A Study on the Spatiotemporal Patterns and Influencing Factors of Urban–Rural Integrated Development: A Case Study of the Chengdu Plain Economic Zone

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Abstract
Urban-rural integration is essential for China's modernization, aiming to bridge the urban-rural divide and promote common prosperity. The Chengdu Plain Economic Zone, accounting for 63.2% of Sichuan's GDP, faces challenges such as a 39.3 percentage point urbanization gap and industrial homogenization. This study assesses integration from 2012 to 2021 across economic, social, spatial, and demographic dimensions, using the entropy method and geographical detector model. Results reveal an 8.65% annual growth in integration, with a spatial pattern of "high in the center, low in the southwest." Chengdu leads consistently, while De yang and Mian yang progress via industrial upgrades; Ya an and Leshan lag due to geographical constraints. Key drivers include urbanization rate (q=0.62), per capita GDP (q=0.58), and income gap (q=0.45). The proposed policy framework advocates multi-center collaboration, industrial complementarity, infrastructure connectivity, and talent sharing to achieve "value symbiosis," providing a model for less-developed regions in Western China.

Keywords: urban-rural integration; spatio-temporal patterns; geographical detector; multi-center collaboration

1. Introduction
Urban-rural integration is a central issue in China's modernization process, aiming to dismantle the urban-rural dual structure, promote bidirectional factor flows, and achieve balanced and coordinated socio-economic development between urban and rural areas. As a key growth pole for high-quality development in Western China, the Chengdu Plain Economic Zone encompasses eight prefecture-level cities, including Chengdu, Deyang, and Mianyang. In 2021, it accounted for 63.2% of Sichuan Province's GDP, with an urbanization rate of 56.16%, making it one of the most densely populated and economically vibrant regions in Western China. However, significant regional imbalances persist: Chengdu, the core city, boasts an urbanization rate of 79.5% and an urban-rural income ratio reduced to 2.01, while peripheral areas such as Ya'an and Ziyang face challenges including widening urban-rural income gaps (Ya'an's urban-rural income ratio was 2.35 in 2021), pronounced industrial homogenization, and inadequate infrastructure connectivity. Against this backdrop, studying the spatio-temporal evolution patterns and driving mechanisms of urban-rural integration in the Chengdu Plain Economic Zone not only responds to the policy demands of China's 14th Five-Year Plan for Urban-Rural Integration but also addresses the practical need to optimize regional resource allocation and promote coordinated development across the region.

Theoretically, current research on urban-rural integration predominantly focuses on developed eastern regions such as the Yangtze River Delta and Pearl River Delta, with relatively limited dynamic analyses of Western economic zones. Moreover, existing evaluation systems often overemphasize singular economic dimensions, neglecting multifaceted aspects such as social equity and spatial balance. This study constructs a four-dimensional indicator system encompassing economic efficiency, social equity, spatial coordination, and population mobility. By integrating the entropy method and the geographical detector model, it seeks to address the paucity of empirical studies in Western China and provide methodological advancements to urban-rural integration theory. Practically, the findings offer scientific evidence to support differentiated policymaking and cross-regional resource collaboration in the Chengdu Plain Economic Zone. For instance, a "core city radiation–secondary center absorption" model could mitigate Chengdu's "siphon effect," while optimizing transportation networks could narrow the development gap in the southwestern peripheral areas.

Focusing on the Chengdu Plain Economic Zone and utilizing statistical data from 2012 to 2021, this study addresses two key questions: (1) how to scientifically quantify the level of urban-rural integration, and (2) the spatio-temporal patterns and core driving factors of regional disparities. Methodologically, the entropy method is employed to construct a comprehensive evaluation model to analyze the temporal evolution characteristics of urban-rural integration. ArcGIS spatial analysis techniques are used to delineate the "high in the center, low in the southwest" spatial differentiation pattern. The geographical detector model identifies key influencing factors such as urbanization rate and per capita GDP. The innovation of this study lies in proposing a composite framework of "static indicator weight allocation + dynamic spatial attribution analysis," which overcomes the limitations of traditional studies confined to a single spatio-temporal dimension.

2. Theoretical Foundation and Literature Review

The theoretical evolution of urban-rural integration has consistently paralleled deepening understandings of urban-rural relationships. Early scholars often analyzed urban-rural dynamics from an "opposition-coordination" perspective. For instance, Ebenezer Howard's "Garden City" theory, proposed in 1898, advocated for planned integration of urban economic vitality and rural ecological value to achieve functional complementarity [1], laying a cornerstone for subsequent urban-rural integration studies. In the mid-20th century, Arthur Lewis's "dual economy structure theory" elucidated the economic roots of urban-rural segmentation in developing countries [2], emphasizing that the transfer of surplus agricultural labor to industrial sectors is essential for resolving urban-rural divides. However, its "urban-biased" perspective was critiqued by scholars like Michael Lipton, who argued that overly urban-centric policies lead to rural resource depletion and exacerbate urban-rural inequality. Lipton's concept of "balanced urban-rural development" marked a significant shift in the field [3].

Since the 21st century, with the acceleration of globalization and informatization, urban-rural integration theories have expanded to encompass multidimensional interactions across spatial, social, and ecological domains. John Friedmann's "core-periphery" theory highlighted the radiating influence of central cities on surrounding areas [4], while Michael Storper's "new regionalism" advocated for institutional innovation and local governance to facilitate the free flow of urban-rural factors [5]. Chinese scholars, building on Western theories and adapting to national conditions, have proposed localized interpretations. For example, Liu Yansui introduced the concept of "urban-rural equivalence," advocating for equalized public services and industrial linkages to narrow the quality-of-life gap between urban and rural areas [6]. Lu Dadao, from the perspective of "human-land relationships," emphasized the need to balance resource and environmental carrying capacity with socio-economic development demands in urban-rural integration [7]. These theories provide critical support for constructing the "economic-social-spatial-demographic" four-dimensional analytical framework in this study.

Empirical research on urban-rural integration, both domestically and internationally, exhibits a pattern of "eastern focus and methodological diversity." Early international studies were predominantly qualitative, such as T.G. McGee's exploration of the "Desakota" (urban-rural transition zone) model in Southeast Asia, which revealed the unique role of informal economies in transitional areas [8]. In recent years, quantitative modeling has gained prominence; for instance, J. Van den Bergh used spatial econometric methods to verify the role of infrastructure connectivity in promoting urban-rural income convergence [9]. In China, early studies focused on policy interpretation and case descriptions. After 2010, with improved statistical data, scholars began developing comprehensive evaluation systems. Liu Rongrong's team constructed an indicator system based on economic, social, and environmental integration, finding that urban-rural integration levels in the Yangtze River Delta urban agglomeration followed a "center-periphery" declining pattern [10,11]. Che Bingqing's study on the Huaihai Economic Zone identified topographic complexity and policy implementation capacity as key factors influencing urban-rural integration [12,13]. However, existing indicator systems often prioritize economic dimensions, with insufficient quantification of social equity (e.g., accessibility to public services) and spatial justice (e.g., ecological resource allocation). Moreover, dynamic spatio-temporal analyses targeting less-developed economic zones in Western China remain scarce.

