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Structural Efficiency Research of Chinese Regional Economy Based on Data Envelopment Analysis

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Abstract
In this paper, we make use of shadow price to help build a reasonable data envelopment analysis (DEA) model. Then we use the model to calculate and analyze the structural efficiencies of Chinese regional economy from 2003 to 2014. By the data results, we summarize that during the 12 years, the overall structural efficiency of Chinese regional economy is on the rise. However, both the aggregate technical efficiency and the aggregate allocative efficiency slightly decline. Therefore, the economic structure adjustment of China is necessary.
Key words: *structural efficiency; technical efficiency; allocative efficiency; re-allocative efficiency; data envelopment analysis (DEA); the three strata of industry;*

1 Introduction

National economic structure means the composition of national economy. Whether the economic structure of a country is healthy and reasonable or not is very important. The reasonable economic structure will help the country take advantage of its economy, and facilitate the coordination of all departments in the national economy. We can say that the status of economic structure is an important benchmark to measure the level of economic development of countries or regions. Therefore, doing research on structural efficiency of Chinese regional economy is quietly helpful for the development of China's economic structure.

Nowadays, scholars around the world have done a lot of research on evaluations and analyses of economic efficiency and economic structure. For example, *You*, *Sarantis* (2013)[1] have studied the impact, which is caused by Chinese rural transformation from 1980 to 2010 on total factor productivity. Also, data envelopment analysis (DEA) is applied to evaluate the efficiency of industry or economy by many scholars. For example, *Milana*, *Nascia*, *Zeli* (2013)[2] have used data envelopment analysis (DEA) and Malmquist productivity index to assess the effectiveness of industries in Italy from 1998 to 2004. *Amores*, *ten Raa* (2011)[3] have used data envelopment analysis (DEA) to do a three-level benefit analysis of the economy of Andalusia region in southern Spain. In this paper, we will analyze Chinese regional economy from 2003 to 2014 by an input-oriented DEA method.

In the next section, we briefly introduce the shadow price model from input-oriented viewpoint by *Li*, *Ng* (1995)[4], and then we propose an input-oriented DEA model to calculate the structural efficiencies of Chinese regional economy from 2003 to 2014. The model proposed in this paper is similar to the output-oriented method in *Li*, *Cheng* (2007)[5]. In Section 3, we first explain the data source, then we present the main results, and find the development of China's economic structure by analyzing the data results. In Section 4, we summarize the results of the paper.

2 Model and method

2.1 Shadow price model

In order to quantitatively analyze the structural efficiency of Chinese regional economy, here we use the shadow price model introduced by *Li*, *Ng* (1995)[4]. Suppose that a group is formed by I production units, and each production unit has M inputs and N outputs. For $i \in \{1, 2, \dots, I\}$, the input vector of the *i*th production unit is x_i, and the output vector of the *i*th production unit is y_i, where $x_i \in R_+^M, y_i \in R_+^N$. Moreover, the production possibility set is $\xi^i = \{(x, y): x\ can\ produce\ y\}$, and the corresponding input set is $P^i(y) = \{x: (x, y) \in \xi^i\}$, which follows that $x_i \in P^i(y)$.

In order to measure the structural efficiency of a group as a whole, *Li*, *Ng* (1995)[4] introduce the group production possibility set as

$$\xi = \{(X, Y): for\ a\ group\ of\ I\ production\ units, X\ can\ produce\ Y\} = \sum \xi^i \qquad (1)$$

The group technology set describes the aggregate input/output of the production units as a whole, and the corresponding input set is $P(Y) = \{X: (X, Y) \in \xi\}$.

Let the input/output vector of one production unit be $(x_i^0, y_i^0), i \in \{1, 2, \dots, I\}$, and the aggregate input/output vector of the group is $(X^0, Y^0) = \sum_{i=1}^{I}(x_i^0, y_i^0)$. Thus, the input-oriented structural efficiency is

$$H = min\, \theta \{\theta: \theta X^0 \in P(Y^0)\} \qquad (2)$$

By definition, we have $H \in (0, 1]$ and the group is structurally efficient if and only if $H = 1$. Also, for the aggregate output Y^0, the structurally efficient aggregate input $X^* = H \cdot X^0$.

