Construction and Empirical Testing of an Evaluation Index System for Regional Innovation Ecosystems: Evidence from 12 Provinces in Western China

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Abstract. Amid global economic integration, technological revolution, and the development of "new-quality productive forces," innovation-driven development in China's western regions is strategically vital. However, existing evaluation tools fail to match its unique characteristics. This study expands the "Four-Helix" theory to build an evaluation framework covering five dimensions: foundational innovation environment, subject vitality, outcome production, input resources, and open collaboration. Using the CRITIC-TOPSIS method, it empirically analyzes the innovation ecosystems of 12 western provinces from 2018 to 2023. Results show a "three-strong-leaders, mid-tier-catch-up, lagging-tail" pattern, with Sichuan, Shaanxi, and Chongqing topping consistently, revealing obvious regional disparities. Key influencing factors include the proportion of education expenditure, and provincial development is imbalanced across dimensions. Corresponding countermeasures are proposed to provide references for western innovation governance.

Keywords: Western Region; Innovation Ecosystem; Quadruple Helix Theory; CRITIC-TOPSIS; Evaluation System

1 Introduction

Against the backdrop of global economic integration and technological revolution, scientific and technological innovation has become a core driver of regional competition. "New-quality productive forces" point the way for innovation-driven development, while the "New Era Western Development Strategy" prioritizes building western innovation hubs as a key goal; digital transformation also plays a crucial role in en-

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hancing the resilience of regional innovation ecosystems [1]. However, western China faces a mismatch between transformation needs and evaluation tools: resource-rich provinces rely on innovation for green industrial upgrading, and border areas need it to boost open economy levels, yet existing evaluation systems based on eastern experience fail to fit western characteristics, leading to assessment biases and reduced policy precision [2]. From the symbiosis theory perspective, the dissipative evolution of regional innovation ecosystems also calls for tools that can identify system dynamics [3]. Thus, developing a tailored diagnostic tool for western innovation ecosystems is of great significance.

To address the insufficient explanatory power of existing theories for western innovation ecosystem particularities, this study expands the "Quadruple Helix" framework by explicitly incorporating the "public" dimension, constructing an evaluation system covering "innovation environment foundation—subject vitality—output results—input resources—openness and collaboration" [4]. This enriches research perspectives on the link between regional innovation ecosystems and corporate foreign direct investment [5], strengthening the theoretical capacity to analyze regional heterogeneity.

In terms of practical application, this indicator system covers the entire innovation value chain, enabling assessment of ecosystem "health" and resilience. It helps identify bottlenecks and weaknesses, provides a basis for analyzing innovation efficiency and drivers, and promotes a shift from experience-based governance to precision management for western innovation.

2 Theoretical Foundations and Evaluation Indicator System Construction

2.1 Theoretical Foundations

Expanding the traditional "Triple Helix" (government, industry, universities/research institutions) by adding "society/public," it forms a four-subject collaborative innovation system. Government guides digital transformation and ecological sustainability; industry converts innovation value; universities/research institutions supply knowledge and talent; the public provides oversight and feedback—this networked symbiosis matches the evolutionary rules of western green innovation ecosystems. Regional innovation evaluation involves five dynamically linked dimensions: environmental stimulation of vitality, stakeholder resource allocation, resource-supported output, output-driven synergy, and synergy-optimized systems. This framework fits the western green innovation competitiveness assessment and reflects the spatio-temporal characteristics of regional innovation niche adaptation.

2.2 Evaluation System Design

2.2.1 Design Principles. Balancing systematic rigor and scientific validity, covering five dimensions with CRITIC method weighting; integrating qualitative and quantitative approaches, incorporating both hard metrics (e.g., R&D funding intensity) and soft metrics (e.g., collaborative spirit assessed by experts); unifying simplicity and feasibility by retaining high-discrimination core indicators sourced from public statistics; combining dynamic and static elements to enable both single-year static assessments and multi-year trend tracking.

2.2.2 Indicator Framework.

The designed evaluation indicator system for the regional innovation ecosystem is presented in Table 1, which covers five dimensions—Innovation Environment Foundation, Vitality of Innovation Entities, Innovation Output, Resources for Innovation Investment, and Innovation Openness and Collaboration—comprising a total of 28 specific indicators.

