The Research on Spatial Distribution of Agricultural Products Logistics Efficiency in China

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Abstract

The improvement of agricultural products logistics efficiency is of practical significance to promote the level of agricultural industrialization and drive rural economic construction in China. This paper uses SBM model in DEA method to study the efficiency level of agricultural products logistics of 28 provincial administrative regions in Mainland China from 2000 to 2014. On this basis, spatial autocorrelation method is used to analyze the spatial distribution status of logistics efficiency of each region. The results show that the overall TE level of agricultural products logistics in Mainland was low, which resulted from low PTE. Since 2000, the clustering trend of provinces with high efficiency level has been strengthening. The high significant hot spots and high level zones mainly distributed in east and central regions.

Keywords: agricultural products logistics, efficiency level, spatial autocorrelation analysis

1. INTRODUCTION

Now, low agricultural products logistics efficiency has been one of the bottlenecks that is hindering the development of agricultural industrialization and rural economy, which makes the logistics cost stay at a high level, decreases the producers’ profits and harms the consumers’ benefits. Therefore, there is no doubt that the study on how to improve agricultural products logistics efficiency is of great practical significance.

In the research field of agricultural products logistics efficiency, foreign scholars focus on the qualitative study on influence factors and promotion countermeasures of logistics efficiency. Hobbs and Young (2000) established analytical framework to analyze agricultural products logistics efficiency based on supply chain theories. Quinn and Murray (2005) indicated that the specificity and uncertainty of agricultural product logistics property was the key factor to affect efficiency level. Muralidhar (2012) discovered that freight charge and commission fees were the key factors to hinder the improvement of agricultural products logistics efficiency.

Few Chinese scholars specialize in agricultural product logistics efficiency, most of whom indirectly analyze it from the point of circulation efficiency. Luo et al., (2000) believed that the major factors included property right structure, measure capacity of the organization to members’ effort and compensatory and crytic system content of logistics organization. Li and Li (2005) put forward that the popularity of information technology has promoted the scale and the efficiency of agricultural products circulation. Zhang et al., (2009) introduced Relational Exchange Theory and Organization Relationship Governance Theory to solve some sociality factor problems neglected in existing studies, and indicated that the governance structure with the core of composite structure could largely affect circulation efficiency. Gao and Wang (2015) found that the main reasons leading to low circulation efficiency were complex circulation channel structure, low organizational degree, imperfect information networks and feeble circulation infrastructure. Chen et al., (2015) pointed out that the circulation efficiency level was different in different models. And many factors,
such as scale of production, specialization level, TPL level and the input of dedicated device, would influence agricultural products logistics efficiency.

Among these research results, a few refer to circulation efficiency measurement. Sun (2011) constructed the index system to measure agricultural product circulation efficiency in China, which consisted of velocity of circulation index, performance of circulation index and scale of circulation index. And by means of factor analysis method he discussed total tendency and stage change of circulation efficiency from 1998 to 2009. Ouyang and Huang (2011) measured the agricultural products circulation efficiency of 28 provinces in China, and considered that the efficiency level was not high, but tended to rise. There existed apparent difference in regional circulation efficiency and positive influence factors encompassed rural logistics infrastructure, quality of labor and level of informatization. Huang and Zhang (2015) found that the circulation efficiency of Gannan navel orange was generally low and the most effective pattern was “farmer + company” pattern.

The existing results show that so far, the studies on agricultural products logistics efficiency are of two outstanding features: 1) The dynamics of empirical analysis is not sufficient. Amount of research findings concentrate upon discussing influence factors on the basis of various theories and few are to measure efficiency level using empirical analysis methods, which brings about vague cognition of logistics efficiency status quo and its spatial distribution status in China. 2) Logistics efficiency and circulation efficiency have not been clearly distinguished. As previously mentioned, many domestic scholars directly analyze agricultural products logistics efficiency through the researches on circulation efficiency. However, agricultural products logistics is only one of essential parts of circulation. Hence, the research results lack of veracity and accuracy without precisely distinguishing logistics efficiency from circulation efficiency.

