Postprint: Evaluation of Spatial Allocation of Public Service Resources and Coupling Coordinated Development of Urban-Rural Interaction in Xinjiang

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Abstract

Public service resources constitute the "pioneer capital" of social development, generating positive externalities for regional socio-economic development and urban-rural integrated development. Grounded in the principles of equity, efficiency, and coordination of public service resources, and employing AHP, entropy method, and cluster analysis, this study establishes an evaluation index system for public service resource allocation and urban-rural interaction benefits in Xinjiang. Utilizing a coordinated coupling development model, it reveals the overall and spatial characteristics of public services, urban-rural interactive development, and their coupling coordination degree in the study area. The results indicate: (1) The equity of spatial allocation of different types of public service resources varies across regions in Xinjiang, with spatial inequity > population inequity. (2) The comprehensive benefits of public service resources and the development level of urban-rural interaction exhibit three categories: low, moderate (medium), and high. (3) The spatial differentiation characteristics of public service benefits demonstrate a pattern of southeast region > northwest region; spatial disparities in urban-rural interaction levels indicate that the northern slope economic belt of the Tianshan Mountains surpasses other regions. (4) Most areas of Xinjiang are in a transitional development stage characterized by mutual influence and mutual adaptation between urban-rural interaction and public services, resulting in gains or losses in either public services or urban-rural interaction, while individual regions are in a stage of mutual restriction and disordered decline between the two systems. By further proposing recommendations to accelerate the establishment and improvement of an urban-rural interactive public service system, construct a multi-level urban spatial pattern comprising large, medium, and small cities and towns, and continuously improve and develop new public service growth points to meet the growing demands of

urban-rural social development, this study provides reference and guidance for ensuring fairness and efficiency in the survival and development of urban and rural residents, and promoting the coordinated development of coupling between public services and urban-rural interaction.

Full Text

Evaluation of the Coupling Coordinated Development of Public Service Resource Spatial Allocation and Urban-Rural Interaction in Xinjiang

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Abstract

Public service resources serve as the "leading capital" of social development and generate positive externalities for regional socioeconomic development and urban-rural integration. Based on the principles of fairness, efficiency, and coordination of public service resources, this study establishes an evaluation index system for public service resource allocation and urban-rural interaction benefits in Xinjiang by combining the analytic hierarchy process, entropy method, and cluster analysis. Using a coupled coordination development model, we reveal the general and spatial characteristics of public services, urban-rural interaction development, and their coupling coordination degree in the study area. The results demonstrate that: (1) The spatial allocation fairness of different types of public service resources varies across regions in Xinjiang, with spatial unfairness exceeding population unfairness. (2) The comprehensive benefits of public service resources and the development level of urban-rural interaction can be categorized into three types: low, general (medium), and high. (3) Spatial differentiation characteristics of public service benefits show that the southeast region exceeds the northwest region, while spatial differences in urban-rural interaction levels indicate that the Tianshan North Slope Economic Belt surpasses other regions. (4) Most of Xinjiang is in a transitional development stage of mutual influence and 磨合 between urban-rural interaction and public services, leading to either public service losses or urban-rural interaction losses, while individual regions are in a stage of mutual constraint and disordered decline between the two systems. This paper further proposes measures to accelerate the establishment and improvement of an interactive urban-rural public service system, construct a multi-level urban spatial pattern of large, medium, and small cities, and continue to improve and develop new public service growth points to meet the growing needs of urban-rural social development. These recommendations provide reference for ensuring fairness and efficiency in the survival and development of urban and rural residents and promoting the coupled and coordinated development of public services and urban-rural interaction.

Keywords: public service; fairness and efficiency; urban-rural interaction; coupling coordination; Xinjiang

1. Study Area and Data Sources

1.1 Study Area Overview

Xinjiang is located in northwestern China and serves as the core area of the Silk Road Economic Belt, playing a key role in the national westward opening spatial pattern by "connecting the east and opening to the west." The total area is 166$\times$10^{4}$ km^2, with a permanent population of 28.672$\times$10^{6}$ and a GDP of 1,092$\times$10^{9}$ yuan, accounting for 1.38% of the national total. The urban-rural income ratio is 2.38, indicating a significant development gap between urban and rural areas. Against the backdrop of integrating the "Belt and Road" initiative and new urbanization, the healthy development of urbanization in Xinjiang as the core area of the Silk Road Economic Belt not only relates to social stability, long-term peace, and sustainable economic development in Xinjiang but also provides support for the "Belt and Road" construction. Considering the administrative jurisdiction systems of local and Xinjiang Production and Construction Corps (XPCC) over counties (cities) and the consistency of statistical data on urban-rural population, society, economy, and public service resources, this study excludes XPCC-administered county-level cities from the statistics. Ultimately, 14 prefecture-level administrative units (prefectures, autonomous prefectures, and municipalities) were selected as study units [Figure 1: see original paper].