Existing studies provide important insights for this research but exhibit three main limitations. First, at the theoretical level, most studies reduce urban-rural integration to "gap narrowing," overlooking the deeper logic of functional complementarity and value symbiosis between urban and rural areas. Second, at the methodolog-

ical level, static cross-sectional analyses predominate, with insufficient tracking of the dynamic evolutionary pathways of urban-rural integration. Third, at the regional level, there is inadequate attention to the unique and complex characteristics of Western China, particularly the influence of factors such as topographic barriers and ethnic diversity, which have not been fully incorporated into analytical frameworks. This study seeks to advance the field in the following ways: (1) constructing a composite indicator system encompassing economic efficiency, social equity, spatial coordination, and population mobility to address the multidimensional nature of urban-rural integration; (2) utilizing a decade-long time-series dataset to reveal the staged characteristics of the integration process in the Chengdu Plain Economic Zone; and (3) employing the geographical detector model to identify the interactive effects of natural conditions and institutional factors on the spatial differentiation of urban-rural integration, thereby providing a basis for differentiated policy design in less-developed regions of Western China.

3. Study Area Overview and Data Methods

3.1 Study Area Overview

The Chengdu Plain Economic Zone is located in the western Sichuan Basin, spanning a geographical range between 28°28'–33°02'N and 101°56'–106°59'E. It encompasses eight prefecture-level cities: Chengdu, Deyang, Mianyang, Leshan, Meishan, Ziyang, Suining, and Ya'an, covering a total area of 86,400 square kilometers. As a core component of the Chengdu-Chongqing Economic Circle, the region had a permanent population of 42.141 million in 2021, accounting for 50.3% of Sichuan Province's total population, and a GDP of 3.29 trillion yuan, contributing 63.2% of the province's economic output. This makes it one of the most densely populated and economically dynamic regions in Western China. However, internal development disparities are pronounced: Chengdu, with less than 20% of the region's land area, contributes 46.7% of the economic zone's GDP, and its urbanization rate (79.5%) is nearly double that of Ya'an (40.2%). Although the urban-rural income gap has gradually narrowed (from an urban-rural income ratio of 2.57 in 2012 to 2.01 in 2021), challenges such as insufficient rural public service provision and lagging infrastructure connectivity remain prominent in peripheral areas.

3.2 Data and Methods

The research data primarily come from the Sichuan Statistical Yearbook (2012–2021), the China City Statistical Yearbook, and statistical bulletins on national economic and social development from the respective prefecture-level cities. For missing data (e.g., county-level fiscal expenditures in certain years), linear interpolation was applied, and raw data were standardized to eliminate dimensional differences. The indicator system was constructed based on principles of "systematicity, operability, and policy orientation," selecting 16 indicators across four dimensions: economic integration, social integration, spatial integration, and population integration (Table 3-1). Economic integration focuses on urban-rural production efficiency and income equity (e.g., per capita GDP, non-agricultural industry share). Social integration emphasizes public service accessibility and consumption equity (e.g., medical insurance coverage, urban-rural consumption expenditure ratio). Spatial integration measures infrastructure and ecological coordination (e.g., highway density, green coverage rate in built-up areas). Population integration reflects labor structure and mobility (e.g., urbanization rate, non-agricultural employment ratio). Indicators are classified as positive or negative: for example, a smaller urban-rural income ratio (negative) indicates higher integration, while a larger per capita GDP (positive) reflects superior development levels.

Table 3-1 Evaluation Index System for the Level of Urban-Rural Integration in the Chengdu Plain Economic Zone

Dimension	Indicator	Indicator Calculation or Description	Attribute
Economic Integration	Per Capita Regional GDP	Per capita regional GDP (Yuan/person)	Positive
	Proportion of Non-Agricultural Industries in GDP	Proportion of secondary and tertiary industry added value in GDP * 100 (%)	Positive
	Proportion of Agricultural Expenditure in Total Expenditure	Agricultural fiscal expenditure / total fiscal expenditure * 100 (%)	Positive
	Urban-Rural Per Capita Disposable Income Ratio	Urban per capita disposable income / rural per capita disposable income	Negative
	Dual Production Efficiency Ratio	(Primary industry added value / primary industry employees) / (secondary and tertiary industry added value / secondary and tertiary industry employees)	Positive
Social Integration	Education Expenditure as a Proportion of GDP	Education expenditure / GDP * 100 (%)	Positive
	Basic Medical Insurance Coverage Rate	Insured population / total population * 100 (%)	Positive
	Hospital Beds per 10,000 People	Number of hospital beds in medical institutions per 10,000 people (beds/10,000 people)	Positive
	Urban-Rural Per Capita Consumption Expenditure Ratio	Urban per capita consumption / rural per capita consumption	Negative
	Urban-Rural Engel Coefficient Ratio	Urban Engel coefficient / rural Engel coefficient	Negative
Spatial Integration	Regional Urban Greening Rate	Green space area / construction land area * 100 (%)	Positive
	Highway Network Density	Highway operating mileage / total land area (km/km²)	Positive
	Proportion of Built-Up Area	Built-up area / total land area * 100 (%)	Positive
Population Integration	Population Urbanization Rate	Permanent urban population / total population * 100 (%)	Positive
	Proportion of Non-Agricultural Employed Population	Number of employees in secondary and tertiary industries / total employees * 100 (%)	Positive
	Urban-Rural Population Interaction Degree	Total urban-rural population migration rate (‰)	Positive

The entropy method was employed to determine indicator weights, avoiding biases from subjective weighting. First, raw data were standardized using the range method, and the information entropy and redundancy of each indicator were calculated to derive weight values. Next, a weighted sum formula was applied to compute the comprehensive urban-rural integration score, with values ranging from [0, 1]; higher scores indicate superior integration levels. Spatial analysis was conducted using the ArcGIS 10.2 platform, employing the natural breaks method to classify integration levels into five categories (low, medium-low, medium, medium-high, high). Standard deviational ellipse and hotspot analysis were used to reveal spatial differentiation patterns. The geographical detector model was utilized to identify key driving factors by calculating the explanatory power (q-value) of each factor, with q-values ranging from [0, 1]; higher q-values indicate greater contributions to spatial differentiation.

4. Spatio-Temporal Patterns and Evolution of Urban-Rural Integration in the Chengdu Plain Economic Zone

4.1 Measurement and Classification of Integration Levels

To evaluate the urban-rural integration levels in the Chengdu Plain Economic Zone from 2012 to 2021, this study applied the entropy method to measure the weights of each indicator. Subsequently, a specific computational formula was used to derive the comprehensive urban-rural integration score for the economic zone, serving as the benchmark for assessing the degree of integration. These comprehensive scores are detailed in Table 4-1, providing a foundation for subsequent in-depth analysis.

