Postprint: Spatiotemporal Variation Characteristics of Development Zones and Industries in Western China

Authors: Fu Jiao, Li Jing, Jia Hongwen, Huang Yinzhou

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Abstract

By collecting basic data on 714 development zones across 12 provinces in western China and employing nearest neighbor distance, kernel density analysis, and geospatial analysis methods, this study examines the spatial pattern evolution and industrial distribution characteristics of development zones in western China (hereinafter referred to as the western region) during 1993-2015. The research findings indicate: (1) Development zones in the western region exhibit significant spatial agglomeration characteristics, demonstrating an evolutionary pattern of "multi-level agglomeration" anchored by key cities and urban agglomerations. (2) Both the degree and scale of spatial agglomeration of development zones in the western region display a continuously increasing trend, with the growth rate of agglomeration scale exceeding that of agglomeration intensity. (3) National-level development zones in the western region show stronger agglomeration degree across various industry types compared to provincial-level development zones, but weaker agglomeration scale. National-level development zones primarily develop capital-intensive and technology-intensive industries, with distribution patterns of various industry types exhibiting single-core agglomeration characteristics; provincial-level development zones focus on labor-intensive and capital-intensive industries; significant disparities exist in the layout characteristics across different industry types—technology-intensive industries display a "large agglomeration, small dispersion" distribution pattern, labor-intensive industries agglomerate toward central cities, and capital-intensive industries develop through contiguous large-scale expansion. The research findings hold practical significance for the western region to rationally utilize development zones to strengthen urban agglomeration linkages and achieve coordinated regional development.

Full Text

Spatial-Temporal Evolution Characteristics of Development Zones and Industries in Western China

FU Jiao[1], LI Jing[1], JIA Hong-wen[2], HUANG Yin-zhou[1],[3]

[1]College of Earth and Environmental Sciences, Lanzhou University, Lanzhou, Gansu, China
[2]School of Economics, Lanzhou University, Lanzhou, Gansu, China
[3]Arid Region & Desert Research Center, Lanzhou University, Lanzhou, Gansu, China

Abstract

This study collected basic data from 714 development zones in western China and employed nearest neighbor distance analysis, kernel density analysis, and geographic spatial analysis methods to examine the spatial pattern evolution and industrial distribution characteristics of development zones in the western region from 1990 to 2015. The results reveal several key findings: (1) Development zones in western China exhibit significant spatial agglomeration characteristics, following an evolution pattern of "multi-level agglomeration" that relies on key cities and urban agglomerations. (2) Both the degree and scale of spatial agglomeration have shown continuous growth, with the growth rate of agglomeration scale exceeding that of agglomeration intensity. (3) National-level development zones demonstrate stronger agglomeration intensity across all industry types compared to provincial-level zones, though with smaller agglomeration scale. National-level zones primarily develop capital-intensive and technology-intensive industries, with various industry types showing a single-core agglomeration pattern. Provincial-level zones are dominated by labor-intensive and capital-intensive industries, with significant variations in industrial layout characteristics: technology-intensive industries display a "large agglomeration, small dispersion" pattern, labor-intensive industries agglomerate toward central cities, and capital-intensive industries develop in contiguous large-scale patterns. These findings offer practical significance for rationally utilizing development zones to strengthen connections among urban clusters and achieve coordinated regional development in western China.

Keywords: development zones; spatial-temporal evolution; pillar industries; western China

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Introduction

Since China' s reform and opening up, development zones have become crucial spatial carriers for attracting foreign investment, introducing technology and management expertise, and expanding exports, playing a significant role in promoting regional economic development. As primary spatial carriers for industrial layout, examining the spatial evolution processes and industrial characteristics of development zones is essential for optimizing industrial distribution, improving economic development efficiency, and fostering regional economic growth.