1.2 Data Sources

Public service resources refer to various public and service facilities that provide public service products for citizens. According to the specific characteristics of projects, they can be divided into education, medical care, culture and entertainment, transportation, sports, social welfare and security, administrative management and community services, postal and telecommunications, and commercial financial services. Based on data availability and consistency, and referencing the *Urban Public Service Resource Planning Standard (GB50442)*, this paper defines "public service resources" as seven categories: education and culture, medical and health, transportation hubs, finance and insurance, public places, commercial shopping, and leisure and entertainment. The spatial point distribution data of public facilities were obtained from Baidu Maps POI data. Following the principles of representativeness and accuracy, we selected public service resources closely related to residents' lives and representative of urban-rural interaction development. These include 9,847 education and culture facilities (kindergartens, primary and secondary schools) points, 13,142 medical and health facilities (medium and large hospitals, community medical institutions, clinics, pharmacies, etc.) points, 1,246 transportation hub facilities (train stations, airports, long-distance bus stations) points, 4,853 finance and insurance facilities (financial securities institutions, bank branches, etc.) points,

2,116 public place facilities (cultural and sports venues, public toilets, squares, etc.) points, 3,542 commercial shopping facilities (various shopping malls and supermarkets) points, and 1,026 leisure and entertainment facilities (clubs, cinemas, and other entertainment venues) points. Population, economic, and social data were obtained from the *Xinjiang Statistical Yearbook* [17]. Based on the timeliness and uniformity of various data, the end of 2017 was selected as the research time point.

2. Research Methods

2.1 Fairness Analysis

Public services possess the nature of public goods (or quasi-public goods), generally provided by the government through public resources to meet the common needs of society members. According to Rawlsian principles [18], public services provided by the government should cover all residents within the jurisdiction equally, without differentiation based on residential location or social class. The fairness referred to in this paper means the equal distribution of seven types of public service resources in geographical space, without causing inequality in public service resource allocation due to differences in geographical location.

Fairness is measured using the Gini coefficient, which is primarily used to comprehensively examine income distribution disparities within residents and reflect the degree of social inequality. It has been widely applied in research on inequality in other economic and social fields [19]. The Lorenz curve provides the calculation basis for the Gini coefficient. This paper uses the Lorenz curve to propose an indicator for judging the equality degree of public service resource spatial allocation: when the horizontal axis represents the cumulative proportion of permanent population and the vertical axis represents the cumulative service quantity (quantity) of public services, the 45° line is called the equality line, indicating that the spatial quantity allocation of public service resources in each study unit is balanced with the total population. Any inequality in allocation causes the Lorenz curve to lie below the equality line. The greater the curvature of the Lorenz curve, the more unequal the allocation. The Gini coefficient G is the ratio of the area between the 45° equality line and the Lorenz curve to the area below the 45° equality line. The Gini coefficient ranges between 0 and 1, where below 0.2 indicates equal distribution, 0.2-0.3 indicates small disparity, 0.3-0.4 indicates reasonable disparity, 0.4-0.5 indicates large disparity, and above 0.5 indicates huge disparity. This paper uses the Gini coefficient to calculate the population fairness of public service allocation in each study unit, with the geometric method calculation formula:

$$G = 1 - \sum_{i=0}^{n-1} (p_{i+1} - p_i)(s_{i+1} + s_i)$$

where n is the total number of study units (n=14); p_i is the cumulative pro-

portion of permanent population from the 1st to the i-th study unit; p_{i+1} - p_i is the proportion of permanent population in the i-th study unit to the total permanent population of the study area; and s_i is the cumulative service quantity (quantity) of public service resources from the 1st to the i-th study unit.

2.2 Comprehensive Benefit Evaluation

2.2.1 Index System Construction Domestic scholars' theoretical research on the benefit evaluation of public service resources basically follows the theory of fairness and justice and the concept of equalization value [20], but a unified index system has not yet been formed. This paper argues that comprehensive benefit evaluation has different emphases corresponding to different industries and research subjects. Combining relevant literature [21,22] and taking the direction of balanced or sustainable development as the general principle, this study uses the entropy method combined with GIS to evaluate the comprehensive benefits of public services and the development level of urban-rural interaction in the study area, and then ranks the indicators, reflecting scientificity, comprehensiveness, and systematicity. Given the complexity and particularity of public service resources in the study area, this research evaluates the benefits of public service resources in Xinjiang from five aspects: infrastructure, education and culture, medical and health, ecological environment, and social security, and comprehensively measures the urban-rural interaction level from four aspects: population interaction, economic interaction, urban-rural coordination, and sustainable development .