Table 1. Regional Innovation Ecosystem Evaluation Indicator System

Principle Layer (Primary Indicators)	Factor Level (Secondary Indicators)	Indicator Level (Tertiary Indicators)
Innovation Environment Foundation (A1)	Industrial and Public Infrastructure (B1)	Public Library Floor Space per 10,000 People(C1) Value Added of Tertiary Industry as a Percentage of GDP(C2) Industrial Internet Coverage Rate(C3)
	Institutional Environment Foundation (B2)	Transparency of Government Science and Technology Policy Information(C4) Strength of intellectual property protection(C5)
	Natural environment (B3)	Green Coverage in Built-Up Areas(C6)
Vitality of Innovation Entities (A2)	Government (B3)	Number of Technology Business Incubators(C7)
	Enterprises (B4)	Full-time equivalent R&D personnel in industrial enterprises above designated size (C8) Number of high-tech enterprises per 10,000 population(C9) Number of Valid Invention Patents Held by Industrial Enterprises Above Designated Size(C10)
	Academic and Research Institutions (B5)	Number of regular higher education institutions per million population(C11)
	Users (B6)	Number of industrial enterprises above designated size with R&D activities(C12)
Innovation Output (A3)	Knowledge and Technology Output (B7)	Number of Valid Invention Patents Held by Industrial Enterprises Above Designated Size(C13) Number of granted invention patents(C14)
	Technology Transfer (B8)	Total Profit of High-Tech Industries(C15) Sales Revenue of New Products from High-Tech Enterprises(C16) Number of new product projects in industrial

		enterprises above designated size(C17) Contract Value of Technology Market Transactions as a Percentage of GDP(C18)
	Economic and Social Benefits (B9)	GDP per capita(C19) Labor Productivity per Employee(C20)
Resources for Innovation Investment (A4)	Human Capital Investment (B10)	Local Government Education Expenditures(C21) Share of Education Expenditures in Local Government Spending(C22)
	Material Inputs (B11)	R&D Funding Intensity(C23) Local Government Expenditure on Science and Technology Activities(C24)
Innovation, Openness, and Collaboration (A5)	System Openness (B12)	Ratio of Per Capita Disposable Income Between Urban and Rural Residents(C25) Technology Market Contract Value as a Percentage of GDP(C26)
	System liquidity (B13)	Number of Technology Outflow Contracts in Technology Market(C27) Number of Technology Inflow Contracts in Technology Market(C28)

3 Evaluation Methods and Weight Determination

3.1 Evaluation Method

The CRITIC method is an objective weighting approach that calculates information-based weight distribution based on indicator variability and conflict, thereby avoiding subjective bias. It aligns with the quantitative requirements for variable importance in the Lotka-Volterra model for green innovation ecosystems. For the CRITIC method, the weight of the j-th indicator is calculated by first obtaining its standard deviation.

$\sigma_j = \sqrt{\frac{1}{n-1}\sum_{k=1}^{n}(x_{kj} - \overline{x}_j)^2}$ (for variability) and the Pearson correlation coefficient r_{ij} with other indicators (for conflict). Then, the weight is derived as: $w_j = \frac{\sum_{i=1}^{m}(1-r_{ij})\sigma_j}{\sum_{j=1}^{m}\sum_{i=1}^{m}(1-r_{ij})\sigma_j}$,where n is the number of samples, m is the number of indicators, x_{kj} and $\overline{x}_j$ are the value and mean of the j-th indicator in the k-th sample, respectively.

The TOPSIS method ranks evaluation subjects by calculating their relative proximity to positive and negative ideal solutions. This study incorporates CRITIC weights to construct a weighted decision matrix, enhancing the scientific rigor of the ranking process. This approach can be extended for dynamic assessments of regional innovation ecosystem competitiveness.

3.2 Key Findings of Weighting Results

The weighting results calculated by the CRITIC method are shown in Table 2. The proportion of education expenditure in local government spending (C22) holds the highest weight (7.01%), indicating its strong discriminative power in the evaluation system. Weights exceeding 5% form the second tier, including tertiary industry value-added as a proportion of GDP (C2) and green coverage rate in built-up areas (C6). Weights for indicators like IT service revenue (C3) fall into the medium range; weights for indicators such as the number of technology transfer contracts in the technology market (C28) are the lowest due to minimal data variation.

Table 2. CRITIC Weighting Results

Item	Weight	Item	Weight	Item	Weight
C1	3.32%	C11	4.06%	C21	3.27%
C2	4.85%	C12	3.63%	C22	7.01%
C3	5.00%	C13	2.12%	C23	2.60%
C4	2.37%	C14	2.93%	C24	4.56%
C5	4.67%	C15	4.81%	C25	2.20%
C6	5.58%	C16	4.89%	C26	3.32%
C7	4.27%	C17	2.38%	C27	2.05%
C8	4.62%	C18	4.54%	C28	1.84%
C9	3.28%	C19	2.01%		
C10	1.52%	C20	2.29%		

4 Empirical Evaluation of the Innovation Ecosystem in Western Regions

4.1 Evaluation Scope and Data

This study covers 12 provinces in China's western region: Sichuan, Shaanxi, Chongqing, Guizhou, Yunnan, Guangxi, Ningxia, Gansu, Inner Mongolia, Xinjiang, Tibet, and Qinghai. The evaluation spans six years from 2018 to 2023, ensuring comprehensive capture of the dynamic evolution trends in regional innovation ecosystems.