China established its first batch of national economic and technological development zones in coastal cities. In 1984, provincial-level local governments began approving local development zones, subsequently triggering a "development zone fever" characterized by explosive growth nationwide. Over the past 40 years, national and provincial development zones, as carriers of industrial clusters, have become increasingly important in driving regional economic development. Following the success of development zones in central and eastern regions, western China established numerous development zones under the Western Development Strategy, which have contributed to regional economic growth. However, this has also led to problems in some areas where large numbers of poorly planned development zones were approved to promote local industry and economic growth, resulting in chaotic spatial development order, resource waste, and industrial structure convergence—issues that conflict with current regional coordinated development concepts.

Early research on development zones primarily focused on foreign experience theories, location selection, and policy orientation. Meng Jijun (1999) deeply analyzed the planning, market, and policy mechanisms of China' s development zones, identifying these as the threefold operational mechanisms. Zhang Xiaoping (2002) proposed that the main driving forces for development zone growth are policy effects, market effects, and socio-cultural effects, arguing that understanding development zone evolution should not be limited to policy effects alone. In recent years, as development zone mechanisms and institutions have matured, scholarly perspectives have gradually shifted toward industrial development and pathways. Zhang Shiyu (2009) argued that national development zones are entering a critical period of industrial transformation and "second entrepreneurship," requiring proper policy adjustment, rational industrial layout, and industrial transformation. Zhu Yanheng et al. (2006) elaborated on the industrial development mechanisms of China' s economic and technological development zones, outlining the evolutionary paths of industrial development. Yu Jie (2009), Chen Botao (2012), and Gao Wenhuan (2014) conducted industrial development studies on Jinan High-tech Industrial Development Zone, Dantu Economic Development Zone, and Linyi Economic and Technological Development Zone respectively, proposing suggestions for industrial cluster cultivation and industrial structure adjustment directions. Li Lixing et al. (2015) emphasized strengthening the close integration between development zones and local economies and timely adjusting development zone industrial structures. Gao Chao et al. (2015) studied the spatial patterns and industrial evolution of development zones in coastal areas, concluding that the spatial evolution pattern transformed from "multi-center agglomeration" to "single-center agglomeration," with significant differences in industrial evolution.

Overall, existing research has emphasized studies on the spatial pattern evolution of development zones, but most analyses have examined overall layouts from macro perspectives without distinguishing between national and provincial-level development zone industries. Moreover, research on development zone industrial characteristics remains insufficient. Regarding study areas, scholarly attention has concentrated on national, coastal, and central regions, with insufficient focus on western China. Therefore, this paper selects 12 provinces in western China and development zone statistical data from 1990–2015, employing spatial analysis methods to systematically analyze spatial changes and industrial layout characteristics of development zones in the western region. Against the strategic backdrop of advancing the Western Development Strategy to form a new pattern, this study aims to provide references for optimizing the spatial structure and industrial development of western China’ s development zones.

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1. Data Sources and Research Methods

1.1 Data Sources According to the *China Development Zone Audit Announcement Directory (2018 Edition)*, national-level development zones are divided into six categories: Economic and Technological Development Zones, High-tech Industrial Development Zones, Bonded Zones, Export Processing Zones, Border Economic Cooperation Zones, and other types. Provincial-level development zones are divided into three categories: Provincial Economic Development Zones, Provincial High-tech Industrial Parks, and Provincial Characteristic Industrial Parks. This paper focuses on the two major categories of national and provincial development zones without further subdividing specific types.

Basic research data were obtained from the *China Development Zone Statistical Yearbook*, the *China Development Zone Audit Announcement Directory (2018 Edition)* (hereinafter referred to as the *Directory*), official websites of relevant provincial development zones, and statistical yearbooks from various years. A total of 138 national-level development zones and 576 provincial-level development zones in western China were selected. Data attributes include development zone names, establishment years, built-up areas, and pillar industries. Using latitude and longitude coordinate information, 714 development zones were vectorized to obtain the spatial distribution of western China’ s development zones.

