An application of DEA model to measure the efficiency of ecological agricultural informatization in Heilong Jiang Province.

Liu, X.; Zhang, Z.

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Abstract

This paper presents a case study in DEA methodology which was applied to agricultural informatization system and measured its efficiency in Heilong Jiang ecological agriculture. Agricultural economic data of 1980-2012 time period in Heilong Jiang province were used and the results showed that the correlation of agricultural informatization and agricultural economic development is very strong ($R^2 =0.998$). Mean value of pure technical efficiency (PTE) and technical efficiency (TE) are 0.971 and 0.876, respectively. In addition, as a big agriculture province, it has not built up a diversified agricultural information service system and its information resources are scattered which are lack of information resources integration, and the agricultural sector that belongs to different authorities which brings great difficulties to agricultural information resource integration.

Keywords: DEA model. Agricultural informatization. Efficiency. Agricultural economic development.

1. Introduction

Productivity in its most elemental definition is a ratio of outputs to inputs (COOPER, SEIFORD E TONE: 2006), with a more productive unit achieving higher outputs for a given set of inputs. The efficiency of a production unit, on the other hand, is a comparison between observed and optimal values of its output/input combinations (ZHU: 2009). A production unit is more efficient the closer it is to the frontier for its technology. Hence, efficiency and productivity are indicators of how the producers are making use of different inputs to obtain outputs. This assessment is prepared, by implementing the DEA methodology for the agricultural economic data of 1980-2012 time period in Heilong Jiang Province.
Data envelopment analysis (DEA), is a non-parametric productivity analysis, has become an accepted approach for assessing efficiency in a wide range of fields (RESTUCCIA, YANG E ZHU: 2008). There are a number of reasons why DEA is used for numerous applications. First, it does not require any under-lying assumptions for inputs and outputs. Second, it allows managers to consider simultaneously multiple inputs and multiple outputs of decision-making units (DMU). Third, it provides managers with a procedure to differentiate between efficient and inefficient DMUs. Fourth, it pinpoints the sources and the amount of deficiency for each of the inefficient DMUs. Finally, it can be used to detect specific inefficiencies that may not be detectable through other techniques such as linear regression or ratio analyses (LIANG ET AL.: 2008; WU ET AL.: 2009; WU ET AL.: 2008).

This article takes the data envelope analysis (DEA) theory as a foundation, discusses the agricultural informatization system quantitative analysis frame, constructs the agricultural informatization system to put into production the efficiency rating indicator system, and the performance data envelope analysis method put into production the efficiency to the Heilong Jiang Province agriculture informationization system to conduct the empirical study.

2. Efficiency Measurement and Analysis of Heilong Jiang Province Agriculture Informationization System

2.1. Sample and the original data acquisition

Based on the existing data and the characteristics of the Heilong Jiang agricultural informationization, numbers of agricultural information websites around the city, the fixed telephones, ratios of broadband into the village, and agricultural labors in the cultivated land area, agricultural machineries, per capita net income of rural residents, agricultural production value as output index were collected from the yearbook of Heilong Jiang statistical in 2013.

Some of the data from the yearbook cannot be directly used to calculate the model, they must be used after being processed, so some artificial statistical measurement error can be avoided.

2.2. Data analysis

The principal component analysis and the factor analysis method were used to check the data qualitatively and quantitatively, the correlation analysis were used to identify the main factors which influence the rural economic development in Heilong Jiang province informatization, and then C2R model of DEA method is defined as the typical county of...
Heilong Jiang province (city) agriculture informationization system efficiency of quantitative research. C2R model consensus as follows.

\[
\begin{align*}
\max h_{j0} &= \frac{\sum_{i=1}^{s} u_i y_{i0}}{\sum_{i=1}^{m} v_i x_{i0}} \\
\sum_{i=1}^{s} u_i y_{ij} &= \frac{1}{v_i x_{ij}} \leq 1, j = 1, 2, \ldots, u \tag{1}
\end{align*}
\]

\(u \geq 0, v \geq 0\)

Charnes Cooper’s Change Theory (WU, ZHOU E LIANG; 2010) and dual planning and slack variable is introduced into the fractional programming that can be transformed to linear programming problem, as shown in equation (2).

\[
\begin{align*}
\min \theta & \\
\text{s.t.} \sum_{j=1}^{m} \lambda_j x_j + s^+ &= \theta x_0 \\
\sum_{j=1}^{m} \lambda_j y_j - s^- &= \theta y_0 \\
\lambda_j &\geq 0, j = 1, 2, \ldots, n \\
\theta &\text{withunrestrain}, s^+ \geq 0, s^- \leq 0 \tag{2}
\end{align*}
\]

when \(\theta^* = 1\), and \(s^+ = 0, s^- = 0\), \(j_0\) DEA is valid. Decision making unit of economic activity is the scale of effective technology, when \(\theta^* = 1\), one input or output is more than \(r\) than zero, the decision making units \(j_0\) is less efficient for DEA, decision-making unit of economic activity is not the best of technical efficiency and scale, when \(\theta < 1\), the decision making units \(j_0\) is not valid for DEA model, economic activity is neither technical efficiency best nor the best of scale.
2.3. The efficiency evaluation and the analysis of the results

