Research Article

Measuring the Smart Growth Spatial Performance in Developing City of Northwest China Plains Area

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“Smart growth” is an urban planning concept. In this paper, the overall urban-rural smart growth efficiency is explored, which serves as an indicator to effectively measure the allocation of urban-rural spatial resources and structural rationality of the urban-rural space. Taking a developing county city in northwest China plains area as an example, the urban-rural spatial efficiency system was established and the evaluation model constructed by using the data envelopment analysis (DEA)-slack-based measure (SBM) model. The model was used to empirically analyze the characteristics in 2000, 2010, and 2018. The results show that the urban-rural spatial efficiency of the urban-rural space degree of a county in northwest China plains area exhibits growth trend on the whole, and scale efficiency increases the most. The increase of technical efficiency promotes the growth of spatial performance, which is mainly manifested in the construction of industrial parks. Although urban and rural spatial performance has made great achievements, there are still problems. Results of the test for each city indicate that the method proposed in this study is, in fact, quite effective in evaluating the smart growth pattern for developing cities. Finally, the corresponding improvement social and economic policies' strategy is proposed.

1. Introduction

The paths for developing the urban-rural space focus on the long-term growth and macrolevel organization of towns and rural areas as discussed by Addae and Oppelt [1, 2]. In recent waves of urban expansion, significant disparities between urban-rural developments have transpired as discussed by Grimm et al. [3]. As built-up lands and urban areas have grown to enormous sizes, the construction boundaries between counties are regularly breached, and severe hollowing occurs in rural areas. Apart from the low urban-rural spatial performance, in many developing and emerging countries around the world, there is a growing contradiction between the shortage of indicators for construction land in urban areas and the abundance of unoccupied construction land and wastelands. Eventually, long-term urban-rural characteristics emerge, including unique neither-rural-nor-urban landscapes, overlapping spaces in towns (rural areas), counties, and cities,

and severe “plagued and mosaic” land parcels as discussed by Munthali et al. [4]. Thus, the overall urban-rural spatial performance remains low.

On this basis, the urban-rural spaces in Pucheng County, in western China, were taken as the study objects of this paper with the emphasis laid on their performance calculation. As for the research method, the current connotation descriptions of urban-rural integrated spatial performance were comprehensively analyzed. It is actually a process of inputting various resources into the regional urban-rural spatial system to acquire all kinds of outputs, which is input and output efficiency relationship. To quantify the efficiency relationship needs to construct input index system and output index system, where urban-rural integration is a first-level input index, and there are three second-level output indexes—efficiency outputs of urban-rural ecological integration, economic integration, and social integration as discussed by Mawenda et al. [5].

TABLE 1: Indicators of the urban-rural spatial efficiency input system.

Indicator	Indicator meaning	Evaluation objective
X1	Expenditure within the local financial budget	Financial input in spatial operation
X2	Financial input in education	Impact of educational input
X3	Financial input in science/ten thousand yuan	Impact of scientific & technological input
X4	Book collection of public library/thousand volumes	Impact of cultural factors
X5	Financial input in medical and public health/ten thousand yuan	Impact of medical and public health guarantees
X6	Total number of mobile calls/ten thousand households	Impact of informational guarantee factors
X7	Highway mileage of regional space/km	Impact of spatial land connectivity
X8	Cultivated land area/hm ²	Impact of agricultural conditions
X9	Constructed urban area/hm ²	Impact of land input factors
X10	Forest coverage rate/kw	Impact of ecological guarantee factors
X11	Total power consumption of society	Impact of resource input-output performance
X12	Regional population/ten thousand	Impact of human resource input
X13	Fixed asset input of the society/ten thousand yuan	Infrastructure and input in production facilities

A mathematical calculation was performed via a data envelopment analysis (DEA)-slack-based measure (SBM) model, an efficiency model based on variable scale without restriction of input and output or impact on efficiency value. Three numerical values—comprehensive efficiency, technical efficiency, and scale efficiency—will be obtained by the DEA-SBM model, where comprehensive efficiency indicates comprehensive urban-rural spatial development efficiency within the territorial scope, technical efficiency denotes urban-rural economic development efficiency within the territorial scope, and scale efficiency represents use efficiency of urban-rural construction land within the territorial scope.