Table 4-1 Comprehensive Score for Urban-Rural Integration Level in the Chengdu Plain Economic Zone, 2012–2021

Region	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	Average for each city
Chengdu City	0.502	0.537	0.570	0.594	0.626	0.716	0.742	0.731	0.719	0.782	0.652
Deyang City	0.275	0.295	0.294	0.333	0.321	0.331	0.368	0.376	0.423	0.443	0.346
Mianyang City	0.234	0.262	0.330	0.351	0.351	0.365	0.412	0.403	0.449	0.497	0.365
Meishan City	0.210	0.236	0.251	0.305	0.286	0.316	0.320	0.325	0.366	0.408	0.302
Leshan City	0.225	0.224	0.258	0.308	0.301	0.295	0.331	0.339	0.366	0.406	0.305
Ziyang City	0.215	0.228	0.247	0.277	0.328	0.334	0.341	0.364	0.390	0.414	0.314
Suining City	0.347	0.302	0.302	0.370	0.351	0.358	0.390	0.395	0.469	0.517	0.380
Ya'an City	0.186	0.191	0.185	0.226	0.235	0.224	0.280	0.307	0.367	0.389	0.259
Average	0.274	0.284	0.305	0.346	0.350	0.367	0.398	0.405	0.444	0.482	
Average growth rate %		3.692	7.121	13.418	1.266	5.002	8.336	1.759	9.537	8.650	

Building on the practical context of urban-rural integration in the Chengdu Plain Economic Zone, combined with national policy orientations, Sichuan Province's urban-rural development plans, and various comprehensive factors, this study thoroughly analyzes the spatio-temporal evolution characteristics of urban-rural integration levels in the region. The analysis reveals not only temporal progression but also significant spatial differentiation and variation. To comprehensively and accurately assess urban-rural integration levels, ArcGIS 10.2 software was utilized to conduct detailed hierarchical processing of the comprehensive urban-rural integration scores for the eight prefecture-level cities in the Chengdu Plain Economic Zone.

Adhering to the concept of high-quality urban-rural integration development, this study employed the natural breaks method to classify the comprehensive scores into five levels, sequentially named "high-level integration zone," "medium-high-level integration zone," "medium-level integration zone," "medium-low-level integration zone," and "low-level integration zone." Table 4-2 provides a detailed breakdown of the number of prefecture-level cities included in each level, offering valuable reference for in-depth research and strategy formulation for urban-rural integration in the Chengdu Plain Economic Zone.

Through this comprehensive analysis, the evolutionary trends of urban-rural integration levels can be more fully understood, providing robust data support and strategic guidance for future sustainable development strategies.

Table 4-2 Statistics on the Number of Prefecture-Level Cities at Various Levels in the Chengdu Plain Economic Zone by Urban-Rural Integration Level, 2012–2021

Year	Relatively high level	Relatively medium high level	Relatively medium level	Relatively medium low level	Relatively low level
2012	1	1	1	4	1
2013	1	2	1	3	1
2014	1	3	1	2	1
2015	1	2	3	1	1
2016	1	2	2	2	1
2017	1	2	3	1	1
2018	1	2	1	3	1
2019	1	2	2	2	1
2020	1	2	3	1	1
2021	1	3	2	1	1

4.2 Temporal Evolution of Urban-Rural Integration Levels

4.2.1 Overall Characteristics of Temporal Evolution

As shown in Table 4-1 and Figure 4-1, from 2012 to 2021, the urban-rural integration levels in the Chengdu Plain Economic Zone generally exhibited an upward trend. Chengdu City maintained a relatively high urban-rural integration score throughout the period, displaying steady growth, while the integration scores of other cities showed varying degrees of increase.

(1) The overall urban-rural integration level in the Chengdu Plain Economic Zone shows a fluctuating upward trend.

The comprehensive urban-rural integration score increased from 0.274 in 2012 to 0.482 in 2021, reflecting an overall increase of 0.208 over the decade. This indicates significant improvement in urban-rural integration levels during this period. Data on annual growth rates reveal fluctuations in the pace of growth. The growth rate was relatively high between 2014 and 2015, reaching 13.418%, but it slightly declined between 2019 and 2020 to 1.759%. Nevertheless, the average annual growth rate remained positive, demonstrating a steady upward trend. Between 2018 and 2019, the annual growth rate was 1.759%, while it increased to 8.65% from 2020 to 2021. This suggests notable progress in urban-rural integration efforts in the later stages, with an accelerated growth rate. Significant disparities in integration levels exist across regions. For instance, Chengdu City consistently achieved high comprehensive scores, whereas Ya'an City recorded relatively low scores. These differences may be influenced by factors such as regional economic development levels and the extent of policy support.

(2) The urban-rural integration level in the Chengdu Plain Economic Zone has risen from relatively medium-low to relatively medium-high levels.

From 2012 to 2021, the number of prefecture-level cities with relatively high integration levels remained stable, with only one city (Chengdu) consistently at this level each year. This indicates that Chengdu has achieved notable success in urban-rural integration and maintained a relatively high level. The number of prefecture-level cities with medium-high integration levels fluctuated but showed an overall increasing trend. From 2014 to 2018, the number of such cities steadily increased, peaking in 2021. This may reflect relatively stable and positive development in urban-rural integration in these areas. The number of cities with medium integration levels also exhibited an overall increase from 2012 to 2021, with significant growth between 2014 and 2017, reaching a peak in 2020. These regions likely made some progress in urban-rural integration, but their development levels still require further improvement. The number of cities with medium-low integration levels showed a fluctuating downward trend, decreasing from four in 2012 to one in 2021. These regions may face challenges in urban-rural integration, necessitating greater policy support and resource investment. The number of cities with low integration levels remained stable from 2012 to 2021, with one city (Ya'an) consistently at this level each year. This suggests that Ya'an is a region with persistently low urban-rural integration levels, requiring intensified reform efforts and policy support to enhance its integration.

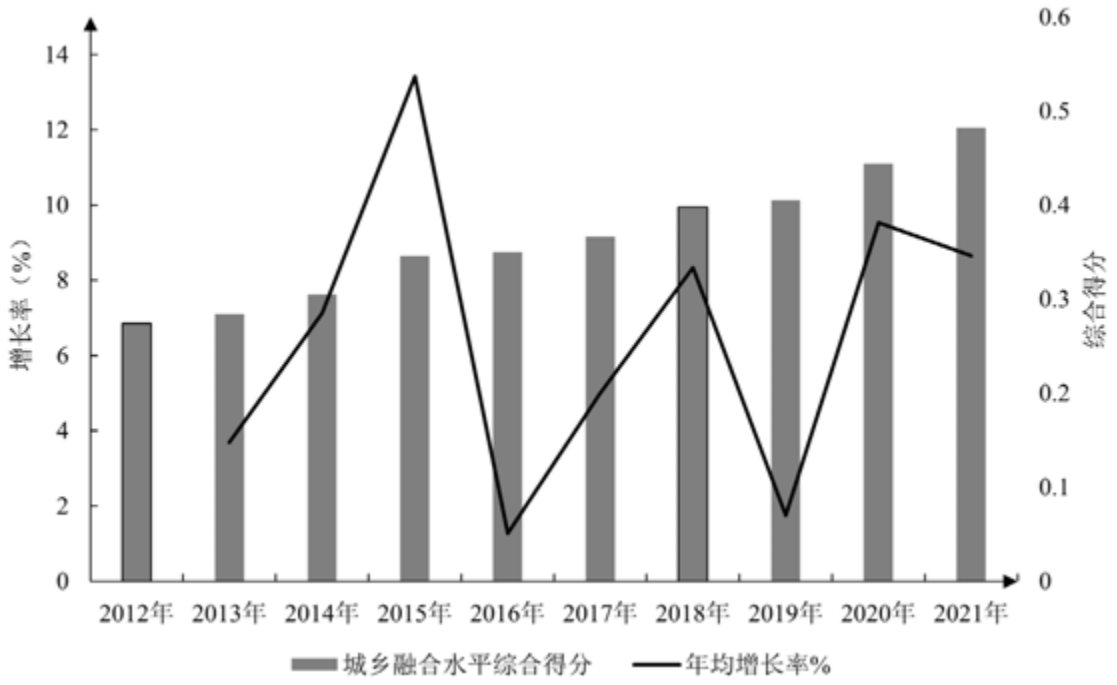

Figure 4-1 Comprehensive Score Trend for Urban-Rural Integration Level in the Chengdu Plain Economic Zone (2012-2021)