Hence, taking now available research results for reference, based on the characteristic of agricultural product logistics, this paper uses SBM model in DEA method to study the efficiency level of 28 provincial administrative regions in Mainland China from 2000 to 2014 and spatial autocorrelation method to analyze spatial distribution status of efficiency level of each region.

2. EFFICIENCY LEVEL MEASUREMENT OF AGRICULTURAL PRODUCTS LOGISTICS

2.1 Efficiency

Using Debreu’s (1951) and Koopmans’s (1951) research findings for reference, Farrell (1957) put forward new efficiency theory to effectively measure the efficiency level of a certain organization in various input conditions, which has been widely recognized and applied. According to Farrell, the Economic Efficiency (EE) of one Decision Making Unit (DMU) can be decomposed into Technical Efficiency (TE) and Allocative Efficiency (AE). TE is the capacity of the DMU to realize minimized input in the process of manufacturing a certain amount of products or maximized output under the premise of invariant input level, in accordance with fixed proportion of factor input, under the condition of invariable production technology and market price. AE refers to the capacity of allocating every kind of resources to the most fitting use direction under the condition of fixed market price and production technology on hand. In addition, TE can further break up into the product of pure TE and scale efficiency to respectively discuss the resource utilization capacity of a certain DEU under current scale and measure whether it has reaches optimal scale.

Since it’s difficult to obtain the price information of input factors in different regions in different times from now available authoritative statistical materials, there is no way to calculate AE value. Based on Farrell’s theory, the paper aims at study the TE of agricultural product logistics, which conforms to the regular practice of existing researches on efficiency.
2.2 DEA-SBM model

Data Envelopment Analysis (DEA) is one of the frequently-used nonparametric methods to measure TE. But both CCR model and BCC model in classical DEA method allow the existence of "weak effectivity", that is, the DMU is thought to be valid in technology even if there is redundant input or insufficient output, which doesn't conform to the cognition of technology efficiency in general meaning. Therefore, this paper employs non-radial, non-angular SBM model put forward by Tone (2001). SBM model directly put slack variable into objective function. And the influence of slack input and slack output are taken into consideration of efficiency calculation, which has made up for the flaw in CCR model and BCC model.

It’s assumed that there are n DMUs, m kinds of input and k kinds of output in each DMU. Under CRS, The SBM model is shown as formula (1).

\[
\min \rho = \frac{1 - \frac{1}{m} \sum_{i=1}^{m} s_i^- / x_{i0}}{1 - \frac{1}{k} \sum_{j=1}^{k} s_j^+ / y_{j0}}
\]

\[\begin{align*}
    x_0 &= X \lambda + s^- \\
    y_0 &= Y \lambda - s^+ \\
    \lambda &\geq 0, s^- \geq 0, s^+ \geq 0
\end{align*}\]

In this formula, \(s^-\) and \(s^+\) respectively represent excessive input and insufficient output, \(\rho\) represents the efficiency value evaluated by the model. The features of SBM model are as follows: (1) \(\rho\) isn’t affected by the measuring units of input and output data. (2) \(\rho\) is of preferable monotonicity, whose value decreases with the increase of slack input and output. (3) The value of \(\rho\) is between 0 and 1, which can equal to 1. (4) \(\rho\) is 1 when both slack input and output are 0, which means this DMU is valid in SBM model. So, there is no "weak effectivity" in SBM model. If constraint condition \(\sum_{j=1}^{n} \lambda_j j^{*}=1\) \((j=1,2,..., n)\) is added into formula (1), the SBM model under VRS can be obtained.

2.3 Index setting and data and sample selection

2.3.1 Input and output index

In terms of index set, this paper takes some scholars’ views for reference. (Yusuf, 2014; Nwaruwu and Iheke, 2011; Zhang, 2016; Yao and Liao, 2015). According to Cobb–Douglas production function, under vested technical condition, the main influence factors on output are capital and labor force. To embody the continuity of the function of early capital, in this paper the capital stock of logistics industry is selected to be the index, and it’s accounted by means of “perpetual inventory method”. The formula of this method is shown as follows.

\[K_t = K_{t-1}(1-\delta) + I_t\] (2)

In this formula, \(K_t\) and \(K_{t-1}\) respectively represent the capital stock of regional agricultural product logistics of province i during the period of t and t-1. \(\delta\) is rate of depreciation. And I is the capital input of province i during the period of t.