1.2 Research Methods

1.2.1 Nearest Neighbor Index The distribution of point features in geographic space generally follows three patterns: random, uniform, or clustered. To measure the spatial distribution type of development zones in western China, this study employs the nearest neighbor distance and nearest neighbor index, which intuitively express point target distribution patterns, to quantitatively measure their spatial distribution types. The basic principle involves calculating the distance (r_i) from each point to its nearest neighbor, then obtaining the average value ($\bar{r}_i$) as the average nearest neighbor distance for all points. When points in the study area follow a random distribution, the theoretical nearest neighbor distance (r_j) is calculated as:

$$r_j = \frac{1}{2\sqrt{D}} = \frac{1}{2}\sqrt{\frac{A}{n}}$$

where r_j is the theoretical nearest neighbor distance, A is the study area, n is the number of points, and D is point density. Among the three distribution types, the theoretical nearest neighbor distance value is largest for uniform distribution, intermediate for random distribution, and smallest for clustered distribution.

The nearest neighbor index R is the ratio of the actual nearest neighbor distance to the theoretical nearest neighbor distance:

$$R = \frac{\bar{r}_i}{r_j}$$

When $R = 1$, the development zone distribution is random; when $R > 1$, development zones tend toward uniform distribution; when $R < 1$, development zones tend toward clustered distribution.

1.2.2 Multi-Distance Spatial Cluster Analysis When analyzing clustering patterns of actual geographic point objects, Ripley's $K(d)$ function is used to examine point distribution patterns across all spatial scales in the study region according to a certain radius distance search range. This can precisely identify the degree of clustering and dispersion of points at different spatial scales. The formula is:

$$K(d) = \frac{A}{n^2}\sum_{i=1}^{n}\sum_{j=1}^{n} w_{ij}(d)$$

$$L(d) = \sqrt{\frac{K(d)}{\pi}} - d$$

where $i, j = 1, 2, \dots, n$ represents the number of development zones in the study area; A is the study area; d is the distance scale; and $w_{ij}(d)$ is the distance between development zones i and j within the d range. When $L(d) > 0$, development zones show a clustering distribution trend; when $L(d) < 0$, they show a dispersion trend; and when $L(d) = 0$, they show a random distribution trend. The d value corresponding to the first peak of $L(d)$ values that deviate from the confidence interval is used to measure the clustering scale.

1.2.3 Kernel Density Analysis Kernel density estimation assumes that the probability of geographic events occurring at any location in space is random, with higher probabilities in dense point areas and lower probabilities in sparse areas. It primarily studies point distribution characteristics through spatial variations in point density within regions. This paper employs kernel density estimation, treating development zones as "points" in space and using 1990, 2000, 2010, and 2015 as time nodes to analyze the spatial distribution patterns and clustering changes of development zones in western China. The kernel density analysis function is expressed as:

$$f_h(x) = \frac{1}{nh} \sum_{i=1}^{n} k\left(\frac{x - x_i}{h}\right)$$

where $k(x)$ is the kernel function, $h > 0$ is the bandwidth, and $(x - x_i)$ represents the distance from the estimated point x to event x_i. Using the Kernel Density tool in geographic spatial analysis, kernel density analysis was conducted on western China's development zones. Due to differences in development scale among individual zones, this study selected built-up area attributes as weights, ultimately generating kernel density distribution maps for western China's development zones.

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2. Results and Analysis

2.1 Spatial Agglomeration Characteristics The earliest development zones in western China emerged in the 1990s, with relatively small numbers. Following the implementation of the Western Development Strategy, the number of development zones in the region increased annually. Using nearest neighbor distance analysis, the nearest neighbor index and distance for western China's development zones from 1990-2015 were calculated. The results show that the actual nearest neighbor distance ($\bar{r}_i = 0.272724$) is smaller than the theoretical nearest neighbor distance ($r_j = 0.383564$), with a ratio less than 1 ($R = 0.711027$). Thus, development zones in western China exhibit a clustered spatial distribution pattern.

Kernel density analysis was further employed to explore the spatial distribution characteristics and evolution patterns of development zones in western China. Based on the overall development history, four time cross-sections (1990, 2000, 2010, and 2015) were selected to investigate spatial distribution features [Figure 2: see original paper]. The maps reveal that during 1990-2015, development zones gradually expanded outward from high-density cores, showing both significant agglomeration and dispersed layout trends.