4.2.2 Temporal Variation Characteristics of Each Dimension

Based on the urban-rural integration indicator data for the Chengdu Plain Economic Zone from 2012 to 2021, this study employed the entropy method to calculate comprehensive scores for the four key dimensions: economic integration, social integration, spatial integration, and population integration. These scores are presented in detail in Figure 4-2 and Table 4-3, providing a comprehensive and in-depth understanding of the urban-rural integration levels in the Chengdu Plain Economic Zone.

As shown in Figure 4-2, the comprehensive score for urban-rural economic integration exhibited a steady upward trend from 2012 to 2021, increasing from 0.620 in 2012 to 1.106 in 2021, a growth of approximately 78.7%. From 2012 to 2015, the comprehensive score grew relatively slowly, with an increase of 0.181. During this period, constraints such as urban-rural development disparities and industrial structure transitions likely contributed to uneven economic development, slowing the progress of urban-rural integration. From 2016 to 2021, the comprehensive score increased more significantly, by 0.486. This may be attributed to accelerated urbanization, enhanced government policy support, and notable progress in industrial structure optimization and regional economic output growth.

The comprehensive score for urban-rural social integration showed a gradual increasing trend from 2012 to 2021, rising from 0.570 to 1.016, a growth of approximately 78.6%. Based on the magnitude of growth, this period can be divided into two phases: from 2012 to 2015, the comprehensive score grew slowly, with an increase of 0.237. This may have been influenced by issues such as widening urban-rural income gaps and imbalances in access to basic education and healthcare resources. From 2016 to 2021, the comprehensive score increased more noticeably, by 0.446. This is likely due to increased government investment in infrastructure, improvements in social security systems, and enhanced public service levels, which helped narrow the urban-rural social development gap.

The comprehensive score for urban-rural spatial integration demonstrated a steady upward trend from 2012 to 2021, increasing from 0.549 to 0.920, a growth of approximately 67.0%. From 2012 to 2015, the comprehensive score grew slowly, with an increase of 0.036, possibly due to issues such as inadequate transportation and

lagging infrastructure. From 2016 to 2021, the comprehensive score increased more significantly, by 0.371. This may be attributed to improvements in urban planning and transportation network development, which reduced spatial distances between urban and rural areas and strengthened their connectivity.

The comprehensive score for urban-rural population integration exhibited a fluctuating upward trend from 2012 to 2021, rising from 0.455 to 0.813, a growth of approximately 78.7%. From 2012 to 2015, the comprehensive score grew slowly, with an increase of 0.175, likely constrained by factors such as household registration (hukou) restrictions and limited urban-rural population mobility. From 2016 to 2021, the comprehensive score increased more significantly, by 0.358. This may be driven by household registration system reforms and increased absorption of rural populations into urban areas, facilitating greater population mobility and reducing urban-rural population disparities.

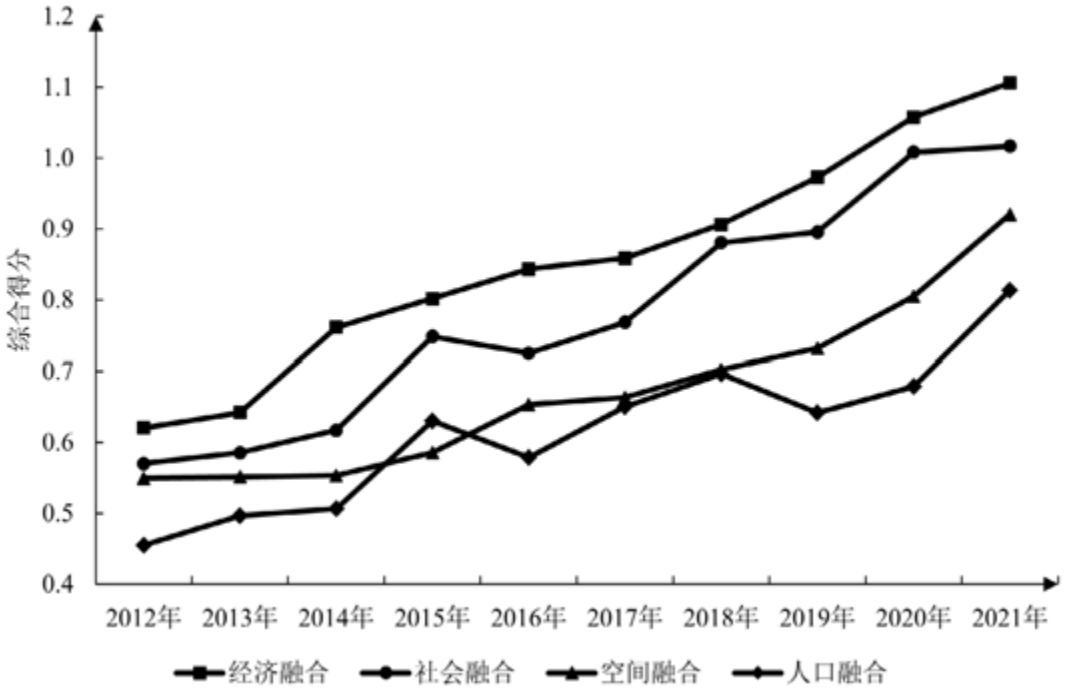

Figure 4-2 Comprehensive score trends for various indicators of urban-rural integration in the Chengdu Plain Economic Zone (2012-2021)

Table 4-3 Comprehensive Scores for Each Indicator Level of Urban-Rural Integration in the Chengdu Plain Economic Zone from 2012 to 2021

Year	Economic integration	Social integration	Spatial integration	Population integration
2012	0.620	0.570	0.549	0.455
2013	0.642	0.585	0.551	0.497
2014	0.761	0.617	0.553	0.506
2015	0.801	0.748	0.585	0.630
2016	0.843	0.724	0.653	0.579
2017	0.858	0.768	0.663	0.650
2018	0.906	0.880	0.702	0.696
2019	0.973	0.895	0.732	0.642
2020	1.058	1.008	0.805	0.679
2021	1.106	1.016	0.920	0.813

4.3 Spatial Patterns and Evolution of Urban-Rural Integration

4.3.1 Overall Characteristics of Spatial Patterns

Using the ArcGIS 10.2 platform, the spatial differentiation patterns of urban-rural integration levels in the Chengdu Plain Economic Zone were examined based on the average annual comprehensive scores of its eight prefecture-level cities from 2012 to 2021. The results (see Appendix Figure 4-3) reveal distinct spatial characteristics in the urban-rural integration levels of the Chengdu Plain Economic Zone: Chengdu City, located in the central region, exhibits the highest development level, followed by the northeastern areas, while the southwestern regions show lower levels of urban-rural integration, with significant internal spatial differentiation overall.