2.3.1. Factor analysis for Heilong Jiang province agricultural economy development

The agricultural production condition indicators include national agricultural investment (one hundred million yuan), labor (ten thousand), farmers investment (one hundred million yuan), total power of agricultural machinery (kw), irrigation area (thousand hectares), applying quantity of chemical fertilizer (ten thousand tons), rural power consumption (kw); Agricultural product yield and breeding numbers indexes include newborn piggy and other animals: food production (ten thousand tons), oil yield (ten thousand tons), sugar yield (ten thousand tons), fruit yield (ten thousand tons), pigs, beef and mutton (ten thousand tons), the output of aquatic products (ten thousand tons); Animal husbandry fishery output indicators include: agricultural (one hundred million yuan), forestry (one hundred million yuan), animal husbandry (one hundred million yuan), fisheries (one hundred million yuan).

Table 1: ANOVA

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<th>Eigenvalue</th>
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<th>Accumulation</th>
<th>Variance</th>
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<tr>
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</tbody>
</table>

Extraction method: principal component analysis

Significance level of Bartlett’s spherical inspection is 0.000, indicating that these samples are suitable for factor analyses, above 17 indicators can be proposed three components through the principal component analysis whose contribution rate amounted to 93.39%.
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Table 2: Matrix of each elements

<table>
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<tr>
<th>Elements</th>
<th>1</th>
<th>2</th>
<th>3</th>
</tr>
</thead>
<tbody>
<tr>
<td>National agricultural investment (one hundred million yuan)</td>
<td>- .852</td>
<td>- .074</td>
<td>.518</td>
</tr>
<tr>
<td>Labor (ten thousand)</td>
<td>.679</td>
<td>.576</td>
<td>.455</td>
</tr>
<tr>
<td>Farmers investment (one hundred million yuan)</td>
<td>.963</td>
<td>.106</td>
<td>- .248</td>
</tr>
<tr>
<td>Total power of agricultural machinery (kw)</td>
<td>.997</td>
<td>- .036</td>
<td>.072</td>
</tr>
<tr>
<td>Irrigation area (thousand hectares)</td>
<td>.996</td>
<td>.046</td>
<td>.075</td>
</tr>
<tr>
<td>Applying quantity of chemical fertilizer (ten thousand tons)</td>
<td>.991</td>
<td>.099</td>
<td>.094</td>
</tr>
<tr>
<td>Rural power consumption (kw) food production (ten thousand tons)</td>
<td>.939</td>
<td>- .154</td>
<td>- .306</td>
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<tr>
<td>Oil yield (ten thousand tons)</td>
<td>- .974</td>
<td>- .064</td>
<td>.215</td>
</tr>
<tr>
<td>Sugar yield (ten thousand tons)</td>
<td>.945</td>
<td>.315</td>
<td>- .083</td>
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<tr>
<td>Fruit yield (ten thousand tons)</td>
<td>- .136</td>
<td>.972</td>
<td>.190</td>
</tr>
<tr>
<td>Yields of pigs, beef and mutton (ten thousand tons)</td>
<td>.960</td>
<td>- .106</td>
<td>.259</td>
</tr>
<tr>
<td>Output of aquatic products (ten thousand tons)</td>
<td>.534</td>
<td>- .663</td>
<td>.525</td>
</tr>
<tr>
<td>Agricultural (one hundred million yuan)</td>
<td>.988</td>
<td>- .153</td>
<td>- .025</td>
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<tr>
<td>Forestry (one hundred million yuan)</td>
<td>.986</td>
<td>- .157</td>
<td>.057</td>
</tr>
<tr>
<td>Animal husbandry (one hundred million yuan)</td>
<td>.998</td>
<td>- .022</td>
<td>- .059</td>
</tr>
<tr>
<td>Fisheries (one hundred million yuan)</td>
<td>.961</td>
<td>- .218</td>
<td>.172</td>
</tr>
</tbody>
</table>

extraction method: principal component analysis
a. extract three elements
2.3.2. The relativity analysis of agricultural informationization and agricultural economic development

Through correlation analysis, the correlation of agricultural informationization and agricultural economic development is very strong, the Person correlation coefficient reached 0.952 from the linear regression test using SPSS (Table 3).