In 1990, development zones primarily formed first-level clustering centers in Sichuan, Chongqing, and Shaanxi, creating a "point-line" diffusion pattern that spread from three core points to southeastern Gansu, Guizhou, Yunnan, and

Guangxi, forming a "V" -shaped curve. By 2000, a small-area "patch" development pattern emerged, with southwestern regions developing contiguously across eastern Sichuan, Chongqing, Guizhou, and Yunnan, while northwestern regions clustered around Shaanxi, developing contiguously into Ningxia and Gansu. During 2010–2015, patch development gradually diffused, forming an overall pattern with Chengdu-Chongqing as the first-level clustering center relying on the Chengdu-Chongqing urban agglomeration, and Shaanxi-Ningxia as the second-level clustering center relying on the Guanzhong Plain urban agglomeration. In Xinjiang, development zones continuously expanded in scale, centered around the provincial capital Urumqi. After the 2003–2006 national development zone rectification, the spatial distribution of development zones basically stabilized, though agglomeration forms continued to expand, ultimately forming a multi-core development pattern. Among these, the clustering scales of Sichuan, Chongqing, and Shaanxi expanded annually; Guizhou, Guangxi, and Yunnan became new clustering centers; Lanzhou-Xining and Xi' an-Yinchuan became cores for development zone growth in northwestern China; and Inner Mongolia and Xinjiang exhibited spatial diffusion development patterns with lower clustering degrees.

The scale and distribution of development zones are strongly associated with regional economic development levels and location conditions. Economic development provides financial support for development zone construction and infrastructure investment, while location conditions partly determine the ease of attracting investment, with areas having convenient transportation and resource endowments more easily attracting investors. For western China' s development zones, regional economic growth in some areas has difficulty matching the expansion speed of development zones. The article compiled the 2015 rankings of development zone numbers and total GDP by province [Figure 3: see original paper], using a single indicator to verify the imbalance between economic development and development zone numbers. Gansu and Xinjiang rank relatively low in total GDP among western provinces but rank high in development zone numbers. In Xinjiang, development zones are mainly located in Urumqi, Karamay, Turpan, and Hami—regions with better economic development and abundant land resources. However, the establishment of development zones has not effectively driven Xinjiang' s overall economic development. Gansu' s economy ranks fourth from the bottom in western China, yet its development zone number ranks among the top five. Most of Gansu' s development zones emerged after the Western Development Strategy, with industrialization processes primarily government-driven and lacking external drivers. By 2015, all Gansu prefectures except Gannan had development zones, but with dispersed layouts and low concentration degrees.

2.2 Spatial Agglomeration Scale Multi-distance spatial cluster analysis was conducted on western China' s development zones using ArcGIS spatial analysis tools. Built-up area was used as the weight value, with Monte Carlo simulation applied and a confidence interval of 99%, yielding the results shown in [Figure 4: see original paper]. The analysis shows that $L(d)$ values for all four time cross-sections are positive and exceed the maximum values of the 99% confidence interval, indicating the data pass significance tests. Within the 0-1,000 km spatial scale range, the spatial distribution shows a significant clustering pattern. Examining the three time periods, the $L(d)$ curves show similar trends of rising to stable development across all periods, though the maximum $L(d)$ values and their corresponding spatial distances differ among periods. The maximum $L(d)$ value was 18.91 in 1990, corresponding to a spatial distance of 750 km; 23.32 in 2000, corresponding to 750 km; 27.45 in 2010, corresponding to 760 km; and 35.67 in 2015, corresponding to 850 km. This analysis reveals that both the degree and scale of spatial agglomeration of western China' s development zones have shown continuous growth, with the agglomeration scale increasing faster than agglomeration intensity. Spatial agglomeration intensity changed minimally during 1990-2010 but increased substantially during 2010-2015. In terms of spatial agglomeration scale, changes were small during 1990-2000, but the spatial range expanded significantly during 2000-2015.