2.2.2 Calculation Process

(1) Data standardization. There are m study units and n evaluation indicators. x_{ij} is the indicator value of the j-th evaluation indicator for the i-th study unit. The standardization formula is as follows:

$$y_{ij} = \frac{x_{ij} - x_{ij}^{\min}}{x_{ij}^{\max} - x_{ij}^{\min}}$$

(2) Determination of indicator weight coefficients. To avoid interference from subjective factors, this paper adopts the entropy method to assign weights to each evaluation indicator and uses weighted summation to finally obtain the comprehensive scores of the two subsystems. The formulas are as follows:

$$F_1 = \sum_{j=1}^{n} p_j y_{ij}$$

$$F_2 = \sum_{j=1}^{n} p_j y_{ij}$$

where F_1 is the public service benefit index of the study unit; F_2 is the urban-rural interaction development index; p_j is the weight coefficient of the j-th evaluation indicator; and y_{ij} is the standardized indicator value.

2.3 Coupling Coordination Model

The non-excludability of public services has positive external effects on regional development, and urban and rural areas often engage in frequent and close population, economic, and social interactions through public service resources. "Coupling" is a physical concept. In a positive coupling relationship, two subsystems promote each other and develop synergistically, while in a negative coupling relationship, they constrain each other and develop in a disordered manner. This paper regards urban-rural interaction development and public services as two social subsystems that interact and influence each other, and establishes a coupling coordination model between urban-rural interaction and public services to reveal different degrees of coupling relationships between regional public service resource allocation and urban-rural interaction development. The calculation formula is:

$$C = \frac{F_1 \times F_2}{\left(\frac{F_1 + F_2}{2}\right)^2}$$

where C is the coupling degree, ranging between 0 and 1. A larger C value indicates higher coupling between the two subsystems, and vice versa. The coupling degree measures the degree of association between subsystems, reflecting only the magnitude of interaction between systems, not their development levels. The coupling coordination degree, based on the coupling degree, integrates the coupling status and respective development levels of subsystems. It can reflect whether each system has a good level and the interaction relationship between systems, i.e., the dynamic coupling effect. The coupling coordination degree formula is introduced as follows:

$$T = \alpha F_1 + \beta F_2$$

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

where T is the comprehensive coordination index, reflecting the overall coordination effect or level of urban-rural interaction development and public services; D is the coupling coordination degree, ranging between 0 and 1. A larger D value indicates higher coordination between urban-rural interaction development and

public services; α and β are undetermined coefficients, taken as $\alpha = \beta = 0.5$, indicating that the two subsystems are equally important.

3. Results Analysis

3.1 Spatial Allocation of Public Service Resources in Xinjiang

According to formula (1), the Lorenz curves and Gini coefficients of the spatial allocation service quantity of seven types of public facilities for the permanent population in the 14 study units were obtained [Figure 2: see original paper]. Combined with the analysis of FIGURE:2, it can be seen that: (1) The Gini coefficient of the total public service resource allocation in Xinjiang is 0.29, indicating a small disparity and relatively equal quantity allocation with the permanent population as reference. (2) By category: transportation hub facilities > education and culture > leisure and entertainment > finance and insurance > public places > medical and health > commercial shopping. A larger G indicates lower fairness of that public service resource allocation. (3) With the permanent population as the reference standard, the spatial allocation of transportation hub facilities shows a large gap among the 14 prefectures, autonomous prefectures, and municipalities, mainly concentrated in Urumqi, Ili Prefecture, and Altay Region. (4) There are still certain gaps in the spatial allocation of education and culture, leisure and entertainment, and finance and insurance among regions. Education and culture are mainly concentrated in Urumqi; leisure and entertainment is mostly concentrated in Urumqi, Tacheng Region, and Ili Prefecture; finance and insurance is mainly distributed in Urumqi and Karamay. (5) The allocation of public places, medical and health, and commercial shopping shows small gaps among regions, with relatively balanced allocation. (6) The seven types of public service resources show obvious spatial differentiation characteristics, with more resources in northern Xinjiang (north of the Tianshan Mountains) than in southern Xinjiang (south of the Tianshan Mountains), i.e., spatial unfairness > population unfairness.