This paper uses the method put forward by Hall and Jones (1999) to estimate the capital stock of base year. It is to calculate the capital stock of logistics industry of each province in the base year 1981 with the amount of fixed investments of the whole country from 1981...
to 2014 divided by the sum of geometric average growth rate of fixed investments and rate of depreciation. Taking the method put forward by Zhang (2004) for reference, with the assumption of relative efficiency of capital goods geometrically diminishing, the rate of depreciation \( \delta \) in formula (2) is calculated by means of balance depreciation method, which is on behalf of geometric diminishing returns, which is shown in formula (3).

\[
d_t = (1-\delta)^\tau, \tau = 0,1,\ldots
\]

(3)

In this formula, \( d_t \) is relative efficiency of capital goods, which is the marginal production efficiency of former capital goods relative to new capital goods. \( \delta \) is rate of depreciation and \( \tau \) is period. The distribution of rate of depreciation in each year is unchanged in the diminishing geometric mode of relative efficiency.

In the paper, fixed investments of whole society in current year is taken as capital input to agricultural products logistics industry that very year, and amount of investment of each year is calculated taking the constant price in 1981 as the base.

In terms of labor input, because communication and transportation, storage and mall business are the main body of logistics industry, the number of practitioners in these three parts is regarded as that in agricultural product logistics industry in this paper.

In the paper, the volume of the circular flow of regional agricultural products is set to be output index. With a hundred million ton kilogram as unit of measurement, it is an ideal output variable since it can not be affected by fluctuation in prices and be on behalf of volume of freight traffic and freight distance at the same time.

2.3.2 Data and sample selection

In order to ensure the authenticity and veracity, the data used in the paper are mainly selected from China Statistical Yearbook and China Statistical Yearbook of Fixed-asset Investment. It should be pointed out that after 2008, the statistical caliber on highway and waterway transportation has been changed, which has made a certain influence on original data of volume of the circular flow of regional agricultural product logistics. Therefore, the follow-up study in this paper is divided into two periods, which are from 2000 to 2007 and from 2008 to 2014.

The sample of this paper includes each provincial administrative region in Mainland China. Because there is serious lack of relative data, Tibet and Hainan province are not taken into consideration. Chongqing is combined with Sichuan province because it's not upgraded to be municipality directly under the central government until 1997. So, 28 provinces are studied in the paper. Meanwhile, With reference to the regional division method, 28 provinces in mainland China are divided into east region (Beijing, Shanghai, Tianjin, Hebei, Liaoning, Shandong, Jiangsu, Zhejiang, Fujian and Guangdong), central region (Shanxi, Jilin, Heilongjiang, Henan, Hubei, Hunan, Jiangxi and Anhui) and west region (Inner Mongolia, Shanxi, Yunnan, Guizhou, Sichuan, Guangxi, Gansu, Qinghai, Ningxia and Xinjiang).

2.4 The Measurement Results

2.4.1 The calculation of TE value

Under CRS, with the help of software MAXDEA pro 6.3, SBM-CRS model is employed in the paper to calculate the TE value of 28 provinces in Mainland China from 2000 to 2007 and from 2008 to 2014. The results are shown in table 1.
Table 1. The TE of Agricultural Products Logistics in Mainland China from 2000-2014