The spatiotemporal development characteristics of western China's development zones are closely related to China's reform and opening-up strategy implementation. Beginning in 2000, the national Western Development Strategy provided substantial policy support to the 12 western provinces. By 2010, the Western Development Strategy entered an accelerated development phase, causing development zones to "bloom everywhere" across the region. Economically, through continuous efforts, western China' s regional GDP grew from 1.568282×10^{12} yuan to 1.66546×10^{12} yuan. During 1990-2015, western China's total economic output continuously increased, with both agglomeration intensity and scale of development zones peaking in 2015. This demonstrates that as government-led public industrial platforms, development zones' development trajectories align with regional economic development.

2.3 Leading Industry Distribution Characteristics Based on pillar industry data from the *Directory*, leading industries of national and provincial development zones were categorized. According to industrial characteristics, national-level development zones were divided into six industries, selecting frequently occurring leading industries for analysis. These include: Equipment Manufacturing (covering general equipment, special equipment, transportation equipment, and electrical equipment manufacturing); Pharmaceutical Manufacturing (covering biological, biochemical products, medicine, and traditional Chinese/Tibetan medicine); New Materials (including new energy, general aviation, titanium alloys, and medical devices); Electronic Information (including electronic and communication equipment, information technology); Chemical Industry (including coal-electricity chemical, fine chemical, and daily chemical industries); and Food Industry (including food, beverages, alcohol, and dairy products). Provincial-level development zones were divided into five categories: Chemical Industry (including coal-electricity chemical, petrochemical, salt chemical, and fine chemical industries); Agricultural and Sideline Products

Processing (including fine processing of agricultural and sideline products, and agricultural and livestock product processing); Building Materials (as a separate category); Food Industry (including food, beverages, alcohol, and dairy products); Pharmaceutical Manufacturing (including biological, biochemical products, medicine, and traditional Chinese/Tibetan medicine); and Metal Smelting (including metal processing, vanadium-titanium steel, non-ferrous metals, and aluminum smelting).

The top six industries for national-level development zones and top five for provincial-level development zones show significant differences, involving 11 industries total, reflecting the spatial heterogeneity of industrial positioning among development zones at different levels in western China. For provincial-level development zones, the lack of differentiated development has led to industrial homogenization in some sectors. For example, Sichuan, Chongqing, Shaanxi, and Guizhou, which are rich in mineral resources, have all chosen chemical and equipment manufacturing industries as leading industries. Development zone development is closely related to government investment. As western China is still in an accelerated economic development stage, governments at all levels tend to select industries that can directly generate economic benefits, leading to redundant construction and industrial convergence across provinces.

As previously noted, differences in conditions and policies between national and provincial-level development zones result in significantly different industrial development models. To more clearly analyze the characteristics of leading industries in western China' s development zones, this paper categorizes pillar industries into three types based on factor input intensity: labor-intensive, capital-intensive, and technology-intensive. Specifically, agricultural and sideline products processing and food industry are classified as labor-intensive; chemical industry, building materials, metal smelting, and equipment manufacturing as capital-intensive; and new materials, pharmaceutical manufacturing, and electronic information as technology-intensive.

National-level development zones in western China focus on equipment manufacturing, pharmaceutical manufacturing, new materials, electronic information, chemical industry, and food industry, while provincial-level zones emphasize chemical industry, agricultural and sideline products processing, building materials, food industry, pharmaceutical manufacturing, and metal smelting. The agglomeration degree of all industry types in national-level development zones is stronger than in provincial-level zones, though with smaller agglomeration scale. Technology-intensive industries in national-level zones are concentrated in Xining, Lanzhou, Xi' an, and other provincial capital cities, relying on the Lanzhou-Xining and Guanzhong Plain urban agglomerations. Labor-intensive industries mainly cluster in the Guanzhong Plain, Karamay City in Xinjiang, and Nanning City in Guangxi. Capital-intensive industries show a multi-core agglomeration pattern, primarily clustering in the Lanzhou-Xining urban agglomeration, Chengdu-Chongqing urban agglomeration, and key cities such as

Yinchuan, Xi' an, and Kunming.