The urban-rural spatial performance will be high under comprehensive spatial development efficiency of $CRS > 1$, medium under $0.8 \leq CRS < 1$, low under $0.6 \leq CRS < 0.8$, and nearly zero under $CRS < 0.6$. The scope in which CRS value falls is judged through numerical values as discussed by Charnes et al. [6], and the current urban-rural spatial performance and development status will be comprehensively determined by combining statistical data like scale of urban-rural construction land use, scale of urban-rural industrial land use, and functions of cities and towns. The final goal is to propose suggestions and strategies for the future urban-rural spatial development by means of guidance and regulation. Great importance is attached to revealing the difference change between urban-rural spaces in development efficiency.

2. Review of Existing Studies

Performance refers to both benefits and efficiency, which are both related to the ex ante state as discussed by De Vries and Verhagen [7]. American economists have put forward the concept of performance as discussed by Elhendy et al. [8, 9], while German scholars have proposed the use of the grading system for the farming economy as discussed by Deakin et al. [10]. Since the 1970s, performances have become increasingly diversified, incorporating social and cultural problems into the scope of urban spatial performances. Harvey put forward the concept of society-space integration as discussed by Harvey [11]. David Harvey has defined and

redefined the relationship between politics, capitalism, and the social aspects of geographical theory. And he analyzes core issues in city planning and policy—employment and housing location, zoning, transport costs, and concentrations of poverty—asking in each case about the relationship between social justice and space.

Since the end of the last century, China has been paying attention to spatial performances. With rapid economic development, research has gradually been focusing on the efficiencies of urban economy, land, space, and general utilization. Zhao Min (2006) put forward the concept of urban spatial performances for the first time. Further research was then directed towards understanding the relationship between the internal mechanism of urban spatial performances and urban planning.

In 2012, Pei Zhang quantified and improved the urban spatial performance indicator system. The 13 parameters were used as indicators of the spatial efficiency input system and are listed in Table 1. The output system consists of three secondary indicator systems (i.e., ecological, economic, and social) (Table 2). Other researchers have divided the urban-rural spatial performance into economic, environmental, social structural, and institutional performances and have offered comprehensive discussions for each as discussed by Charnes et al. and Coelli [6, 12].

The evaluation and development of the overall urban-rural spatial efficiency involve integrating limited land resources for construction, coordinating the reasonable allocation of life, production, and ecology in the urban-rural spatial layout, and pursuing spatial efficiency as discussed by Rizwan et al. [13]. Simply put, the evaluation is aimed at exploring and understanding the changes in the development efficiency of the urban-rural space based on examining its essential characteristics.

Starting from the essential features of urban-rural integrated spatial efficiency, comprehensive urban-rural spatial efficiency is quantified through a mathematical model, which can help to intuitively understand urban-rural spatial efficiency as discussed by Suebpongsakorn [14]. In particular, for county-level cities in underdeveloped western areas

TABLE 2: Indicators of the urban-rural spatial efficiency output system.

System	Indicator	Indicator meaning
Urban-rural economic spatial efficiency output	Y1	Aggregate GDP (hundred million yuan)
	Y2	GDP per capita (yuan)
	Y3	The proportion of tertiary industry (%)
	Y4	The ratio of practitioners in the primary industry to total practitioners in society (%)
	Y5	Urban Engel coefficient (%)
	Y6	Urbanization rate (%)
Urban-rural social spatial efficiency output	Y7	Total urban and rural passenger volume (in ten thousand)
Urban-rural ecological spatial efficiency output	Y8	Power consumption per ten thousand yuan of GDP (kWh)
	Y9	Environmental quality index of the regional space (EQI)

in China with complicated influence factors of development and restricted urban fiscal cost and development and construction land use, coordinating reasonable allocation of “life, production, and ecology” in urban-rural spatial layout by integrating construction land stocks under the current situation of construction land use has become a critical issue, and spatial efficiency should be pursued on this basis. The quantification of spatial performance contributes to final improvement of urban-rural spatial efficiency within the county territory and promotes allocation of input resources in the urban-rural spatial development. The emphasis should be laid on revealing the difference change between urban-rural spaces in development efficiency as discussed by Thipbharos [15].

3. Methods

3.1. Overview of the Study Region. Pucheng County is the jurisdiction of Weinan City in western China and located in the north of Weinan City. Weinan City is the “east gate” of Shaanxi province. It is the second most populous city and the fifth economically developed in Shaanxi province. Weinan’s urbanization rate is 49%. Pucheng is situated 40 km off the urban district of Weinan City. It is located about one hour away from Weinan’s financial district. Its urbanization rate is 53%. Pucheng County has experienced rapid improvement in its urban-rural spatial efficiency, which is significantly higher than the average efficiency level in Weinan City. On the other hand, a myriad of problems still exists, including unbalanced regional growth and low utilization efficiency.