Within the Chengdu Plain Economic Zone, Chengdu, as the central city, plays a pivotal leadership role, exerting substantial influence across the entire region. This area displays a clear pattern of radiating outward from the center, forming a typical core-periphery structure. As a sub-provincial city and one of China's national central cities, Chengdu benefits from unique resource conditions and policy advantages that other cities in the region cannot match. Consequently, Chengdu's socio-economic development level is generally high, resulting in relatively weaker competitive capacity in other areas of the Chengdu Plain Economic Zone.

Regarding the overall spatial differentiation within the study area, Deyang, Mianyang, and Suining exhibit relatively high comprehensive scores for urban-rural integration, classifying them as medium-high-level integration zones. As secondary central cities within the Chengdu Plain Economic Zone, Deyang and Mianyang have slightly lower development levels compared to Chengdu. However, they are actively promoting urban-rural integrated development by improving infrastructure, adjusting industrial structures, enhancing rural living environments, and advancing the equalization of urban-rural public services. These efforts aim to narrow urban-rural development gaps and achieve regional development and shared prosperity. Although Suining may hold a relatively smaller position compared to Deyang and Mianyang, its economic development is more balanced and stable, with relatively high rural economic development levels, contributing to a favorable degree of urban-rural integration.

Meishan and Leshan, located in the mountainous regions of Sichuan Province, are geographically remote with rugged terrain. The mountainous topography results in lagging transportation and infrastructure development. Compared to the main cities in the Chengdu Plain Economic Zone, Meishan and Leshan have relatively lower economic development levels. Weak economic foundations lead to sluggish rural economic growth and significant urban-rural development disparities, resulting in medium-low levels of urban-rural integration.

Ya'an City, situated in northwestern Sichuan Province, is characterized by mountainous terrain and inconvenient transportation, which hinders connectivity between urban and rural areas and restricts the flow of resources

and industries. Ya'an's economy is predominantly agricultural, with relatively weak industrial and service sectors. This leads to uneven urban-rural development, with rural areas suffering from inadequate infrastructure and low levels of public services, resulting in significant urban-rural disparities. Furthermore, Ya'an's infrastructure development lags behind, and population outflow is severe, contributing to its persistently low level of urban-rural integration.

Figure 4-3 Spatial pattern of urban-rural integration in the Chengdu Plain Economic Zone

4.3.2 Spatial Characteristics of Each Dimension

Based on the average annual comprehensive scores for economic integration, social integration, spatial integration, and population integration across the eight prefecture-level cities in the Chengdu Plain Economic Zone from 2012 to 2021, the spatial characteristics of the four dimensions of urban-rural integration were analyzed using the data visualization capabilities of ArcGIS 10.2. The results are presented in Figure 4-4.

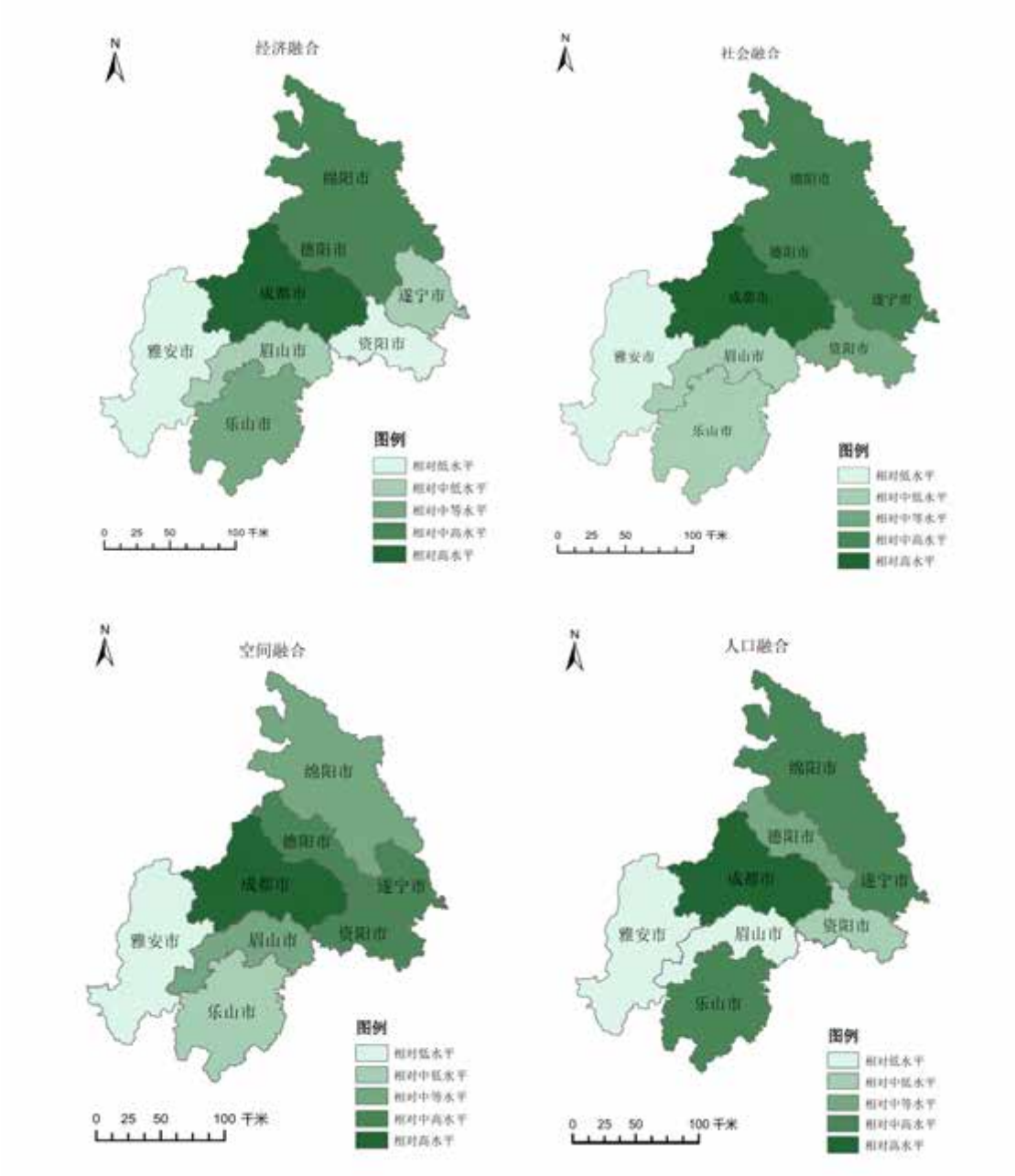

Figure 4-4 Spatial pattern of urban-rural integration levels in various dimensions of the Chengdu Plain Economic Zone

