Research on Agricultural Production Efficiency of Lanzhou-Xi’ning Urban Agglomeration

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Abstract: To clarify the efficiency and spatial-temporal characteristics of regional agricultural production is of great significance for adjusting the structure of agricultural production, improving the mode of agricultural production and coordinating the relationship between industries development. Based on the spatial constraints of the main function division, taking the counties providing agriculture products in Lanxi urban agglomeration as the basic research unit, using DEA model, we analyze the spatial-temporal characteristics, dynamic trends and the total factor productivity of the agricultural production efficiency from 2000 to 2015. The results showed that: 1. The overall agricultural efficiency of Lanxi urban agglomeration was very low and a few of regions were in the productive frontier, agricultural scale efficiency was greater than pure technical efficiency. 2. The spatial characteristics of the overall efficiency was “middle collapse”, while the pure technical efficiency and scale efficiency presented a gradient distribution pattern. The provincial differences showed that the overall agricultural efficiency and pure technical efficiency of Gansu Province were relatively high, while the opposite is true in Qinghai Province. 3. The overall TFP of agriculture was on the rise, and the overall efficiency improvement was shifted from the improvement of pure technical efficiency to the increase of scale efficiency. The TFP and its decomposition indicated that technological progress is the most important factor, which drives the rise of agricultural total factor productivity.

1 Introduction
China’s agricultural development has made remarkable achievements since the reform and opening-up, but there were still some problems such as high agricultural production cost, low production efficiency and weak competitiveness [¹,²], which restrict the realization of the strategic goal of regional coordinated development. Urban agglomeration is an important carrier to realize the coordinated development of industries [³], among the efficiency researches of urban agglomeration, more attention was paid to the research of urbanization efficiency, land use efficiency and ecological environment efficiency, and the research of agricultural production efficiency was ignored [⁴,⁵]. Compared with other urban agglomerations in the whole country, Lanxi urban agglomeration is a typical watershed type city group. Many counties are located in the agricultural essence area of the Yellow River basin, Huangshui River Basin, Datong River basin, Tao River Basin and Weihe basin. From the perspective of main function, agricultural economy of most counties accounts for a large proportion, the agricultural efficiency production are of great significance to ensure regional food production and food
security, which is related to the coordinated development of the upper, middle and lower reaches of the river basin. Lanzhou- Xining urban agglomeration development plan has approved on March 1, 2018, the planning scope includes 39 county administrative units, with a total area of 9.75 × 10^5 hm^2. The inner river network density of Lanxi urban agglomeration is relatively large, which is advantageous to the agriculture development in the lower altitude, better heat, sufficient water source basin valley. In this paper, Lanxi urban agglomeration is regarded as a community of river basin destiny, from the perspective of main function, the counties with important agricultural production function are selected to carry out the research, which can provide decision basis for the adjustment of industrial structure and formulation of coordinated development strategy of urban agglomeration.

2 Research methods and index system

2.1 Methods

2.1.1 DEA-BCC Model. Data Envelopment Analysis (DEA) method extends the concept of single input and single output engineering efficiency to the evaluation of relative effectiveness of decision making unit (DMU) with multiple input and multiple output. The basic model of DEA is C^2R model, CRS is the static comprehensive efficiency of C^2R, which can be further decomposed into pure technical efficiency (VRS) and scale efficiency (SCAL), that is, CRS = VRS × SCAL. DEA model can be divided into input-oriented, output-oriented and non-oriented model. In this paper, we choose the input-oriented model, which focuses on how to reduce the technical effective input without reducing the output, the formula is:

\[
\min \theta \\
\text{s.t. } \sum_{j=1}^{n} \lambda_j x_{ij} \leq X_i \\
\sum_{j=1}^{n} \lambda_j y_{ij} \geq \theta y_{ih} \\
\sum_{j=1}^{n} \lambda_j = 1; \lambda \geq 0 \\
i = 1, 2, ..., m; j = 1, 2, ..., n; r = 1, 2, ..., q
\]

Where: \( n \) is the number of decision-making units; \( m \) and \( q \) are the number of input and output variables; \( x \) is the input element; \( y \) is the output; \( \theta \) is the effective value of DMU, if \( \theta = 1 \), the decision-making unit DEA is effective, if \( \theta < 1 \), the decision-making unit is not DEA effective.