For a group of production units with aggregate input X^*, the gradient vector $p \in R_+^M$ is called the shadow price vector. Here $p \cdot X^* = min\, X\{p \cdot X: X \in P(Y^0)\}$ when the group input set is convex. Using the shadow price vector, we can get

$$\text{Invested efficiency: } oe_i = (p \cdot x_i^0)^{-1} \cdot min\, x_i\{p \cdot x_i: (x_i, y_i^0) \in \xi^i\} \qquad (3)$$

$$\text{Technical efficiency: } te_i = min\, \lambda_i\{\lambda_i: (\lambda_i x_i^0, y_i^0) \in \xi^i\} \qquad (4)$$

$$\text{Allocative efficiency: } ae_i = \frac{oe_i}{te_i} \qquad (5)$$

Therefore, the technical efficient input vector is $te_i \cdot x_i^0$, and the invested efficient (both technical efficient and allocative efficient) input vector is $oe_i \cdot x_i^0$. Then the aggregate technical efficient input vector is $X^{te} = \sum te_i \cdot x_i^0$, and the both aggregate technical efficient and aggregate allocative efficient input vector is $X^{oe} = \sum oe_i \cdot x_i^0$.

The input-oriented aggregate technical efficiency (ATE) is defined as

$$ATE = \frac{p \cdot X^{te}}{p \cdot X^0} \tag{6}$$

Obviously, we have $ATE \in (0, 1]$ and $ATE = 1$ if and only if all $te_i = 1$.

The input-oriented aggregate allocative efficiency (AAE) is defined as

$$AAE = \frac{p \cdot X^{oe}}{p \cdot X^{te}} \tag{7}$$

The input-oriented re-allocative efficiency (RE) is defined as

$$RE = \frac{p \cdot H \cdot X^0}{p \cdot X^{oe}} \tag{8}$$

We can find that $H \cdot X^0 < X^{oe}$ when $RE < 1$, which means the performance of the production unit is better than that of the group; $H \cdot X^0 > X^{oe}$ when $RE > 1$, which means the performance of the production unit is not better than that of the group; $H \cdot X^0 = X^{oe}$ when $RE = 1$ (although it's very rare), which means the performance of the production unit is the same as that of the group.

Finally, from Eq. (6), Eq. (7) and Eq. (8), we can get

$$H = RE \cdot AAE \cdot ATE \tag{9}$$

2.2 Input-oriented DEA method

In this paper, we use the three strata of industry of 31 provincial administrative regions as the three outputs, total investment in fixed assets and labors as the two inputs. Let (x^{it}, y^{it}) be the input/output vector of the *i*th region in year *t*, where $i \in \{1, 2, \dots, 31\}, t \in \{2003, 2004, \dots, 2014\}$. Thus, we have

Structural efficiency: $H^t = min\, \theta$

$$\min_{\lambda \geq 0} \theta : \lambda X \leq \theta X, \lambda Y \geq Y \tag{10}$$

Technical efficiency: $te_i^t = min\, \theta_i$

$$\min_{\lambda_i \geq 0} \theta_i : \sum \lambda_i x_i \leq \theta_i x_i, \sum \lambda_i y_i \geq y_i, \sum y_i = 1 \tag{11}$$

Invested efficiency: $oe_i^t = min\, \theta_i$

$$\min_{\lambda_i \geq 0} \theta_i x_i : \sum \lambda_i x_i \leq \theta_i x_i, \sum \lambda_i y_i \geq y_i \tag{12}$$

Then, we can get the shadow invest $SI^0 = p \cdot X^0$, the technical efficient shadow invest $SI^{te} = p \cdot X^{te}$, and the both technical efficient and allocative efficient shadow invest $SI^{oe} = p \cdot X^{oe}$.

Finally, we can get $ATE = SI^{te}/SI^{0}, AAE = SI^{oe}/SI^{te}$, and $RE = H/ATE/AAE$, just like Eq. (6), Eq. (7) and Eq. (8).

3 Data and results analysis

3.1 Data source

All data used in this paper come from National Bureau of Statistics of China[6], Annual by Province from 2003 to 2014.

The outputs: Value-added of the Primary Industry; Value-added of the Secondary Industry; Value-added of the Tertiary Industry

The inputs: Total Investment in Fixed Assets in the Whole Country; Working-age Population

3.2 Calculation results and analysis

The calculated group efficiency and its components are shown in Table 1.

