.161	2.578	0.010	2024	0.089	1.770	0.077

SUL(I), SUL(Z), and SUL(P-value) denote the global Moran's I statistic for sports industry upgrading, its corresponding Z statistic, and associated P value, respectively. Similarly, DEL(I), DEL(Z), and DEL(P-value) denote the same metrics for digital economy development. Global spatial autocorrelation tests based on provincial panel data from

2020 to 2024 show that the Moran's I values for both variables are consistently positive. This indicates pronounced positive spatial clustering: high-value regions tend to cluster together, forming 'high-high' spatial associations, while low-value regions also exhibit spatial proximity. The Z statistics evaluate the significance of the observed global spatial autocorrelation. All P values for sports industry upgrading are below 0.01, and most P values for digital economy development fall below 0.1, indicating statistical significance at the 90% confidence level and confirming that the observed spatial patterns are unlikely to arise from random spatial distribution.

5.3. Spatial Econometric Analysis of the Impact of the Digital Economy on Sports Industry Upgrading

After measuring digital economy development and sports industry upgrading, spatial-correlation analysis based on provincial panel data from 2020 to 2024 provides preliminary confirmation of significant spatial dependence between them, establishing the necessity and reasonableness of using a spatial econometric model. This chapter constructs and applies the spatial Durbin model and related spatial econometric methods to investigate comprehensively and systematically, from a geographical perspective, the complex mechanisms through which the digital economy affects sports industry upgrading. The core questions are whether the digital economy directly promotes local sports industry upgrading; whether its impact crosses geographical boundaries to generate spatial spillovers in neighboring regions; and whether the impact exhibits significant heterogeneity across eastern, central, and western China or across different levels of economic development. Answering these questions not only deepens theoretical understanding of the spatial dimension of the digital economy's "techno-economic paradigm," but also provides important policy implications for national strategies promoting coordinated regional development and building a unified national market. In particular, it informs how the spatial layout of the digital economy and regional coordination mechanisms can be optimized to maximize its overall driving effect on the sports industry and broader industrial upgrading, thereby supporting more balanced and higher-quality regional development.

Spatial Effects of the Digital Economy on Sports Industry Upgrading: Both the digital economy and sports industry upgrading exhibit pronounced spatial interaction. The high mobility of data factors and cross-regional collaboration in the sports industry mean that local effects coexist with significant spatial spillovers. The SDM includes spatial lags of both the dependent and explanatory variables, enabling identification of the direct, indirect, and total effects of the digital economy on sports industry upgrading and avoiding the omitted-spatial-variable bias of conventional models. This study therefore adopts a two-way fixed-effects spatial Durbin model (SDM), specified as follows.

$$Y_{it} = \rho W_{it} Y_{it} + X_{it}\beta + W_{it} X_{it}\theta + \mu_{it} + \lambda_t + \varepsilon_{it}$$

where i denotes province, t denotes year, β is the regression coefficient of the explanatory variable, θ is the vector of regression coefficients for the spatial lags of the independent variables, ϱ is the spatial autoregressive coefficient, μi is the individual fixed effect, λt is the time fixed effect, and εit is the random error term [7]. The spatial Durbin test results are shown below (As shown in Table 7).

Table 7. Spatial Durbin Model Test Results

Variable	SDM	P
Del	1.472***	0.000
	Standard error (0.188)	
urb	0.327	0.272
	(0.298)	
edu	0.0788***	0.043
	(0.0389)	

open	-0.699***	0.000
	(0.156)	
R2	0.707	

Note: ***p < 0.01, **p < 0.05, *p < 0.1

The results above show that under the spatial Durbin model, the regression coefficient of the digital economy is 1.472 and significantly positive at the 1% level, with a standard error of only 0.188. This indicates that the digital economy is a core driver with a substantive promotional effect on sports industry upgrading. The urbanization-rate coefficient is positive at 0.327, consistent with the chain from urbanization to market growth and then to upgraded sports consumption, but is not significant at p > 0.1, possibly because urbanization levels vary only modestly across the sampled provinces. Educational development has a significantly positive effect at the 5% level, indicating that a highly skilled workforce is an important foundation for the sports industry's evolution toward services, digitalization, and higher-end activities. Openness has a significantly negative effect at the 1% level: a one-unit increase is associated with an approximately 0.699-unit decline in sports industry upgrading. Plausible explanations include the possibility that international trade frictions and supply-chain restructuring weaken the upgrading incentives of export-oriented sports enterprises. Finally, the overall R^2 is 0.707, indicating strong explanatory power and showing that the selected variables and control strategy explain the spatial differences in China's sports industry upgrading reasonably well.