2.1.2. Malmquist Index. Malmquist index can describe the dynamic change of relative efficiency. In the case of variable returns to scale, the distance function of \((x^t, y^t)\) in t period and t+1 period was respectively \(D_t(x^t, y^t)\) and \(D_t^{t+1}(x^t, y^t)\), the distance function of \((x^{t+1}, y^{t+1})\) in t period and t+1 period was respectively \(D_t(x^{t+1}, y^{t+1})\), \(D_t^{t+1}(x^{t+1}, y^{t+1})\), \(x^t\) and \(y^t\) were the input and output values of T period respectively. Under the technical conditions of T period, the technical efficiency changes from T to t + 1 period can be expressed as [7]:

\[M_t = \frac{D_t^{t+1}(x^{t+1}, y^{t+1})}{D_t(x^t, y^t)}\] (2)

Under the technical conditions of T+1 period, the technical efficiency changes from T to t + 1 period can be expressed as:

\[M_t^{t+1} = \frac{D_t^{t+1}(x^{t+1}, y^{t+1})}{D_t^{t+1}(x^t, y^t)}\] (3)

The geometric mean of two Malmquist productivity indexes is used to calculate the change of productivity from t period to t + 1 period:

\[MI = TFP = (M_t^{t+1})^{\frac{1}{2}} = \left[ \frac{D_t^{t+1}(x^{t+1}, y^{t+1})}{D_t(x^t, y^t)} \cdot \frac{D_t^{t+1}(x^{t+1}, y^{t+1})}{D_t^{t+1}(x^t, y^t)} \right]^{\frac{1}{2}}\] (4)

In 1997, Ray and Desli put forward the Malmquist index to the RD model, which has been widely...
used. The decomposition formula is as follows:

\[
MI = TFP = (x', y', x'^{e}, y^{e})
\]

\[
= \frac{D_{2}^{x}(x'^{e}, y^{e})}{D_{2}^{x}(x', y')} \times \left[ \frac{D_{2}^{y}(x'^{e}, y^{e})}{D_{2}^{y}(x', y')} \times \left( \frac{D_{1}^{x}(x'^{e}, y'^{e})}{D_{1}^{x}(x', y')} \right)^{\frac{1}{2}} \times \left( \frac{D_{1}^{y}(x'^{e}, y'^{e})}{D_{1}^{y}(x', y')} \right)^{\frac{1}{2}} \right]
\]

where, \(MI\) and \(TFP\) are pure technical efficiency change index, \(TE\), \(TC\), \(SE\) and \(TEC\) are respectively represent the pure technology efficiency change index, technology progress index, scale efficiency change index and comprehensive technology efficiency change index.

2.2. Indexes
Considering the scientific nature and availability of indicators, six input indicators and one output indicator were selected (Table 1). Index data comes from Gansu Development Yearbook and Qinghai Statistical Yearbook.

| Type           | First level index                                                                 | Second level index                          | Unit   |
|----------------|----------------------------------------------------------------------------------|---------------------------------------------|--------|
| Input          | Labor force elements                                                             | Employees of agriculture, forestry, animal  | Person |
| indicators     | Total power of agricultural machinery                                            | Total output value of agriculture, forestry, |
|                | Net amount of agricultural chemical fertilizer                                    | animal husbandry and fishery                |        |
|                | Planting area of crops                                                           |                                              | hm\(^2\) |
|                | Effective irrigation area                                                        |                                              | hm\(^2\) |
|                | Rural power consumption                                                          |                                              | 10\(^4\)kW-H |
| Output         | Monetary output                                                                  |                                              | 10\(^4\)¥ |

3 Spatial-temporal characteristics of agricultural production efficiency

3.1. General characteristics
The agricultural production efficiency of 28 county-level administrative units in Lanxi urban agglomeration was calculated by deap2.1, and the agricultural comprehensive efficiency, pure technical efficiency and scale efficiency in 2000, 2005, 2010 and 2015 were saw in Table 2.

| Year | Comprehensive efficiency Value (number) | Pure technical efficiency Value (number) | Scale efficiency Value (number) |
|------|----------------------------------------|-----------------------------------------|---------------------------------|
| 2000 | 0.621(3)                               | 0.797(11)                               | 0.803(3)                        |
| 2005 | 0.660(4)                               | 0.857(15)                               | 0.781(4)                        |
| 2010 | 0.677(4)                               | 0.795(7)                                | 0.852(4)                        |
| 2015 | 0.703(6)                               | 0.76(10)                                | 0.921(6)                        |
| Average| 0.665                                  | 0.802                                  | 0.839                           |

From table 2, it can be seen that the comprehensive agricultural efficiency of Lanxi urban agglomeration was relatively low, with an average value of 0.665, and the number of regions in the front of production is relatively small. The agricultural scale efficiency (average value 0.839) and pure technical efficiency (average value 0.802) were higher than the comprehensive efficiency, among which the scale efficiency is higher, and increased faster, indicating that the agricultural production of
Lanxi urban agglomeration was changing to the scale operation. However, the number of regions with effective scale was relatively small, which reflected that there was a large gap in the regional agricultural development. Only relying on a small number of regional scale production could not improve the overall efficiency of agricultural production, and the production scale should be adjusted according to the regional agricultural production situation. The number of regions with the effective of pure technical efficiency was large, which showed that the counties of Lanxi urban agglomeration paid more attention to the investment of advanced production methods, technologies and the use of scientific management methods.