The urban-rural integration in the Chengdu Plain Economic Zone exhibits significant spatial differentiation and dynamic evolution characteristics. In the economic dimension, Chengdu, as the core city, leverages its diversified industrial structure and national strategic positioning to lead regional coordinated development. Deyang and Mianyang, relying on equipment manufacturing and aerospace industries, form secondary growth poles. Leshan depends on tourism resource development but has a lower industrial level, while Ya'an and Ziyang face integration lags due to isolated transportation and singular industrial structures. In the social dimension, Chengdu promotes social equity through high-quality public services and infrastructure. Deyang and Mianyang maintain medium levels through balanced resource allocation, while Meishan and Leshan are constrained by shortcomings in education and healthcare. Ya'an, with significant urban-rural consumption gaps and deficiencies in public services, remains a low-performing area. In the spatial dimension, Chengdu achieves urban-rural spatial inte-

gration through efficient road networks and ecological planning. Deyang and Suining facilitate factor flows via transportation hubs, whereas Leshan and Ya'an are limited by topographic constraints and unplanned expansion, resulting in weaker spatial integration. In the population dimension, Chengdu's high urbanization rate and non-agricultural employment advantages create a strong agglomeration effect. Deyang and Suining optimize labor structures through industrial upgrading, while Leshan attracts population settlement through cultural and tourism resources but with low conversion efficiency. Ya'an and Meishan, hindered by economic lag and transportation barriers, face population outflow and weak urban-rural interactions. The regional pattern overall displays a gradient differentiation of "core polarization–secondary emergence–peripheral decline," necessitating targeted policies to address the dual constraints of natural conditions and institutional barriers in peripheral areas.

4.3.3 Characteristics of Spatial Pattern Evolution

Based on detailed data from 2012 to 2021, this study conducted a comprehensive assessment of urban-rural integration levels in the Chengdu Plain Economic Zone. Using ArcGIS software and the natural breaks method within standard classification techniques, the comprehensive urban-rural integration scores were meticulously categorized. The study specifically focused on the comprehensive scores for the key years of 2012, 2016, and 2021, integrating these with vector maps of the Chengdu Plain Economic Zone to create spatial pattern evolution maps of urban-rural integration levels for these three years.

Building on these results, the study further analyzes and explores the evolutionary characteristics of the overall spatial pattern of urban-rural integration levels in the economic zone, aiming to provide robust data support and theoretical reference for future strategic planning of urban-rural integration.

Analysis of Figure 4-5 (see Appendix) reveals that in 2012, the urban-rural integration levels in the Chengdu Plain Economic Zone exhibited a spatial distribution pattern centered on Chengdu, radiating outward, with lower levels in the southwest and higher levels in the northeast. As the core city of the Chengdu Plain Economic Zone, Chengdu plays a leading and driving role. Its urban-rural integration development is at a relatively high level, characterized by close integration between urban and rural areas. Chengdu's development serves as a "pacesetter," exerting a radiating effect on surrounding areas. Suining City ranks at a relatively medium-high level of urban-rural integration. Although its development level is slightly lower than Chengdu's, it still has a certain radiating and driving effect, contributing to the integration development of neighboring areas. Deyang City's urban-rural integration level is at a relatively medium level. While it ranks at a medium level within the Chengdu Plain Economic Zone, its performance in urban-rural integration remains relatively stable, serving as a bridge connecting Chengdu with other regions. The remaining five cities maintain medium-low to low levels of urban-rural integration, with significant gaps compared to Chengdu. These disparities may be related to factors such as economic development levels, infrastructure development, industrial structures, and policy support in these regions.

Figure 4-5 Spatial pattern of urban-rural integration in the Chengdu Plain Economic Zone in 2012

In 2016, the significant improvement in urban-rural integration levels in the Chengdu Plain Economic Zone reflected the region's positive achievements in advancing urban-rural integrated development. First, Chengdu City, as the core city of the economic zone, continued to play a leading role, maintaining a relatively high level of urban-rural integration and demonstrating its advantages in economic, social, and cultural domains. Second, Mianyang City, an important component of the economic zone, achieved a notable increase in its urban-rural integration level, likely benefiting from the city's sustained efforts in urbanization and rural reform policies. Additionally, Ziyang City's urban-rural integration level advanced from a medium-low to a medium level, reflecting progress in infrastructure development and public service provision. These positive changes indicate that various regions within the Chengdu Plain Economic Zone have made significant strides in urban-rural integration, gradually narrowing urban-rural disparities and laying a solid foundation for comprehensive regional socio-economic development. (See Appendix Figure 4-6)

Figure 4-6 Spatial pattern of urban-rural integration in the Chengdu Plain Economic Zone in 2016

In 2021, the urban-rural integration level in the Chengdu Plain Economic Zone further improved, demonstrating a positive and upward development trend. However, the spatial distribution pattern of "low in the southwest, high in the northeast, and highest in the center" persisted. Within this pattern, Chengdu City remained the only region with a relatively high integration level, continuing to lead in urban-rural integration performance. Additionally, Deyang City saw a significant improvement in its urban-rural integration level, emerging as a new force in the medium-high-level integration zone. Meishan City progressed from a relatively low level to a medium level, indicating a positive trend in the development of its urban-rural integration. Overall, the urban-rural integration level in the Chengdu Plain Economic Zone exhibited a strong development trajectory in 2021, with all regions actively working to address urban-rural development imbalances and advance urban-rural integration to higher levels. (See Appendix Figure 4-7)

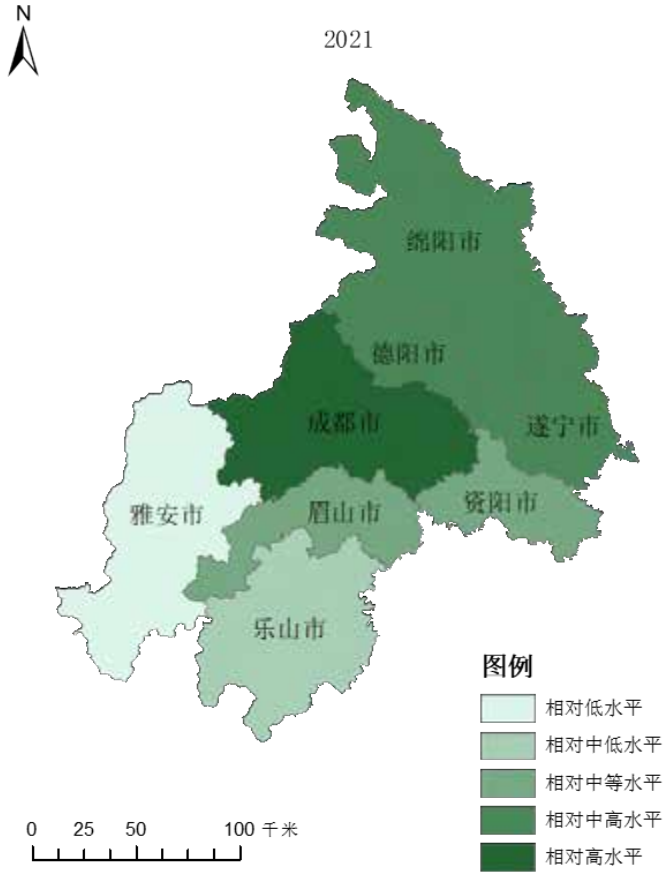

Figure 4-7 Spatial pattern of urban-rural integration in the Chengdu Plain Economic Zone in 2021

5. Influencing Factors of Urban-Rural Integration Levels in the Chengdu Plain Economic Zone

5.1 Variable Selection and Data Sources

5.1.1 Variable Selection

To explore the comprehensive influencing factors of urban-rural integration development levels, this study conducted a thorough review of relevant literature and studies, identifying six key dimensions: economic development level, population structure, policy investment, natural conditions, social conditions, and information development level. Subsequently, eight representative variables were carefully selected under these dimensions to comprehensively analyze how these variables influence and constrain the overall level of urban-rural integration. The selection of these variables not only enriches the dimensions of the study but also enhances the accuracy and comprehensiveness of the analysis.