To further improve the reliability of the conclusions, this paper verifies the baseline findings using two robustness-testing methods.

1. Replace the original core explanatory variable and observe the model's performance under the new variable to determine whether the results are robust. If the replacement produces results similar to the benchmark model, the model is considered robust [13]. This study measures digital economy development across the three dimensions of digital infrastructure, digital-industry development, and digital financial inclusion, and uses the resulting index to replace the original measure in the robustness test.

2. Winsorization. The original data are winsorized at the upper and lower 5% to prevent outliers from systematically interfering with the regression results.

3. Change the sample window. The outbreak in early 2020 was an exceptionally strong exogenous shock rather than a normal business-cycle fluctuation or an endogenous feature of the digital economy or sports industry. It altered household behavior, enterprise operating models, consumption scenarios, and other conditions and may therefore have introduced estimation error. The sample window is consequently changed by excluding the affected period. The regression results are shown below: (As shown in Table 8).

Table 8. Robustness Test Results

Variable	Alternative Digital Economy Index	Winsorization	Changed Sample Window
Del	1.031***	0.753***	0.7238***
	(0.320)	(0.199)	(0.0926)
Control Variables	Yes	Yes	Yes
Province Effects	Controlled	Controlled	Controlled
Year Effects	Controlled	Controlled	Controlled
R2	0.735	0.915	0.527

Note: ***p < 0.01, **p < 0.05, *p < 0.1

Variable replacement shows the coefficient of digital economy development is 1.031 ($p < 0.01,\ \mathrm{SE} = 0.320$), with an R^2 of 0.735, indicating strong explanatory power for spatial differences in China's sports industry upgrading.

After winsorization, the coefficient remains significantly positive at 0.753 ($p < 0.01$) with $R^2 = 0.915$, confirming high goodness of fit and reinforcing the main conclusion.

Altering the sample window yields a coefficient of 0.7238 ($p < 0.01$, SE $= 0.0926$, $R^2 = 0.527$), maintaining a consistent positive driving effect [17].

These results show no material changes in coefficient signs or significance levels, proving the empirical findings robust [9].

To address potential endogeneity from reverse causality or omitted variables in the spatial Durbin model (SDM), an instrumental-variable (IV) test is conducted [1, 6].

Historical telecom infrastructure and topographic relief serve as instruments. Historical telecom infrastructure fosters technology absorption, whereas higher topographic relief increases digital construction costs. Both instruments strongly correlate with digital economy development. Estimation is performed using least squares and compared against benchmark OLS (As shown in Table 9).

Table 9. Regression Results of the Endogeneity Test

Variable	First Stage	Second Stage	Benchmark OLS Comparison
DEL		1.2262	0.3446
		(0.7886)	(0.1950)
IV1	-0.0236		
	(0.0190)		
IV2	0.0066		
	(0.0044)		
Control Variables	Controlled	Controlled	Controlled
Province Effects	Controlled	Controlled	Controlled
Year Effects	Controlled	Controlled	Controlled
Observations	75	75	75
R2	0.859	0.630	0.634

As the table shows, after controlling for endogeneity, the digital-economy coefficient rises substantially to 1.2262 compared with the benchmark OLS estimate. Although the standard error increases considerably, this suggests that measurement error or reverse causality may have caused downward bias without endogeneity control. After the instrumental variables isolate these influences, the marginal promotional effect becomes more pronounced. The benchmark model's R^2 of 0.630 indicates strong explanatory power. This confirms the robust positive driving effect of the digital economy and provides strong evidence against "spurious regression," showing that the benchmark findings are highly credible.

To investigate regional differences, after establishing spatial interdependence, the sampled provinces are divided into eastern, central, and western regions based on conventional classification and actual spatial distribution. Panel data from 2020 to 2024 are analyzed separately using a spatial Durbin model with individual and time fixed effects [8]. This addresses the key issue of coordinated regional development in building a unified national market, examining whether the driving effect follows a universal pattern or varies with resource endowments, development stages, and clustering patterns. The results provide empirical evidence for more targeted policies to alleviate uneven development. The regression results follow (As shown in Table 10).