Provincial-level development zones show larger agglomeration scale than national-level zones, with labor-intensive industries having the largest scale. Regionally, technology-intensive industries mainly agglomerate in central cities and their surrounding areas, presenting a "large agglomeration, small dispersion" pattern. Labor-intensive industries show single-core agglomeration characteristics, concentrating heavily in Zunyi City, Guizhou and Luzhou City, Sichuan. Capital-intensive industries exhibit contiguous development with relatively balanced overall distribution.

Based on the three industry types, development zone numbers were compiled . National-level development zones have 27 technology-intensive industries, 41 capital-intensive industries, and 21 labor-intensive industries, accounting for 30.00%, 45.56%, and 23.33% respectively. Provincial-level development zones have 45 capital-intensive industries, 211 labor-intensive industries, and 98 technology-intensive industries. This indicates that national-level development zones favor technology introduction, while provincial-level zones focus more on investment attraction. Using the proportion sum (CR_5) of the total frequency of the top five industries to reflect industrial concentration [21], western China' s national-level development zones show a CR_5 ratio of 57.42%, while provincial-level zones show 65.85%. The higher ratio for provincial-level zones indicates greater similarity in leading industry positioning compared to national-level zones. The larger scale of provincial-level development zones may lead to unhealthy competition and unclear industrial division after they become industrial clusters and distinctive industrial zones.

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3. Conclusions

Combining the development history of China' s development zones, this study examined the spatial agglomeration scale and industrial distribution characteristics of western China' s development zones from 1990–2015, distinguishing between national and provincial-level development zones. The conclusions can be summarized as follows: (1) Within a 1,000 km scale range, development zones in western China show a significant clustering pattern. The $L(d)$ curves for the four time periods show consistent trends of rising to stabilization. Spatial agglomeration intensity changed minimally during 1990–2010 but increased substantially during 2010–2015. The spatial range changed little during 1990–2000 but expanded significantly during 2000–2015. Overall, both the degree and scale of spatial agglomeration have continuously increased, with agglomeration scale growing faster than intensity. (2) Different-level development zones exhibit spatial heterogeneity in industrial positioning. National-level zones focus on equipment manufacturing, pharmaceutical manufacturing, new materials, electronic information, chemical industry, and food industry, while provincial-level zones emphasize chemical industry, agricultural and sideline products processing, building materials, food industry, pharmaceutical manufacturing, and metal smelting. National-level zones show stronger agglomeration intensity across all industry types than provincial-level zones, while provincial-level zones show larger agglomeration scale. Technology-intensive industries in national-level zones concentrate in Xining, Lanzhou, Xi' an, and surrounding areas; capital-intensive industries mainly distribute in Yinchuan, Xi' an, Kunming, and the Chengdu-Chongqing urban agglomeration; and labor-intensive industries cluster in the Guanzhong Plain, Karamay, and Nanning. In provincial-level zones, technology-intensive industries show a "large agglomeration, small dispersion" pattern, labor-intensive industries agglomerate in central cities (mainly in Guizhou and Sichuan), and capital-intensive industries have developed contiguously.

Overall, western China has relatively few national-level development zones, as China' s national development zones are mainly concentrated in eastern coastal areas. Western China should firmly grasp the Western Development and Belt and Road strategies, focusing on developing national-level development zones to narrow the quantity gap with eastern regions. Regarding industrial layout, western provinces should strengthen management of provincial-level development zones, enhance technological innovation capabilities, strengthen regional economic interaction, and avoid redundant construction and industrial convergence.

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4. Discussion

From a geographic spatial perspective, this study employs GIS and exploratory spatial data analysis methods to examine the spatial pattern evolution and industrial layout characteristics of development zones at different levels in western China, offering new insights for future research on development zone distribution patterns and providing references for better managing western China' s development zones and leveraging their industrial agglomeration advantages. Limited by understanding of development zones, this paper lacks analysis of the causes and mechanisms behind the spatial patterns and industrial distribution of western China' s development zones. Future research should deeply explore the influences of human, economic, transportation, and natural factors on development zone spatial patterns and systematically analyze the role of leading industries in regional economic development through establishing indicator systems.

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