<table>
<thead>
<tr>
<th></th>
<th>00</th>
<th>01</th>
<th>02</th>
<th>03</th>
<th>04</th>
<th>05</th>
<th>06</th>
<th>07</th>
<th>08</th>
<th>09</th>
<th>10</th>
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</tr>
</thead>
<tbody>
<tr>
<td>Em</td>
<td>0.40</td>
<td>0.41</td>
<td>0.29</td>
<td>0.28</td>
<td>0.28</td>
<td>0.29</td>
<td>0.31</td>
<td>0.29</td>
<td>0.32</td>
<td>0.36</td>
<td>0.38</td>
<td>0.38</td>
<td>0.40</td>
<td>0.42</td>
<td>0.44</td>
</tr>
<tr>
<td>Cm</td>
<td>0.27</td>
<td>0.26</td>
<td>0.19</td>
<td>0.16</td>
<td>0.15</td>
<td>0.14</td>
<td>0.15</td>
<td>0.13</td>
<td>0.28</td>
<td>0.32</td>
<td>0.34</td>
<td>0.34</td>
<td>0.37</td>
<td>0.37</td>
<td>0.40</td>
</tr>
<tr>
<td>Wm</td>
<td>0.27</td>
<td>0.26</td>
<td>0.17</td>
<td>0.15</td>
<td>0.12</td>
<td>0.12</td>
<td>0.15</td>
<td>0.13</td>
<td>0.20</td>
<td>0.25</td>
<td>0.25</td>
<td>0.22</td>
<td>0.26</td>
<td>0.30</td>
<td>0.34</td>
</tr>
<tr>
<td>Nm</td>
<td>0.32</td>
<td>0.31</td>
<td>0.22</td>
<td>0.20</td>
<td>0.19</td>
<td>0.19</td>
<td>0.20</td>
<td>0.19</td>
<td>0.27</td>
<td>0.31</td>
<td>0.32</td>
<td>0.31</td>
<td>0.34</td>
<td>0.36</td>
<td>0.37</td>
</tr>
</tbody>
</table>

Note: Em- Eastern mean, Cm- Central mean, Wm- Western mean, Nm- National mean. For the limitation of length, this paper does not display TE value of each province. The following are the same.

1. During two periods of time, the TE level on a national scale was very low, which was basically in the state of inefficiency.

2. According to specific efficiency value, the TE level presented the diminishing state from the east, the central region to the west during two periods of time. Enhanced development of economy and society provided abundant capital and high-quality labor force for the development of eastern logistics industry. The logistics industry of agricultural products in the eastern region has started earlier and accumulated rich experience in the long development process, which has fostered more logistics operation competence. Meanwhile, high degree of opening to the outside world, advanced import and export trade and introduction of plenty of overseas-funded enterprises have pulled up the TE level of this region to some extent. In comparison, the TE level of the central and the west regions was lower because of late start of logistics industry and the gaps in resource, experience and competence. But during the second period of time, with the improvement of external environment of the central and the west regions and the deepening of cooperation and exchange among enterprises in different regions, the gap among three regions had been narrowed.

3. On the basis of the data in table 1, figure 1 has been drawn, which can mirror the variation tendency of TE value of the whole country and three regions during two periods of time. It indicates that from 2000 to 2007, the TE level presented the downward trend throughout the country. But from 2008 to 2014, it appeared to be upward. The continuous improvement embodied that the governments at all levels increasingly attached importance to the development of logistics industry in recent years and introduced series of supportive policies. In the meantime, the logistics industry in every region were making progress to higher level to meet the needs of market. The TE level of agricultural products logistics showed up the trend of continuous improvement.

Figure 1. The Mean Value of TE of Agricultural Products Logistics of Three Regions and Whole Country from 2000 to 2014

2.4.2 The calculation of PTE and SE

Under VRS, with the help of software MAXDEA pro 6.3, SBM-CRS model is employed in the paper to calculate the PTE (Pure Technical Efficiency) value of 28 provinces in Mainland China from 2000 to 2007 and from 2008 to 2012. The results are shown in table 2.
Table 2 The PTE of Agricultural Products Logistics in Mainland China from 2000-2014