3.2. Data Source. The years 2018, 2010, and 2000 were selected as the research nodes. All data concerning spatial performances were collected from government yearbooks and reports at the national, provincial, municipal, and county

TABLE 3: Urban-rural spatial performance indicators of Pucheng County after dimension reduction (2018).

Indicator	Numerical	Indicator	Pucheng
X1	32453	Y1	151.62
X6	48	Y2	18895.8
X7	393.5	Y4	35
X8	1120	Y5	44.12
X10	25	Y6	50.9
X11	68	Y7	3.21
X12	80.12	Y9	347.1
X13	156000	Y11	1696.02
—	—	Y14	60

levels, including the urban-rural spatial input system and the urban-rural spatial output system. The data concerning the growth and evolution of construction lands were derived from different year’s topographic data (.dwg file or .shp file). Terrain information was generated freely obtained from the Geospatial Data Cloud website, and the data was acquired from the terrain graphs of planning and management departments as discussed by Tone [16] (Table 1).

3.3. Indicator Determination. The urban-rural spatial performance refers to the ratio of the urban-rural input and output systems. In this study, 13 parameters were used as indicators of the spatial efficiency input system and are listed in Table 1. The output system consists of three secondary indicator systems (i.e., ecological, economic, and social) with 9 tertiary indicators as discussed by Karthikeyan and Nalini [17] (Table 2).

3.4. Comprehensive Technical Efficiency. The mathematical model DEA-SBM was selected for calculation. SBM is a kind which can change the size of the model of efficiency. There is no limit to the input and output and will not impact the efficiency value as discussed by Herold et al. [18].

$$\text{Min } \rho = \frac{1 - (1/m) \sum_{i=1}^m (s_i^- / x_{i0})}{1 + (1/s) \sum_{r=1}^s (s_r^+ / y_{r0})}, \quad (1)$$

where ρ refers to the input and output space in production units difference distance, m is the index of input, and s is the index of output. When $\rho = 1$, there will be multiple decision units with the same value of 1, which cannot be effectively evaluated. Therefore, it is necessary to use SPSS software to SBM model of effective unit can continue dimension. Subsequently, all indicators were entered into the SBM model for calculation. The calculated result is CRS. When the CRS (overall spatial development efficiency) > 1 , the urban-rural spatial performance is considered to be high. When $0.8 < \text{CRS} < 1$, the urban-rural spatial performance is at a medium level. When $0.6 \leq \text{CRS} < 0.8$, the urban-rural spatial performance is low. When $\text{CRS} < 0.6$, the performance of the urban-rural space is considered to be extremely low. The overall technical efficiency consists of two parts, such that Comprehensive Technical Efficiency = Pure Technical Efficiency $\times$ Scale Efficiency.

TABLE 4: Measurement results of spatial performances for 2018, 2000, and 2010.

Region	Comprehensive efficiency	Technical efficiency	Scale efficiency	Year
Pucheng County territory	0.802	1.015	0.783	2018
	0.443	0.686	0.319	2000
	0.661	0.718	0.582	2010

FIGURE 1: A map of urban and rural construction land in Pucheng in 2018.

4. Results

The summary of results is shown in Table 3. The results show that in 2018 the comprehensive efficiency of urban and rural space was 0.802, the technical performance was 1.015, and the scale performance was 0.783 (Table 4). In 2010, the comprehensive spatial efficiency of urban and rural areas was 0.661, the technical performance was 0.718, and the scale performance was 0.582 (Table 4). In 2000, the urban and rural spatial efficiency was 0.443, the technical efficiency was 0.686, and the scale efficiency was 0.319 (Table 4).

5. Discussion

5.1. Performance Evaluation of Urban and Rural Space

5.1.1. Evolution of Intensification of Land Utilization. The overall static urban-rural spatial integration efficiency of Pucheng County was 0.802 in 2018. The total construction land within the county's territory covered an area of

1585 km², including the urban and rural construction land, rivers, farmland, mountains, lakes, and scenic spot. The urban-rural construction land covered an area of 100 km² (–61% of the total area). Urban construction land covered an area of 27 km² (–28% of urban-rural construction land), rural construction land was 51.92 km² (–69.6% of urban-rural construction land), and the built-up urban zone extended 18.68 km² (–9.9% of urban-rural construction land). Other construction land also includes industry. In terms of scale efficiency, which mainly reflects the efficiency of land utilization, the computed value was 0.783, which is only slightly lower than the overall efficiency. This indicates a low degree of land intensification, slow improvement in the spatial efficiency as discussed by Mwathunga and Dolnaldson [19], and extensively scattered rural construction lands.