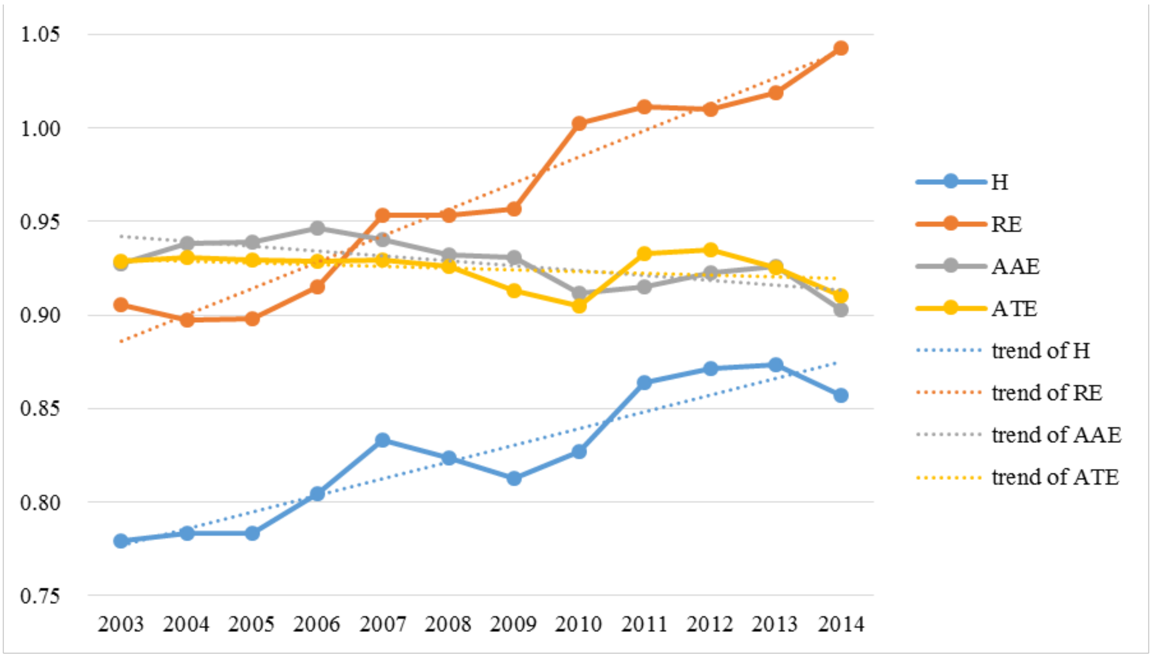
Table 1 – The structural efficiency of Chinese regional economy from 2003 to 2014

Year	2003	2004	2005	2006	2007	2008
Structural efficiency (H)	0.77952	0.78347	0.78332	0.80454	0.83308	0.82334
Re-allocative efficiency (RE)	0.90522	0.89723	0.89817	0.91537	0.95311	0.95344
Aggregate allocative efficiency (AAE)	0.92743	0.93807	0.93862	0.94656	0.94027	0.93226
Aggregate technical efficiency (ATE)	0.92853	0.93085	0.92916	0.92855	0.92959	0.92630
Year	2009	2010	2011	2012	2013	2014
Structural efficiency (H)	0.81278	0.82693	0.86362	0.87115	0.87317	0.85694
Re-allocative efficiency (RE)	0.95683	1.00232	1.01153	1.01013	1.01896	1.04278
Aggregate allocative efficiency (AAE)	0.93061	0.91158	0.91515	0.92256	0.92577	0.90269
Aggregate technical efficiency (ATE)	0.91280	0.90504	0.93294	0.93480	0.92563	0.91038

The trends of group efficiency and its components are shown in Diag. 1.

From Diag. 1, we can find that during the 12 years, the overall structural efficiency (H) is on the rise. However, both the aggregate technical efficiency (ATE) and the aggregate allocative efficiency (AAE) slightly decline. Here we take two years data (2003 and 2014) for discussion. In 2003, H is 0.77952, meaning that all inputs can be decreased by about 22.05% if all inefficiencies are eliminated; in 2014, H becomes 0.85694, meaning that all inputs can be decreased by about 14.31% if all inefficiencies are eliminated. Therefore, China's overall economic structure has been improved. However, the aggregate allocative efficiency (AAE) has a slight decrease for these two years (from 0.92743 to 0.90269), so has the aggregate technical efficiency (ATE) (from 0.92853 to 0.91038), which indicates that provincial administrative regions have lower efficiencies in resource allocation.

Also, the re-allocative efficiencies (RE) in these 12 years have an upward trend. Moreover, the re-allocative efficiencies are lower than one in 2003-2009, but higher than one in 2010-2014. By the explanation of Eq. (8), we can summarize that the economic structure of provincial administrative regions is getting worse.



Diag. 1 – The trends of structural efficiency of Chinese regional economy from 2003 to 2014

4 Conclusion

In this paper, we try to build an input-oriented DEA model with shadow price to calculate the structural efficiencies of Chinese regional economy from 2003 to 2014, and then discuss the trend of China's overall economic structure and the economic structure of provincial administrative regions in these years. Finally, we obtain that in 2003-2014, China's overall economic structure has been improved, but the economic structure of provincial administrative regions is getting worse. In other words, the overall economic structure of China develops well, but the provincial regions have problems in resource allocation, and the productivities need to be improved in each region.

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