<table>
<thead>
<tr>
<th>Year</th>
<th>00</th>
<th>01</th>
<th>02</th>
<th>03</th>
<th>04</th>
<th>05</th>
<th>06</th>
<th>07</th>
<th>08</th>
<th>09</th>
<th>10</th>
<th>11</th>
<th>12</th>
<th>13</th>
<th>14</th>
</tr>
</thead>
<tbody>
<tr>
<td>Em</td>
<td>0.47</td>
<td>0.50</td>
<td>0.46</td>
<td>0.44</td>
<td>0.42</td>
<td>0.49</td>
<td>0.50</td>
<td>0.52</td>
<td>0.48</td>
<td>0.50</td>
<td>0.52</td>
<td>0.53</td>
<td>0.56</td>
<td>0.59</td>
<td>0.62</td>
</tr>
<tr>
<td>Cm</td>
<td>0.29</td>
<td>0.28</td>
<td>0.21</td>
<td>0.18</td>
<td>0.15</td>
<td>0.16</td>
<td>0.17</td>
<td>0.16</td>
<td>0.33</td>
<td>0.37</td>
<td>0.39</td>
<td>0.40</td>
<td>0.50</td>
<td>0.55</td>
<td>0.6</td>
</tr>
<tr>
<td>Wm</td>
<td>0.40</td>
<td>0.38</td>
<td>0.27</td>
<td>0.25</td>
<td>0.22</td>
<td>0.25</td>
<td>0.22</td>
<td>0.25</td>
<td>0.31</td>
<td>0.31</td>
<td>0.36</td>
<td>0.36</td>
<td>0.32</td>
<td>0.35</td>
<td>0.38</td>
</tr>
<tr>
<td>Nm</td>
<td>0.39</td>
<td>0.39</td>
<td>0.32</td>
<td>0.30</td>
<td>0.27</td>
<td>0.30</td>
<td>0.32</td>
<td>0.30</td>
<td>0.31</td>
<td>0.38</td>
<td>0.41</td>
<td>0.42</td>
<td>0.42</td>
<td>0.45</td>
<td>0.48</td>
</tr>
</tbody>
</table>

Note: Em- Eastern mean, Cm- Central mean, Wm- Western mean, Nm- National mean.

It can be observed from the results above that during two periods of time, the PTE level on a national scale was very low, which was similar to TE level and the comparison between figure 1 and figure 2 indicates that the variation tendency of PTE level resembled that of TE level, which illustrated that the primary cause of low TE was low PTE level.

Figure 2. The Mean Value of PTE of Agricultural Products Logistics of Three Regions and Whole Country from 2000 to 2014

3. SPATIAL DISTRIBUTION MEASUREMENT OF LOGISTICS EFFICIENCY LEVEL

Spatial autocorrelation is refers to the clustering of the similar things or phenomena in the space, which can be used to test whether the observation values of a certain factor with spatial position are significantly associated with that at adjacent space point, referring to Li and Shi (2016). Spatial autocorrelation can be classified into global spatial autocorrelation and local spatial auto correlation (Wu and Yang, 2010). Global spatial autocorrelation mainly describes the correlation degree of spatial objects in the whole study area to make clear whether there exist prominent spatial distribution patterns among spatial objects (Cliff and Ord, 1981). It is established on the basis of space stability assumption, but spatial process is not so steady. Therefore, local spatial autocorrelation is also applied to indentify different space clustering patterns in different spatial position to observe the local instability (Getis and Ord, 1992).

3.1 Global Spatial Autocorrelation Analysis

Frequently-used global autocorrelation analysis indexes encompass global Moran’s I index, global Geary’s C index and global Getis-Ord G index, which can analyze global spatial autocorrelation through comparing the level of similarity of observed values of spatial element in adjacent space. For the common flaw of Moran’s I index and Geary’s C index that it’s unable to distinguish whether emerging positive spatial autocorrelation is high values clustering, low values clustering or high and low values clustering, this paper selects global Getis-Ord G index, whose calculation formula is shown as (4).

\[
G = \frac{\sum_{i=1}^{n} \sum_{j=1}^{n} W_{ij} x_i x_j}{\sum_{i=1}^{n} \sum_{j=1}^{n} x_i x_j}, \forall j \neq i
\]

(4)

In the formula, \(x_i\) and \(x_j\) respectively represent the observed value of the element in spatial position \(i\) and \(j\). \(W_{ij}\) is the spatial weight between spatial position \(i\) and \(j\). And \(n\) is the number of observation points in the space. The test is still based on Z standard value of the
index, as shown in formula (5).

\[ Z = \frac{G - E(G)}{\sqrt{\text{Var}(G)}} \]
\[ E(G) = \sum_{i=1}^{n} \sum_{j=1, j \neq i}^{n} w_{ij}, \forall j \neq i \]
\[ V(G) = E(G^2) - [E(G)]^2 \]

When the Getis-Ord G index value is greater than its expected value and Z value is significant, the high observed values in the space tend to gather. On the contrary, when the Getis-Ord G index value is less than its expected value and Z value is significant, the low observed values tend to gather. But when the Getis-Ord G index value approaches the expected value, the observed values show random permutation in the space. The more Z value is, the higher the degree of gathering will be.