Large proportions of the central urban area have been classified as construction lands, and the boundaries between construction zones have repeatedly been broken. A four-core configuration forms the urban-rural spatial structure, which includes the downtown area, Chenzhuang Town,

FIGURE 2: A map of urban and rural construction land in Pucheng in 2010.

Sun Town, and the coalification industrial park. Chenzhuang, Sun Town, Xing Town, and Hanjing Town are situated in the south, east, north, and west of the downtown area of Pucheng County, respectively, along with crisscrossing arterial traffic lines. However, only Sun Town was able to properly develop, while the overall spatial structure of the county remains sluggish. The urban town system is triangle-shaped and includes only a small number of key towns, playing a limited role in driving development to other towns as discussed by Mawenda et al. [5].

5.1.2. Evolution of Dynamic Construction Land. The evolution of construction lands was examined from three-time nodes: 2000, 2010, and 2018. The overall urban-rural spatial efficiency calculated for 2000, 2010, and 2018 was 0.443, 0.661, and 0.802, respectively, indicating an upward trend. In 2010, the level of the overall urban-rural spatial efficiency was low, and in 2018, the efficiency was upgraded to medium level. In comparison, the urban-rural spatial performance of the neighboring county was 0.361 (in 2010) and 0.568 (in 2018). With a higher urban-rural spatial performance, Pucheng County has become a focal point of regional economic development.

Between 2000 and 2018, the scale effect had significantly changed. Based on construction land data, the constructed areas in the center of the county increased by 25 km^2 , while those in designated towns increased by 3 km^2 (Figures 1 and 2). The total urban construction area increased by

67 km^2 , while the rural construction area decreased by 41 km^2 . Regarding the type of urban-rural construction land, the center of the county has undergone extensive growth, while the county's subcenter (Sun Town) and strategic town (Chenzhuang Town) experienced substantial expansion as discussed by Lu et al. [20]. Other designated towns remained stable. The spatial center of construction land in the county shifted from the northwest to the southeast, with a moving distance of 27.2 km . Rural construction land shrunk, from 289 administrative counties to 249. Fifty-six counties moved and coalesced, while 40 counties had land reclamation. The construction area of land-reclaiming villages covered 10.38 km^2 .

5.1.3. Evaluation of Technical Efficiency. The technical efficiency increased from 0.686 in 2000 to 0.718 in 2010, changing only marginally. In 2018, the figure climbed significantly to 1.015. Meanwhile, technical efficiency was found to be higher than the scale efficiency and overall efficiency, suggesting that the industrial performance in Pucheng is better than the land utilization efficiency. This also indirectly suggests the urban function of Pucheng County is primarily based on its industrial mining (Figure 3).

According to the data from the last ten years, intense industrial growth had initially been concentrated around industrial parks. Found within the county territory are seven parcels of industrial parks, which have grown from 665 ha to 1389 ha. The coalification industrial parks mainly developed

FIGURE 3: A map of urban and rural construction land development type in Pucheng.

industrial chains that produced coal-to-methanol and olefins and expanded the current industry into a production base integrating coalification chemical engineering and fine chemical engineering. The scale of land utilization expanded from 195.6 ha to 600 ha. The industrial system of Pucheng Industrial Park expanded into mechanical processing and manufacturing, food processing industry, new material industry, new strategic industry, and modern logistics and extended the land scale from 115.2 ha to 400.67 ha. Meanwhile, strategies were undertaken connecting modern agriculture from the Luyang Lake modern comprehensive industrial park and form modernized agricultural and industrial chains that integrate planting, processing, and selling agricultural products. The data confirms that the construction and development of industrial parks have played a positive role in promoting the urban-rural spatial efficiency as discussed by Melchiorri et al. [21].

5.2. Countermeasures for Improving Urban-Rural Spatial Performance

5.2.1. Natural (Ecological) Space: Combining Rigidity and Flexibility and Placing Ecology First. Relevant personnel should designate and strictly enforce environmental laws, prevent the destruction of fragile and sensitive ecological systems, and optimize the layout of economic security. Once

ecologically protected zones have been designated, the areas should be expanded rather than decreased. The procedures have to be adjusted to promote stricter reporting and approval. Comprehensive monitoring should be implemented based on the national supervision platform that would be able to fulfill the requirements on management and control to achieve boundary settlement and calibration.