Data sources include the China Statistical Yearbook, China Science and Technology Statistical Yearbook, provincial statistical yearbooks, and publicly available government reports. Twenty-eight specific indicators (C1–C28) were selected across dimensions such as innovation environment foundations, innovation resource inputs, innovation output achievements, innovation entity vitality, and innovation openness and collaboration, forming a comprehensive regional innovation ecosystem evaluation indicator system. All data underwent standardization to eliminate dimensional effects, ensuring the evaluation process's standardization and the comparability of results.

4.2 Core Findings Analysis

4.2.1 Overall Characteristics. The comprehensive evaluation of regional innovation ecosystems in the 12 western provinces from 2018 to 2023, calculated using the TOPSIS method, are detailed in Table 3. The results reveals a distinct pattern: "three leaders at the forefront, mid-tier provinces catching up, and laggards at the rear." Sichuan, Shaanxi, and Chongqing consistently ranked in the top three, with Sichuan maintaining the number one position for six consecutive years and demonstrating overwhelming comprehensive strength. Mid-tier provinces such as Guizhou, Yunnan, and Guangxi retained a certain level of competitiveness, but their overall performance lagged significantly behind the top three. Meanwhile, Inner Mongolia, Xinjiang, Tibet, and Qinghai remained persistently at the bottom, with Qinghai consistently ranking last, highlighting pronounced regional imbalances in innovation development.

Table 3. TOPSIS Ranking Calculation Results

Province	2018		2019		2020		2021		2022		2023		Q-average
	Q	rank	Q	rank	Q	rank	Q	rank	Q	rank	Q	rank	
sichuan	0.658	1	0.664	1	0.649	1	0.651	1	0.649	1	0.656	1	0.655
shanxi	0.582	2	0.605	2	0.596	2	0.609	2	0.593	2	0.595	2	0.597
chongqing	0.57	3	0.553	3	0.557	3	0.57	3	0.583	3	0.572	3	0.568
guizhou	0.435	4	0.415	4	0.407	4	0.397	4	0.397	4	0.388	4	0.407
yunnan	0.398	5	0.366	7	0.356	5	0.368	6	0.371	5	0.382	5	0.374
guangxi	0.354	7	0.377	5	0.338	8	0.374	5	0.323	7	0.361	6	0.355
ningxia	0.357	6	0.346	8	0.353	6	0.348	7	0.334	6	0.336	7	0.346
gansu	0.353	8	0.368	6	0.346	7	0.325	9	0.313	8	0.315	8	0.337
neimenggu	0.351	9	0.325	10	0.302	9	0.326	8	0.308	9	0.312	9	0.321
xinjiang	0.316	10	0.326	9	0.302	10	0.251	11	0.287	10	0.302	10	0.297
xizang	0.278	11	0.275	11	0.265	11	0.296	10	0.285	11	0.284	11	0.281
qinghai	0.268	12	0.246	12	0.237	12	0.249	12	0.23	12	0.226	12	0.243

4.2.2 Features by Sub-dimension. Figures 1-5 presents the calculation results of five sub-dimensions for the 12 western provinces from 2018 to 2023 based on the TOPSIS method. Across the five sub-dimensions, provincial performance showed significant variation: Sichuan ranked first in innovation environment, output of achievements, and resource investment, demonstrating comprehensive strengths; Chongqing maintains a leading position in innovation subject vitality, with high activity among innovation entities; Shaanxi excels in the openness and collaboration dimension, demonstrating strong capabilities in international cooperation and technological exchange; Guizhou stands out in resource investment, second only to Sichuan; while Gansu ranks second in openness and collaboration, indicating considerable capacity for external cooperation. The distribution of strengths and weaknesses across dimensions reflects the complex structure and distinct priorities within the innovation ecosystems of western provinces.