5.1.2 Data Sources

The dependent variable data used in this chapter are derived from the comprehensive evaluation scores for the four dimensions of urban-rural integration—economic, social, spatial, and population—calculated using the entropy method in Chapter 4. The data for the explanatory variables primarily come from multiple sources, including the Sichuan Statistical Yearbook, statistical yearbooks of individual cities, the China City Statistical Yearbook, and the China Regional Economic Statistical Yearbook. This study focuses on the eight prefecture-level cities in the Chengdu Plain Economic Zone, covering the period from 2012 to 2021, to thoroughly examine the dynamics of urban-rural integration development in this region.

5.2 Construction of the Indicator System for Influencing Factors

The spatio-temporal evolution of urban-rural integration levels in the Chengdu Plain Economic Zone results from the combined effects of multiple influencing factors. Drawing on existing research and considering the actual conditions of urban-rural integration development in the economic zone, an indicator system for the influencing

factors of spatial differentiation in urban-rural integration levels was constructed, as shown in Table 5-1.

Table 5-1 Spatio-temporal Evolution of Factors Influencing the Level of Urban-Rural Integration in the Chengdu Plain Economic Zone, 2012–2021: Indicator System

Variable factors	symbol	Specific indicators	Explanation of indicators
Level of economic development	X1	GDP per capita	GDP/total land area (10,000 yuan/km²)
	X2	Ratio of non-agricultural to agricultural workers	Number of people employed in non-agricultural industries/number of people employed in agriculture
Population structure	X3	Urbanization rate	Urban population/total population
Policy investment	X4	Per capita fiscal expenditure	Fiscal expenditure/total population
Natural conditions	X5	Green space ratio	Statistical data
Social conditions	X6	Ratio of disposable income between urban and rural areas	Per capita disposable income in cities/per capita disposable income in rural areas
	X7	Ratio of Engel's coefficient between urban and rural areas	Engel's coefficient in cities/Engel's coefficient in rural areas
Level of information development	X8	Limited radio and television penetration rate	Number of cable TV users/total population*100

Building on the previous discussion of the spatio-temporal evolution characteristics of urban-rural integration patterns in the Chengdu Plain Economic Zone, this study selected the years 2012, 2016, and 2021, and comprehensively compiled data on relevant influencing factor indicators for these years. Subsequently, the geographical detector model was employed to analyze the influencing factors of urban-rural integration levels in the economic zone, aiming to explain its spatial distribution characteristics.

5.3 Analysis of Influencing Factors

5.3.1 Main Influencing Factors

According to the detection results presented in Table 5-2, the urban-rural integration levels in the Chengdu Plain Economic Zone across the eight single factors varied in 2012, 2016, and 2021. Based on the average q-values over multiple years, the main influencing factors can be categorized into different tiers. Urbanization rate, per capita GDP, urban-rural disposable income ratio, and the ratio of non-agricultural to agricultural employment rank at the top in terms of average q-value influence, with mean q-values of 0.927, 0.925, 0.922, and 0.907, respectively. The second tier includes the urban-rural Engel coefficient ratio and per capita fiscal expenditure, with mean q-values of 0.643 and 0.521, respectively. The third tier comprises the penetration rate of cable television and the green coverage rate, which have relatively smaller q-values. Overall, the q-values of the second and third tiers are relatively low, indicating their weaker influence on the spatial differentiation of urban-rural integration in the Chengdu Plain Economic Zone.

Observing the changes in the q-values of the influencing factors, the spatial differentiation influence of per capita GDP, the ratio of non-agricultural to agricultural employment, the urban-rural disposable income ratio, and the urban-rural Engel coefficient ratio on urban-rural integration levels in the economic zone shows an increasing trend. This suggests that the differences in these factors across different years have a progressively stronger impact on urban-rural integration levels. Conversely, the influence of green coverage rate and cable television penetration rate on the spatial differentiation of urban-rural integration levels exhibits a decreasing trend. This implies that the impact of changes in these two factors across different years on urban-rural integration levels is gradually weakening, or that the influence of other factors is increasingly dominant.

Table 5-2 Detection results of influencing factors of urban-rural integration in Chengdu Plain Economic Zone

Factor Index	2012		2016		2021		Average	
	q	p	q	p	q	p	q	Average q Value Ranking
Land GDP per Unit Area	0.858	0.414	0.965	0.096	0.951	0.224	0.925	2
Ratio of Non - Agricultural to Agricultural Personnel	0.816	0.578	0.972	0.073	0.934	0.221	0.907	4
Urbanization Rate	0.888	0.33	0.974	0.071	0.919	0.308	0.927	1
Per Capita Fiscal Expenditure	0.234	0.935	0.97	0.07	0.36	0.881	0.521	6
Greening Rate	0.655	0.652	0.451	0.825	0.35	0.911	0.485	8
Ratio of Urban - Rural Disposable Income	0.848	0.458	0.977	0.055	0.94	0.215	0.922	3
Ratio of Urban - Rural Engel Coefficients	0.414	0.83	0.569	0.694	0.945	0.196	0.643	5
Cable TV Penetration Rate	0.84	0.484	0.492	0.77	0.192	0.975	0.508	-

5.3.2 Temporal Variation Characteristics of Main Influencing Factors

Based on the multi-year average values of the eight detection factors, the top four factors were selected as the primary determinants of spatial variation in urban-rural integration levels within the Chengdu Plain Economic Zone for temporal change analysis. The results show:

The multi-year average q-value for urbanization rate in the Chengdu Plain Economic Zone is 0.927, indicating that it is the most significant factor influencing the spatial differentiation of urban-rural integration levels. From 2012 to 2021, the q-value for urbanization rate increased from 0.888 to 0.919, while the p-value approached 0, indicating a significant enhancement in its influence. This change in the degree of influence reflects adjustments in the region's urban-rural development strategies and shifts in its economic structure. On the one hand, the government has implemented a series of policy measures during the urbanization process, such as increasing investment in urban infrastructure, optimizing urban planning and layout, and improving the level of urban public services, to accelerate the urbanization process. These measures have attracted a large number of rural residents to migrate to cities, thereby driving the growth of the urbanization rate. On the other hand, as the urbanization process has advanced, the economic structure of the Chengdu Plain Economic Zone has also undergone changes, shifting toward sectors such as services and high-tech industries. Meanwhile, rural areas have also transitioned toward diversified industrial development, prompting more people to migrate from rural areas to cities, further increasing the urbanization rate. Therefore, the influence of the urbanization rate on the spatial differentiation of urban-rural integration in the Chengdu Plain Economic Zone has gradually strengthened.