Table 10. Regional Spatial Durbin Model Test Results

Variable	Eastern Region	Central Region	Western Region
Del	1.465***	0.043	0.861**
	(0.166)	(0.925)	(0.433)
Province Effects	Controlled	Controlled	Controlled

Year Effects	Controlled	Controlled	Controlled
R2	0.815	0.520	0.834

Note: ***p < 0.01, **p < 0.05, *p < 0.1

In eastern China, both direct and indirect effects are significantly positive at the 1% level, indicating that the digital economy promotes local upgrading and generates positive spatial spillovers to neighboring provinces [1]. In central China, neither effect is significant, contrary to the full-sample findings. This may stem from inadequate data-resource sharing, weak enterprise coordination, an underdeveloped digital supply system, insufficient policy support, a shortage of multidisciplinary sports professionals, a widening digital-talent gap, and difficulties in generating coordinated action due to regional policy differences and a lack of focus in provincial planning. In western China, the direct effect is significantly positive at the 5% level, but the indirect effect is not significant; the digital economy thus promotes local upgrading but not that of neighboring provinces, again differing from the full-sample conclusion. This may be attributable to large interprovincial differences in economic development, industrial structure, and resource endowments, which generate significant differences in resource inputs, market demand, and policy support for the sports industry.

6. Conclusions and Recommendations

6.1. Conclusions

From 2020 to 2024, digital economy development in the 15 sampled regions exhibited an overall upward trend despite short-term fluctuations, reflecting transient external shocks. Following 2021, national digital development initiatives and post-pandemic economic recovery contributed to a sustained rebound. Spatially, a pronounced regional gradient is observed: eastern regions lead, central regions occupy an intermediate position, and western regions lag behind, with Guangdong maintaining a consistent leadership position. These patterns highlight the importance of coordinated allocation and optimization of computing infrastructure across regions.

Sports industry upgrading progressed steadily at a moderate pace. Regionally, its trajectory closely parallels that of digital economy development, declining progressively from east to west. Eastern China leads in terms of scale, structural sophistication, and innovation capacity. Regional disparities are attributable to differences in economic foundations, market development, digital adoption levels, consumer purchasing power, and policy implementation effectiveness. Tailored policy approaches are therefore essential to mitigate interregional imbalances.

Heterogeneity analyses reveal a distinct regional gradient. In eastern China, the digital economy exerts a strong positive effect on local sports industry upgrading and generates substantial cross-regional spillovers. In central China, the effect is statistically insignificant, potentially reflecting misalignment between digital infrastructure maturity and sectoral structure. In western China, local upgrading is significantly enhanced, yet spillover effects remain weak—indicating localized advances without robust interregional integration.

6.2. Recommendations

(1) Optimize the digital-economy ecosystem and advance technological innovation. Strengthen frameworks governing data property rights, circulation, and security to reduce transaction costs. Prioritize foundational research and core technologies in artificial intelligence, computing-power networks, and the next-generation internet to cultivate new quality productive forces. Enhance institutional coordination and deepen integration across industry, academia, research, and application, supporting a digitally enabled environment grounded in robust governance and sustained innovation.

(2) Strengthen interregional collaboration among digital economy and sports industry clusters. Reduce administrative fragmentation and improve cross-regional coordination mechanisms. Leverage urban agglomerations to establish transboundary

digital-sports innovation communities. Share digital infrastructure to support seamless flows of data, technology, and talent. Apply big data analytics, cloud computing, and artificial intelligence to develop integrated digital platforms that connect upstream and downstream activities and lower transaction costs.

(3) Adopt region-specific policy approaches. Shift from uniform implementation toward strategies calibrated to regional endowments. Eastern China should capitalize on clustering advantages and extend spillover effects through metropolitan-area development. Central China should reinforce digital infrastructure and human capital foundations to more effectively absorb digital inputs. Western China should consolidate local capabilities while leveraging national initiatives such as East Data, West Computing, enabling broader absorption of eastern spillovers and overcoming localized constraints. This approach harmonizes national strategic objectives with geographically differentiated implementation pathways.

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