Using AcGis9 software, the paper calculates the global Getis-Ord G index value of agricultural products logistics technology efficiency of 28 provincial administrative regions from 2000 to 2012.

**Table 3** Global Getis-Ord G Index Values of Logistics Technology Efficiency of Agricultural Products from 2000 to 2014

<table>
<thead>
<tr>
<th>Year</th>
<th>Observed Value</th>
<th>Expected Value</th>
<th>Variance</th>
<th>Z</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>2000</td>
<td>0.4036</td>
<td>0.3269</td>
<td>0.0017</td>
<td>1.8648</td>
<td>0.0622***</td>
</tr>
<tr>
<td>2001</td>
<td>0.4134</td>
<td>0.3269</td>
<td>0.0018</td>
<td>2.0390</td>
<td>0.0414**</td>
</tr>
<tr>
<td>2002</td>
<td>0.4187</td>
<td>0.3269</td>
<td>0.0025</td>
<td>1.8524</td>
<td>0.0640***</td>
</tr>
<tr>
<td>2003</td>
<td>0.4211</td>
<td>0.3269</td>
<td>0.0028</td>
<td>1.7812</td>
<td>0.0749***</td>
</tr>
<tr>
<td>2004</td>
<td>0.4456</td>
<td>0.3269</td>
<td>0.0031</td>
<td>2.1220</td>
<td>0.0338**</td>
</tr>
<tr>
<td>2005</td>
<td>0.4613</td>
<td>0.3269</td>
<td>0.0034</td>
<td>2.2967</td>
<td>0.0216**</td>
</tr>
<tr>
<td>2006</td>
<td>0.4394</td>
<td>0.3269</td>
<td>0.0031</td>
<td>2.0117</td>
<td>0.0442**</td>
</tr>
<tr>
<td>2007</td>
<td>0.4457</td>
<td>0.3269</td>
<td>0.0035</td>
<td>2.0116</td>
<td>0.0443**</td>
</tr>
<tr>
<td>2008</td>
<td>0.4603</td>
<td>0.3269</td>
<td>0.0031</td>
<td>2.4073</td>
<td>0.0161**</td>
</tr>
<tr>
<td>2009</td>
<td>0.4447</td>
<td>0.3269</td>
<td>0.0020</td>
<td>2.4237</td>
<td>0.0154**</td>
</tr>
<tr>
<td>2010</td>
<td>0.4491</td>
<td>0.3269</td>
<td>0.0023</td>
<td>2.7529</td>
<td>0.0059*</td>
</tr>
<tr>
<td>2011</td>
<td>0.4660</td>
<td>0.3269</td>
<td>0.0021</td>
<td>3.0132</td>
<td>0.0026*</td>
</tr>
<tr>
<td>2012</td>
<td>0.4525</td>
<td>0.3269</td>
<td>0.0020</td>
<td>2.8307</td>
<td>0.0046*</td>
</tr>
<tr>
<td>2013</td>
<td>0.4608</td>
<td>0.3269</td>
<td>0.0021</td>
<td>2.9573</td>
<td>0.0061**</td>
</tr>
<tr>
<td>2014</td>
<td>0.4623</td>
<td>0.3269</td>
<td>0.0034</td>
<td>2.9967</td>
<td>0.0028**</td>
</tr>
</tbody>
</table>

Note: “*” -1% significance level; “**” -5% significance level; “***” -10% significance level

The data in table 3 indicate that all index values are greater than expected values and Z value is positive and has passed significance testing, which states that the provinces with higher TE level show up the tendency of gathering. Since 2000, the observed values have tended to become large and the significance has been enhancing, which shows the gathering tendency is strengthening.