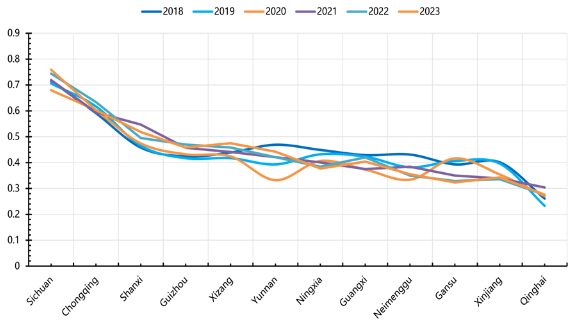

Fig. 1. Trend of Innovation Environment Foundation Dimension Scores

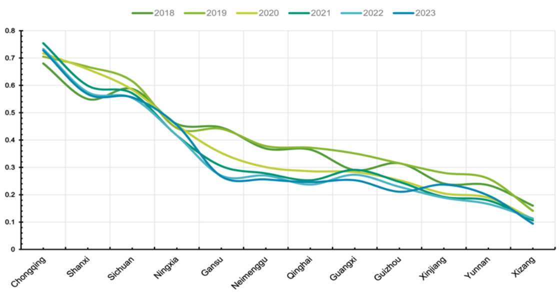

Fig. 2. Score Trends for Innovation Entity Vitality Dimension

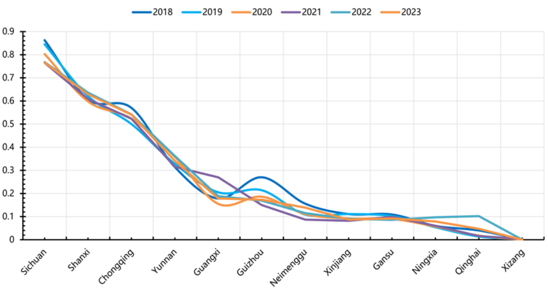

Fig. 3. Score Trends for Innovation Output Dimension

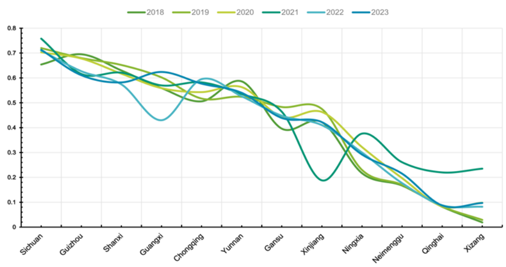

Fig. 4. Trend of Innovation Resource Investment Dimension Scores

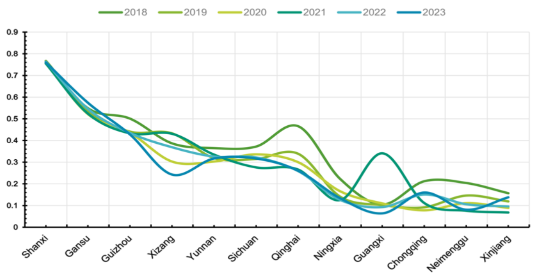

Fig. 5. Trend in Innovation Openness and Collaboration Dimension Scores

5 Conclusions and Recommendations

Western China's innovation ecosystem faces a prominent "demand-tool" mismatch: resource-based provinces rely on innovation to drive green industrial transformation, while border regions need it to upgrade the quality of open economies. However, existing evaluation systems, developed based on eastern China's experience, fail to align with western China's unique characteristics—this misalignment leads to assessment biases and undermines the precision of innovation policies.

To address this gap, this study constructs a diagnostic tool for regional innovation ecosystems based on symbiosis theory, covering five dimensions: "Innovation Environment Foundation, Subject Vitality, Output Results, Input Resources, and Open Collaboration." This tool not only fills the theoretical void in explaining the uniqueness of western innovation ecosystems but also enables effective assessment of ecosystem "health" and resilience by covering the full innovation value chain. Notably, as a core driver of western innovation ecosystem resilience, digital transformation can synergize with this diagnostic tool—together, they provide targeted support for optimizing innovation efficiency and upgrading innovation governance in western China.

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References

1. Wang Y, Xiao J, Xu Z. Digital Transformation Drives Regional Innovation Ecosystem Resilience: A Study Based on the Dynamic QCA Method [J]. Sustainability, 2025, 17(18): 8148.
2. An X, Tong L. Research on the Dissipative Evolution of the Regional Digital Innovation Ecosystem from the Perspective of Symbiosis Theory [J]. Sustainability, 2025, 17(18): 8121-8121.
3. Liu H, Li W, Jiang J, et al. Regional innovation ecosystem and local firms' outward foreign direct investment: an empirical study based on symbiosis perspective[J]. Technology Analysis & Strategic Management, 2025, 37(9): 1045-1060.
4. Deng Q, Long Y. Symbiotic evolution in regional green innovation ecosystems: A Lotka-Volterra model analysis of China's provincial[J]. Ecological Modelling, 2025, 508111244-111244.
5. Shen N, Zhang G, Zhang L, et al. Spatiotemporal evolution characteristics of ecological niche fitness in regional innovation ecosystems: Province-level evidence from China. Environmental Monitoring and Assessment, 2025, 197(5): 579.