The second major factor influencing the spatial differentiation of urban-rural integration levels in the economic zone is GDP per unit of land area. Its multi-year average q-value is 0.925. Between 2012 and 2021, the q-value

of GDP per unit of land area rose from 0.858 to 0.925, while the p-value approached 0, indicating a significant increase in its influence. In the Chengdu Plain Economic Zone, the influence of GDP per unit of land area as a key factor in the spatial differentiation of urban-rural integration has gradually increased for multiple reasons. First, the regional economy has continued to grow. Through measures such as technological innovation, industrial upgrading, and optimized resource allocation, the Chengdu Plain Economic Zone has continuously improved production efficiency and economic benefits, thereby driving the growth of GDP per unit of land area. Second, the government has implemented proactive urban-rural integration policies, strengthened infrastructure construction, promoted industrial structure optimization, and accelerated urbanization, further fostering balanced regional economic development and elevating the level of GDP per unit of land area. Additionally, strengthened urban-rural exchanges and accelerated talent mobility have injected new momentum into regional economic development, further enhancing the influence of GDP per unit area. Therefore, the growing influence of GDP per unit area in the Chengdu Plain Economic Zone reflects the combined effects of sustained regional economic development, proactive government policies, and strengthened urban-rural exchanges.

Over the years, the multi-year average q-value of the urban-rural disposable income ratio has been 0.922, making it one of the key factors influencing the spatial differentiation of urban-rural integration levels within the economic zone. Between 2012 and 2021, this indicator rose from 0.848 to 0.940, while its p-value continued to decline, indicating that the significance of spatial differentiation is increasing. In the process of urban-rural integration, the influence of the urban-rural disposable income ratio as a key factor has gradually increased, for various reasons. First, the optimization of the economic structure has driven this trend. By promoting industrial upgrading, strengthening rural economic development, and providing more employment training, economic ties between urban and rural areas have become closer. Second, the government has implemented proactive urban-rural integration policies, including more in-depth infrastructure development, improved public service levels, and the formulation of more comprehensive urban-rural integration plans. The implementation of these policies helps to further narrow the urban-rural income gap, reflecting greater fairness and balance in economic and social development, enhancing overall social stability and sustainable development, and thereby strengthening the influence of the urban-rural disposable income ratio. Additionally, the widespread adoption of information technology and improvements in transportation networks have provided urban and rural residents with broader employment and income opportunities, further driving the increase in the urban-rural disposable income ratio. Overall, the gradual increase in the influence of the urban-rural disposable income ratio reflects the adjustment and optimization of the economic structure, the comprehensive implementation of government policies, and the combined effects of multiple factors such as information technology.

The average Q-value for the ratio of non-agricultural to agricultural workers over the years is 0.907. From 2012 to 2021, the Q-value increased from 0.816 to 0.934, with the P-value continuously decreasing, indicating a significant increase in the influence of spatial differentiation. As urban-rural integration progresses, the more balanced allocation of social resources has brought about multiple impacts. First, the balanced development of education, healthcare, and science and technology has enhanced the overall quality and skill levels of urban and rural residents, making them more capable and competitive in non-agricultural industries. Second, fairer distribution of social resources has promoted talent cultivation and attraction in rural areas, reducing cities' reliance on migrant labor and thereby increasing non-agricultural employment opportunities and income levels. These factors collectively contribute to the rise in the ratio of non-agricultural to agricultural workers. Urban-rural exchanges facilitate the cross-regional dissemination of technology and management experience, enabling rural laborers to access more advanced technical knowledge and management expertise, thereby enhancing their capabilities and proficiency in non-agricultural industries. Additionally, rural talent also has the opportunity to enter urban areas through urban-rural exchange and participate in urban economic activities, thereby increasing the number of non-agricultural workers. This flow of technology and talent promotes complementary development between urban and rural economies, driving the growth of the ratio of non-agricultural to agricultural workers. These factors collectively enhance the influence of the ratio of non-agricultural to agricultural workers on urban-rural integration.

6. Research Conclusions and Policy Recommendations

6.1 Research Conclusions

The integrated urban-rural development of the Chengdu Plain Economic Zone exhibited significant regional differentiation and dynamic evolution from 2012 to 2021. From a temporal perspective, the comprehensive score for integrated urban-rural development in the region increased from 0.274 to 0.482, with an average annual growth rate of 8.65%, but internal gradient differences persisted. Chengdu, as the core city, has consistently remained in the high-level integration zone, with its economic agglomeration effects and policy advantages driving efficient allocation of urban-rural resources; cities in the northeastern region such as Deyang and Mianyang have gradually risen to the medium-high level through industrial upgrading and population aggregation; while cities in the southwestern peripheral regions such as Ya'an and Leshan have long remained at the medium-low level due to geographical barriers and lagging infrastructure. A dimensional analysis indicates that economic integration and population integration are the fastest-growing areas, with the increase in the proportion of non-agricultural industries and the growth in urbanization rates contributing the core driving forces. However, spatial integration is constrained by insufficient expansion of transportation networks, resulting in relatively slow growth. Geographic detector results show that urbanization rates (q=0.62) and GDP per unit of land area (q=0.58) are the primary factors driving spatial differentiation in urban-rural integration, followed by urban-rural income gaps (q=0.45) and non-agricultural employment structures (q=0.38), confirming the dual logic of "economic efficiency-driven" and "population aggregation-driven" development.

6.2 Policy Recommendations

Based on the above conclusions, policy design should focus on three key directions: regional coordination, factor mobility, and functional complementarity. First, a "core-secondary-peripheral" coordinated development network should be established to enhance the industrial reception capacity of secondary central cities such as Deyang and Mianyang. This would guide the outward expansion of Chengdu's high-tech industries to Deyang's high-end equipment manufacturing base and Mianyang's science and technology Transfer Pilot Zone, while providing targeted support for peripheral regions such as Ya'an and Leshan. Infrastructure projects such as the Chengdu-Ya'an high-speed rail double track and the Leshan-Xichang expressway should be implemented to reduce spatial-temporal distances, and the ecological compensation mechanism should be leveraged to explore a "green industry + rural tourism" integration model. Second, reforms to facilitate the two-way flow of urban and rural resources should be deepened. Pilot programs for the entry of collectively-owned operational construction land into the market should be launched in Chengdu's suburban areas to activate the value of rural land assets. In peripheral regions, the "rural homestead land swap for urban housing" policy should be implemented to promote the urbanization of agricultural populations. Concurrently, a cross-regional talent sharing network should be established to encourage flexible talent mobility through the "weekend engineer" model, and mechanisms for cross-regional social security coordination should be improved to lower barriers for non-resident populations to access public services. Finally, efforts should be made to promote complementary urban-rural functions and shared value creation. The metropolitan area should focus on developing high-end industries such as research and design, and financial services, while peripheral counties should take on labor-intensive industries such as agricultural product processing and logistics warehousing, forming a "research in the city, production in the countryside" industrial chain. At the same time, local cultural resources such as the Sichuan Western Forest Villages and Qiang-Tibetan villages should be explored to create a "intangible cultural heritage workshops + digital tourism" brand, using cultural identity to promote spiritual integration between urban and rural areas, to achieve a profound transformation from "spatial integration" to "value integration."

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