3.2. Temporal and spatial characteristics
Spatial differences in provinces: the level of agricultural comprehensive efficiency and pure technical efficiency in Gansu Province was higher than that of in Qinghai Province, while the level of scale efficiency is slightly lower than that of in Qinghai Province. The main reason was that the terrain differences between Qinghai Province and Gansu Province. Qinghai Province, with the terrain was high, and precipitation was large. Most counties and regions were located in Hehuang valley basin, and the terrain is relatively flat, which was conducive to large-scale agricultural production. Gansu Province was located in the Loess Hilly and gully area, where the terrain is broken, the slope is steep and the gully is deep, and the soil erosion is serious, which was not conducive to the large-scale production of agriculture. However, the dry farming technology in the area is relatively developed, forming the difference between the pure agricultural technology efficiency and the scale efficiency.

Spatial differences in counties: classification of the comprehensive efficiency, pure technical efficiency and scale efficiency of county agriculture (Figure 1). If the efficiency was less than 0.600, the degree of ineffectiveness was very serious, if the efficiency is between 0.601 and 0.750, the degree of ineffectiveness was serious, if the efficiency was between 0.751 and 0.899, the degree of ineffectiveness was moderate, if the efficiency was between 0.900 and 0.999, the degree of ineffectiveness was slight, if the efficiency was between 1 and 0.999, the degree of ineffectiveness was effective.

![Figure 1. Spatial characteristics of agricultural comprehensive efficiency](image_url)

The spatial characteristics of agricultural comprehensive efficiency in 2000 and 2005 were similar. There were a large number of regions with serious ineffectiveness in the middle of the urban
agglomeration, and the regions with moderate and slight ineffectiveness were in the East and West of the urban agglomeration, forming a "middle collapse" agricultural production efficiency pattern, which was high in the East and West, and low in the middle section. In 2010, the regions of the most ineffectiveness were mainly concentrated in the eastern part of the urban agglomeration, and in 2015, the comprehensive efficiency of agriculture in the eastern counties was greatly improved, and the increase speed in Gansu Province was faster than that of in Qinghai Province. The regions of the most ineffectiveness were mainly distributed in the western of the urban agglomeration, the comprehensive efficiency of agriculture was promoted from the western to the eastern, showing the development trend was "fast in the East and slow in the West".

From 2000 to 2015, the pure technical effectiveness of Gansu Province was better than that of Qinghai Province, and the number of regions with serious ineffectiveness gradually decreased, showing a spatial pattern of high in the East and low in the West. "Technology transmission" of spatial neighborhood effect to surrounding areas had greatly increased the pure technology effective areas of agriculture in 2005. Due to the ability of technological innovation and technological renewal in different regions, the ability of technological renewal in Anding District, Longxi County and Yuzhong County in the south central of Gansu Province was relatively strong, mainly because the three counties were the experimental bases of dry farming technology of universities and agricultural scientific research institutions, and the application of advanced technology was the main reason that the spatial pattern of the pure technological efficiency was high in the East and low in the West for a long time.

The scale efficiency value of Lanxi urban agglomeration increased from 0.449 to 0.568, and the number of serious ineffectiveness areas was becoming fewer and fewer, only one region was seriously ineffectiveness in 2015. The scale efficiency of Qinghai Province was higher than that of Gansu Province, showing a spatial pattern of high in the West and low in the East. The comprehensive efficiency, pure technical efficiency and scale efficiency in Linxia and Tongren county were effective in four time sections. Daxia River and Longwu River provided water to guarantee the agricultural production, Linxia basin provided fertile soil for agricultural production, the planting and animal husbandry structure of Tongren County were reasonable, which were the possible reasons for maintaining the efficiency of comprehensive efficiency, pure technical efficiency and scale efficiency in Linxia city and Tongren county.

3.3. Change characteristics of TFP
The temporal change characteristics of TFP showed the average value of TFP index of Lanxi urban agglomeration is 1.240, which was seen in Table 3. The change of technological progress was 1.198, which was significantly higher than that of other factors, indicating that technological progress contributes the most to the growth of agricultural TFP. The agricultural TFP accelerated to rise from 2000 to 2010, but declined inversely from 2010 to 2015, the main reason was that the agricultural technology progress in this stage increased by -31%. From 2000 to 2005, the change of scale efficiency was less than 1, and the change of pure technical efficiency was more than 1, indicating that the scale efficiency of agricultural production was not obvious in this stage. From 2005 to 2015, the scale effect of agricultural increased, and the change of agricultural pure technical efficiency showed a downward trend. From 2010 to 2015, the TFP value declined sharply, among which the technological progress declined significantly, indicating that the agricultural technology of Lanxi urban agglomerations had a backward trend from 2010 to 2015.