**Table 3: Correlation analysis between agricultural informatization and agricultural economic development**

<table>
<thead>
<tr>
<th></th>
<th>Output</th>
<th>Information technology</th>
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<tr>
<td>Person Correlation</td>
<td>1</td>
<td>0.952 (**</td>
</tr>
<tr>
<td>Sig.(2-tailed)</td>
<td>.</td>
<td>0.001</td>
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<tr>
<td>Sum of Squares and Cross-products</td>
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<td>178049.613</td>
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<td>Covariance</td>
<td>48673.58</td>
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<td>N</td>
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</table>

**Correlation is significant at the 0.01 level (2-tailed).**

The correlation coefficient $R = 0.999$, $R^2 = 0.998$, close to 1, so the fitting degree is higher (Table 4). The above analysis shows that each input are very important elements of total output. Although there are many indicators that affect the agricultural output such as weather, policy, the selection of model variables can only choose to have a full understanding of agricultural production, data acquisition and statistical problems can guarantee the selection of variables data is easy to get, which is not only ensure the precision of calculation, but also guarantee the simplicity of computation and conducive of the model.
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Table 4: Model Summary

<table>
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<tr>
<th>Model</th>
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<th>Adjusted R</th>
<th>Std. error of the estimate</th>
<th>Change statistics</th>
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<td>0.987</td>
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2.3.3. Based on data envelopment C2R model analysis, the analysis of Heilong Jiang province agricultural informatization efficiency measure

Use of Deap2.1 software in 13 cities of Heilong Jiang province to evaluate the efficiency of agricultural informationization level, and the efficiency value are shown in table 5. Averages 0.876 comprehensive technical efficiency (TE) in Heilong Jiang province. Mean value of pure technical efficiency (PTE) is 0.971, especially in Harbin, Qiqihar, Mudanjiang, Ji Xi, Qitai He two efficiency values are close to 1, in the technical efficiency frontier, that eight other cities as there are different levels of agricultural information technology efficiency improvement space. Second, agricultural information service system has not yet set up diversified in Heilong Jiang province, some cities and counties have not really realize the combination of agricultural information service and technology service which cannot meet the farmers' real needs and also affect the agricultural information resources utilization. In addition, as a big agriculture province, Heilong Jiang province agriculture information resources are scattered, lack of information resources integration, and the agricultural sector that belong to different authorities which bring great difficulty to agricultural information resource integration.
Table 5: Technical efficiency (TE), pure technical efficiency (PTE) of each prefecture agricultural informatization in Heilongjiang province

<table>
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<tr>
<th>Cities</th>
<th>TE</th>
<th>PTE</th>
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<td>Harbin</td>
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<td>1.000</td>
</tr>
<tr>
<td>Qiqi Haer</td>
<td>1.000</td>
<td>1.000</td>
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<tr>
<td>Ji Xi</td>
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<td>1.000</td>
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<td>He Gang</td>
<td>0.763</td>
<td>0.937</td>
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<td>Shuangya Shan</td>
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<td>0.926</td>
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<td>Da Qing</td>
<td>0.851</td>
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<tr>
<td>Yi Chun</td>
<td>0.918</td>
<td>0.957</td>
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<td>Jiamu Si</td>
<td>0.422</td>
<td>0.893</td>
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<tr>
<td>Qitai He</td>
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<td>Mudan Jiang</td>
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<td>Hei He</td>
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<td>1.000</td>
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<td>Sui Hua</td>
<td>0.771</td>
<td>0.911</td>
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<td>Daxing’an Mountain</td>
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<td>1.000</td>
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<tr>
<td>Average</td>
<td>0.876</td>
<td>0.971</td>
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3. Conclusions

Agricultural growth mainly comes from two aspects: one is the increase of the resources, the other is the productivity. In resources, especially under the condition of limited land resources, the sustainable growth of agricultural production must rely on the accumulation and productivity increase. This shows the importance of agricultural production efficiency. Agricultural production of natural resources strongly dependences on environment, inefficient agricultural production is the necessary outcome of a more resource input. Excessive agricultural inputs can lead to problems such as environmental pollution. Therefore, clear target is an urgent need to coordinate economic development, the contradiction between resource utilization and ecological environment protection. Investment in agriculture informatization system is very important to realize the sustainable development of economic, social and environmental measures, can effectively adjust between land, people and natural harmonious relations. The study introduced the Heilong Jiang agricultural informatization construct target principle, and through the empirical data using SPSS statistical software analyzes the main factors affecting the Heilong Jiang province agricultural informatization, combined with the C2R model in DEA model to construct the efficiency of...
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the Heilong Jiang agricultural informationization measure model, and sums up the different municipal informatization development degree and improve the way in Heilong Jiang province.

4. Acknowledgement

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5. References