**3.2 Local Spatial Autocorrelation Analysis**

Although the certain clustering tendency of the provinces with higher TE level has been made clear, where it happens is still not known. Getis and Ord (1992) put forward Getis-Ord Gi* index to indentify whether it is high clustering or low clustering between a certain space position and its neighbor through calculating the ratio of the sum of observed values of the elements in neighboring position in one space and that of observed values of the elements in all space positions. The calculation formula of Getis-Ord Gi* index is shown
as (6).

\[
G_i^* = \frac{\sum_{j=1}^{n} w_{ij} x_j}{\sum_{j=1}^{n} x_j}, \forall j \neq i
\]  \quad (6)

The test of Getis-Ord Gi* index also depends on Z standard value. If Z value is significantly positive, the observed values of the elements in the spatial position i and the neighboring are relatively large (larger than mean value), which means a clustering zone of high observed values, and position i will be called "hot spot". On the other hand, if Z value is significantly negative, the observed values are relatively small (less than mean value), which means a clustering zone of low observed values, it will be "cold point" area. The calculation formula is shown as (7).

\[
Z = \frac{G - E(G)}{\sqrt{Var(G)}}
\]

\[
E(G) = \frac{\sum_{j=1}^{n} w_{ij}}{n(n-1)}, \forall j \neq i
\]

\[
V(G) = E(G^2) - [E(G)]^2
\]  \quad (7)

Because of the length of this paper, only the data in 2000, 2007 and 2012 are analyzed. With ArcGIS 9 software, the paper calculates the Getis-Ord Gi* index values in three years and displays them in figures, as shown in figure 3.

**Figure 3.** Getis-Ord Gi* Index Values of Technology Efficiency of Agricultural Products Logistics in 2000, 2007 and 2012

In the figure, different colors stand for "hot spots" or "cold point" areas at different significance levels. From top to bottom, The legend in the figure shows in order high significant cold point area, middle significant, low significant cold point area, random area, low significant hot spot, middle significant hot spot and high significant hot spot.
The figure 3 illustrates that in 2000, Jiangsu province was high significant hot spot and Anhui and Shandong were middle significant hot spots. In 2007, Jiangsu and Shandong were high significant hot spots. Tianjin, Anhui and Liaoning were middle significant hot spots and Inner Mongolia was low significant hot spot. In 2012, the situation changed. Jiangsu and Shandong were still high significant hot spots, but the number of middle significant hot spots increased to five, encompassing Shanxi, Tianjin, Anhui, Zhejiang and Shanghai. Jiangxi was low significant hot spot. The rise of significant hot spots had verified the conclusion that the gathering tendency of the administrative regions with high TE has enhanced since 2000.

In accordance with the results, significant hot spots and the neighboring in 2012 are listed, as shown in table 4.