5.2.2. Economic (Production) Space: Adjusting Structure and Improving Quality and Efficiency. Measures should be taken to promote economic efficiency in production and in the positioning of industrial systems in the greater Weinan City. Industrial construction land should be planned prudently, in a manner that would promote spatial intensification. Emphasis should be given towards coordinated development of industries, enhanced spatial links between industries, stronger ecological restoration and perfection of the industrial system, and a more harmonized link with the regionalized layout. Promoting sustainable agriculture should be prioritized through policy measures and incentives and convert the current planting system of “one species in one county” towards more sustainable agronomic techniques.

The industrial sector should play a significant role in improving the economic spatial efficiency of Pucheng County, such as creating new economic subcenters (e.g., in Weinan City), participating in joint developments of industries and

towns through industry-town integration, and enhancing industry-city community where the industrial and urban scales match. Efforts should be taken to optimize and upgrade the industrial structure to achieve cleaner and more efficient utilization of resources, particularly coal as discussed by Bone et al. [22–30].

5.2.3. Social (Living) Space: Balanced Layout, Fairness, and Justice. Currently, construction lands with development rights in Weinan City account for only 15% of the total area of used land, while other spaces comprise zones appropriated for water protection, ecological green land protection, geological disasters, basic farmland, historical relics, and cultural protection. Rational allocation of development rights for rural-urban lands should be prioritized in order to improve efficiency of land consolidation and promote the overall development of the county. Also, the use of industrial parks should be further strengthened to augment town-level growth, particularly in less-developed areas in the south. Construction of central villages should also be prioritized to help drive development in common villages in the vicinity. Furthermore, large central villages with strong economies and large populations should promote community construction and management and establish community general service centers.

6. Conclusions

In the context of measuring and evaluating urban-rural spatial performance, this paper takes Pucheng County in north-west China plains area as an example. Through solving the DEA-SBM model and comparing the results of each model, this study provides the details of measuring urban-rural spatial performance changes in 2018, 2000, and 2010 by an increasing spatial efficiency of the urban-rural space degree. The increase of technical efficiency promotes the growth of spatial performance, which is mainly manifested in the construction of industrial parks. Based on this information, urban development stakeholders can improve urban and rural spatial performance.

After 18 years of development, Pucheng's comprehensive urban-rural development efficiency has been increased from 0.443 in 2000 to 0.802 in 2018. The technical efficiency value was higher than the comprehensive efficiency value, which means Pucheng's economic development was growing during that period of time. By comparing the 2018 comprehensive efficiency, scale efficiency, and urban and rural construction land values, Pucheng had low intensification of land utilization. Rural construction land was larger, which was 51.92 km² (−69.6% of urban-rural construction land). Urban construction land only covered an area of 27 km² (−28% of urban-rural construction land). The technical efficiency increased from 0.686 in 2000 to 0.718 in 2010. In 2018, the efficiency grew significantly to 1.015. The main reason is that Pucheng had many industrial parks, which have grown from 665 ha to 1389 ha. The data confirms that the construction and development of industrial parks had played a positive role in promoting the urban-rural spatial efficiency.

In order to ensure sustainable urban development in Pucheng city, this study shows that the comprehensive efficiency indicates comprehensive urban-rural spatial development efficiency within the territorial scope, technical efficiency denotes urban-rural economic development efficiency within the territorial scope, and scale efficiency represents use efficiency of urban-rural construction land within the territorial scope.

The conclusions of this study provide direction for managing and improving the comprehensive efficiency. The changes of comprehensive efficiency reflect integrated urban development. Scale efficiency is related to the degree of land intensification, which also leads to a shift in the focus of urban and rural construction land. Technological efficiency is related to industrial development, reflecting the scale of land for industrial park construction. Moreover, strategies and policies should be put in place that would promote the professionalized production of sustainable agriculture and industry. They would also help achieve efficient, integrated, and equal development of urban and rural areas.

Data Availability

The [DATA TYPE] data used to support the findings of this study were supplied by [NAME] under license and so cannot be made freely available. Requests for access to these data should be made to [NAME, CONTACT DETAILS].

Conflicts of Interest

The authors declare that there is no conflict of interest regarding the publication of this paper.

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