Table 3. Agricultural Malmquist productivity index and its decomposition

| Time interval | TEC | TC | TE | SE | TFP |
|---------------|-----|----|----|----|-----|
| 2000-2005     | 1.067 | 1.493 | 1.099 | 0.971 | 1.594 |
| 2005-2010     | 1.037 | 1.713 | 0.935 | 1.109 | 1.777 |
| 2010-2015     | 1.001 | 0.672 | 0.920 | 1.089 | 0.673 |
| average       | 1.035 | 1.198 | 0.982 | 1.055 | 1.240 |
From the Table 3, we can see that when agricultural technology progressed rapidly, the total factor productivity increased rapidly too, and the efficiency of agricultural production increased greatly; when agricultural technology declined, the total factor productivity decreased rapidly, and the efficiency of agricultural production dropped sharply, which showed that the progress of agricultural technology and the innovation of agricultural technology was fundamental reason for the promoting the efficiency of agricultural production.

The change of agricultural production efficiency in each period was closely related to the regional development policy. Due to the implemented of the western development strategy in 2000, on the basis of ensuring the food security function, economic function and social function, most of counties continued to promote agricultural modernization and agricultural industrialization, through adjusting the agricultural structure, building water conservancy facilities to improve agricultural technology and promote the overall efficiency of agriculture. Further increased the intensity of agricultural tax exemption and reduction in 2005, and inclined to the key counties of poverty alleviation and development, and increased the support for agricultural infrastructure construction and scientific and technological progress, which means most counties in Lanxi urban agglomeration were the beneficiaries of this policy. After 2010, a large-scale land-use renovation project was carried out nationwide to improve the management efficiency of sporadic, land use mode changed from extensive management to intensive management. The agricultural scale efficiency of Loess Hilly and gully area in Gansu Province was significantly improved, which was reflected in the spatial pattern of scale efficiency in 2015.

| Province      | TEC  | TC    | TE    | SE    | TFP   | Agricultural growth rate | Contribution rate % |
|---------------|------|-------|-------|-------|-------|--------------------------|---------------------|
| Gansu         | 1.115| 1.255 | 1.048 | 1.067 | 1.394 | 22.205                   | 11.818              |
| Qinghai       | 0.977| 1.161 | 0.941 | 1.054 | 1.128 | 4.808                    | 17.767              |

The TFP indexes of Gansu Province and Qinghai Province were 1.394 and 1.128, respectively. The changes of comprehensive efficiency, technological progress, pure technological efficiency and scale efficiency in Gansu Province were greater than 1, which showed that the improvement of TFP in Gansu Province was the result of comprehensive factors of technological progress, scale efficiency and factor input. The change of comprehensive efficiency and pure technical efficiency in Qinghai Province was less than 1, and the change of technological progress and scale efficiency was more than 1, which showed that the improvement of pure technical efficiency in Qinghai Province had a downward (falling) trend, and the dependence of agricultural total factor productivity on factor input was less than the requirement of agricultural technological progress and scale efficiency, which is consistent with the analysis results of static efficiency. From the perspective of efficiency sources, the contribution of agricultural technology progress to TFP was more prominent, on the other hand, it showed that relying on extensive factor investment could not fundamentally improve the agricultural production efficiency of Lanxi urban agglomeration, and agricultural technology progress was the main factor to promote agricultural economic growth.

4. Conclusion
BC², C²R and Malmquist productivity indexes were used to analyze the spatial-temporal characteristics and dynamic trends of agricultural production efficiency of Lanxi urban agglomeration since 2000. The conclusions were as follows:

1) The agricultural comprehensive efficiency of Lanxi urban agglomeration was low, the scale efficiency was greater than the pure technical efficiency, and there was a large space to improve the agricultural technical capacity; the area with scale efficiency was less than the area with pure technical efficiency, which showed that the agricultural scale development in a few region could not promote the overall efficiency of agricultural production.
(2) The static efficiency of agricultural production in Lanxi urban agglomeration showed that the comprehensive efficiency and pure technical efficiency of agriculture were higher in Gansu Province, and the scale efficiency was low, while that in Qinghai Province which was the opposite. The improving rate of agricultural production efficiency showed a trend of "fast in the East (Gansu) and slow in the West (Qinghai) ".

(3) The agricultural total factor productivity of Lanxi urban agglomeration was increasing continuously, and the decline of agricultural technology lead to the decline of agricultural total factor productivity from 2010 to 2015, which means technological progress was the most important factor to promote the increase of agricultural total factor productivity.

(4) Extensive factor input could not fundamentally improve the efficiency of agricultural production. The improvement of total factor productivity in Gansu Province was the result of comprehensive factors such as technological progress, scale efficiency and factor input. The increase of total factor productivity in Qinghai Province was dependent on the agricultural technology progress and scale efficiency.

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