<table>
<thead>
<tr>
<th>Significant Hot Spot</th>
<th>Neighboring Province</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>2000</strong></td>
<td></td>
</tr>
<tr>
<td>Jiangsu</td>
<td>Shandong, Shanghai, Anhui, Henan, Zhejiang</td>
</tr>
<tr>
<td>Shandong</td>
<td>Hebei, Tianjin, Henan, Anhui, Jiangsu</td>
</tr>
<tr>
<td>Anhui</td>
<td>Shandong, Henan, Jiangsu, Zhejiang, Jiangxi, Hubei</td>
</tr>
<tr>
<td><strong>2007</strong></td>
<td></td>
</tr>
<tr>
<td>Jiangsu</td>
<td>Shandong, Shanghai, Anhui, Henan, Zhejiang</td>
</tr>
<tr>
<td>Shandong</td>
<td>Hebei, Tianjin, Henan, Anhui, Jiangsu</td>
</tr>
<tr>
<td>Tianjin</td>
<td>Beijing, Hebei, Shandong, Liaoning</td>
</tr>
<tr>
<td>Anhui</td>
<td>Shandong, Henan, Jiangsu, Zhejiang, Jiangxi, Hubei</td>
</tr>
<tr>
<td>Liaoning</td>
<td>Inner Mongolia, Jilin, Hebei</td>
</tr>
<tr>
<td>Inner Mongolia</td>
<td>Shanxi, Gansu, Shanxi, Ningxia, Hebei, Liaoning, Heilongjiang, Jilin</td>
</tr>
<tr>
<td><strong>2012</strong></td>
<td></td>
</tr>
<tr>
<td>Jiangsu</td>
<td>Shandong, Shanghai, Anhui, Henan, Zhejiang</td>
</tr>
<tr>
<td>Shandong</td>
<td>Hebei, Tianjin, Henan, Anhui, Jiangsu</td>
</tr>
<tr>
<td>Tianjin</td>
<td>Beijing, Hebei, Shandong, Liaoning</td>
</tr>
<tr>
<td>Anhui</td>
<td>Shandong, Henan, Jiangsu, Zhejiang, Jiangxi, Hubei</td>
</tr>
<tr>
<td>Zhejiang</td>
<td>Jiangsu, Anhui, Jiangxi, Fujian, Shanghai</td>
</tr>
<tr>
<td>Shanghai</td>
<td>Jiangsu, Zhejiang</td>
</tr>
<tr>
<td>Shanxi</td>
<td>Hebei, Shanxi, Henan, Inner Mongolia</td>
</tr>
<tr>
<td>Jiangxi</td>
<td>Hunan, Hubei, Anhui, Zhejiang, Fujian, Guangdong</td>
</tr>
</tbody>
</table>

From table 4, it can be known that significant hot spots and the neighboring mainly distribute in the east (Tianjin, Hebei, Liaoning, Shandong, Shanghai, Jiangsu and Zhejiang) and the central region (Henan, Anhui and Hubei). It indicates that with the extending of geographical distance of logistics activity, the interchange among different regions has been more frequent and the influence that the regions at high level make on that at low level has been strengthening. The phenomenon of gathering of regions at high level emerges in certain area, which results in the appearance of the gathering zone of high values. For low TE level and unapparent influence, the gathering zone of high values hasn’t formed in the west.

4. CONCLUSIONS AND SUGGESTIONS

This paper applies DEA-SBM model to measure the efficiency level of agricultural products logistics of 28 provincial administrative regions in Mainland China from 2000 to 2012 and uses spatial autocorrelation method to analyze its spatial distribution status. The conclusions are as follows.

1. During two periods of time, the TE level on a national scale was very low, which was basically in the state of inefficiency, which was due to low PTE.
2. Since 2000, the administrative regions at high TE level has tended to cluster constantly. The hot spots in significant area and the neighboring mainly distributed in the east and the central region.

Relying on above conclusions, the key point of improving the TE level of agricultural products logistics in Mainland China is to elevate the PTE level. Hence, following steps can be taken. Firstly, we should stop blindly expanding the scale and change “extensive growth” depending on quantity input to “intensive growth” relying on quality promotion. Secondly, we should correct the narrow cognition of one-sided enhancing equipped level and focus on the improvement of logistics “soft technique”. We can reinforce the butt joint between public information platform and manage information system of enterprise and spread the application of intelligentized transportation system through constructing national and local logistics information platform. Meanwhile, we should quicken the development of technical standard of agricultural products logistics to form the uniform technology standardization system. Thirdly, governments at all level should intensify policy support and strive to solve the problems that influence the development of logistics industry to give full play to the potential of now available logistics resources. Fourthly, we should boost the construction of logistics integration and make relevant measures to guide the expansion of high-level agricultural products logistics enterprises in the east to the central and the west, which can contribute to the promotion of the PTE level in the central and the west. And lastly, we should introduce foreign high-level enterprises into Chinese market, especially into the central region and the west, to improve the logistics practitioners’ quality and competence and the TE level of agricultural products logistics.

5. ACKNOWLEDGMENTS

The fund program “Internet + Supply Chain (GS201602)” of the brand team in School of Business Administration, Jiangxi University of Finance and Economic; The subject project “Humanities and social science in colleges and universities” in Jiangxi province in 2015.

6. REFERENCES