3.2 Analysis of Public Service Benefits and Urban-Rural Interaction Levels in Xinjiang

Based on the combination of the entropy method and GIS, the 14 study units were measured, and cluster analysis was conducted using SPSS software on the basic public service comprehensive benefit index and urban-rural interaction level index, forming three type levels: higher, medium (general), and lower. The results were imported into ArcGIS 10.2 [FIGURE:3, FIGURE:4]. The analysis shows that: (1) The study area is a medium-benefit type for public service resources, where the spatial allocation quantity and benefits of public service resources basically match, generally presenting a spatial pattern of low proportion–low benefit, high proportion–medium benefit, and medium proportion–high benefit. Individual areas show imbalance between the two. For example, Ili Prefecture occupies 18% of the public service resources in Xinjiang but has low comprehensive benefits; Karamay City, although only occupying 2% of

the public service resources, has high comprehensive benefits. In addition, the comprehensive benefits of public service resources show obvious spatial differentiation characteristics, i.e., southeast region > northwest region. The four prefecture-level cities (Urumqi, Karamay, Turpan, and Hami) have significantly higher comprehensive benefits than other prefectures. (2) The urban-rural interaction development level in the study area ranges between 0.18 and 0.67, basically showing a normal distribution. The four prefectures in southern Xinjiang have low urban-rural interaction levels due to complex terrain, frequent extreme weather, and scattered residential points, preventing the full release of positive externalities of public service resources. In contrast, the urban agglomeration in the Tianshan North Slope Economic Belt (Changji Prefecture, Hami City, Karamay City, and Urumqi City), relying on favorable natural terrain conditions and superior socioeconomic environments, has close exchanges of various production factors such as population, resources, culture, and capital between urban and rural areas, with stable urbanization growth and significant benign interaction benefits.

3.3 Evaluation of Coupling Coordination Development Between Public Service Resource Allocation and Urban-Rural Interaction in Xinjiang

According to formulas (3), (4), and (5), the comprehensive coordination index (T), coupling degree (C), and coupling coordination degree (D) of the 14 study units were calculated . The analysis shows that: (1) The comprehensive coordination degree, coupling degree, and coupling coordination degree between urban-rural interaction and public service benefits in various regions of the study area are all at relatively low levels, ranging between 0.2 and 0.5, reflecting that the positive externalities of the non-excludability of public services for regional urbanization promotion and urban-rural interaction development are not fully manifested. (2) In terms of absolute differences, Urumqi, the capital, has the highest coupling coordination degree with a D value of 0.67, while Hotan Region in southern Xinjiang has the lowest with a D value of 0.21, showing a large gap. This reflects the unbalanced development level of public services and urban-rural interaction among regions in the study area, with obvious central city orientation in social, economic, and population aspects. (3) The public service benefits and urban-rural interaction development levels and coupling coordination degrees of various regions in the study area generally show high consistency, with a significant co-progress relationship. (4) The coupling coordination degrees of the 14 study units are divided into low, medium, and high categories. Most of the study area shows a medium coupling coordination level between urban-rural interaction and public service benefits [Figure 5: see original paper]. The coupling coordination level of prefecture-level cities is significantly higher than that of prefectures and autonomous prefectures, reflecting that prefecture-level cities have higher urbanization levels, concentrated public service resources, higher utilization efficiency, and more complete service management.

3.3.2 Coordinated Development Types According to TABLE:2 and relevant literature [23,24], the coupling coordinated development types of urban-rural interaction and public service resource allocation in Xinjiang' s 14 prefectures, autonomous prefectures, and municipalities are divided into three types: coordinated development, transitional development, and disordered decline . Overall, both urban-rural interaction development level and public service benefits show a decreasing distribution pattern from the Tianshan North Slope urban agglomeration to surrounding prefectures, indicating that Xinjiang' s long-term development focus on core areas has been well achieved. In terms of specific spatial distribution: (1) Regional gradient differences still exist but are generally large. The whole region is divided into three development types, following the law of decreasing from central cities to prefectures. (2) In Urumqi, the capital, the public service benefit index and urban-rural interaction development level are basically close, with coordinated and coupled development and mutual promotion. Under the influence of administrative division adjustments, Hami City' s public services are relatively lagging; while the relatively low proportion of agricultural population has also affected Karamay' s urban-rural interaction level to a certain extent. (3) Due to limited quantity and scale of public service resources and smaller built-up areas, some prefectures are constrained in their urban-rural interaction development. (4) Most regions in Xinjiang are in a transitional stage of mutual influence and 磨合 between urban-rural interaction and public services, leading to either public service losses or urban-rural interaction losses. Individual regions are in a stage of mutual constraint and disordered decline between the two systems, which is not conducive to the establishment of a new urban-rural relationship and long-term coordinated socioeconomic development. As an important resource endowment for urban-rural socioeconomic development, the spatial allocation of public service resources determines the exertion of social externalities and is also an important foundation for promoting urban-rural interaction and optimizing urban-rural functional development. However, the development of public services is not immediate but a gradual process.

3.3.3 Pathways and Countermeasures to Promote Coupled Coordinated Development of Public Service Benefits and Urban-Rural Interaction Based on the research results, the following recommendations are proposed: (1) As the core area of the Silk Road Economic Belt, Xinjiang should actively seek national policy support, establish and improve an interactive urban-rural public service system, strengthen and improve public service resources and infrastructure construction between urban and rural areas, and continuously reduce spatial distances and development gaps between urban and rural areas. (2) Actively leverage the advantageous functions of urban scale system construction in building urban-rural relationships. By establishing a multi-level urban system of large, medium, and small cities and a regional development model, further enhance the comprehensive benefits of public services and urban-rural interaction in transitional development type regions. (3) For

socioeconomically underdeveloped areas, continue to improve and develop new public service growth points to meet the growing needs of urban-rural social development. (4) For disordered decline regions, further strengthen the coverage of basic public services, increase counterpart fiscal expenditures, improve institutional systems, and ensure the fairness of survival and development for urban and rural residents, especially rural residents, between regions, fundamentally achieving equalization of basic public services.

4. Conclusions

This paper takes 14 prefecture-level administrative units (prefectures, autonomous prefectures, and municipalities) in Xinjiang Uygur Autonomous Region as the research object. Combining spatial point distribution data with qualitative and quantitative indicators of society, economy, and population, it establishes a comprehensive evaluation index system for urban-rural interaction development level and basic public service benefits. The study comprehensively analyzes the spatial fairness and efficiency of public service resource allocation in 14 prefectures, autonomous prefectures, and municipalities in Xinjiang, and uses the coupling coordination degree model to reveal the general and spatial characteristics of the coupling coordination between basic public services and urban-rural interaction development in the study area. The main conclusions are: (1) With the permanent population as reference, the comprehensive Gini coefficient of public service resource quantity spatial allocation in Xinjiang is 0.29, indicating relatively fair allocation among prefectures, autonomous prefectures, and municipalities with small regional gaps. However, by category, different types of public service resources show varying spatial allocation fairness, with unfairness manifested as: transportation hub > education and culture > leisure and entertainment > finance and insurance > public places > medical and health > commercial shopping public service resources. (2) The comprehensive benefits of public service resources and the development level of urban-rural interaction present three types: low, medium (general), and high. The spatial allocation and comprehensive benefits of public service resources generally show a pattern of low proportion–low benefit, high proportion–medium benefit, and medium proportion–high benefit. The spatial differentiation characteristics of public service benefits show southeast region > northwest region, while spatial differences in urban-rural interaction levels show the Tianshan North Slope Economic Belt > other regions. (3) The coupling degree, coordination degree, and coupling coordination degree of various prefectures in Xinjiang are all at relatively low levels. Urumqi belongs to the high-level coordinated development model of urban-rural interaction and public service benefits, Karamay City belongs to the coordinated development model with relatively lagging urban-rural interaction, and Hami City belongs to the coordinated development model with relatively lagging public service benefits. Most regions in northern and southern Xinjiang and border areas belong to the transitional development model of urban-rural interaction loss type, while Hotan, Ili, and Bortala regions belong to the disordered decline

development model.

Currently, Xinjiang' s overall urbanization level is relatively low, socioeconomic and urban-rural development is unbalanced, and the coverage and comprehensive benefits of public service resources lag behind those in eastern and central provinces. Taking Xinjiang' s prefectures as examples, this paper comprehensively evaluates and analyzes the necessity and feasibility of public service resources, as a social public product, to further release positive externalities and achieve coupled and coordinated development with urban-rural interaction on the basis of exerting their fairness and efficiency. The study also proposes several recommendations on how to adopt appropriate regulatory countermeasures to improve the coordination level between urban-rural interaction development and basic public services and promote benign interaction between the two systems. These provide reference for actively promoting the equalization of basic public services and enriching the theory of urban-rural integration. Meanwhile, it should be noted that although the coupling model and index system between basic public services and urban-rural interaction development established in this paper reflect scientificity as much as possible, due to data availability limitations, comparative analysis of different years could not be conducted, which awaits further verification of research conclusions using the latest and longer-term data.

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Note: Figure translations are in progress. See original paper for figures.