An Empirical Study on The Competitiveness Assessment of China's Hi-Tech Companies

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Abstract

To scientifically assess the Hi-tech companies' competitive strength is the premise and foundation of effectively improving their competitiveness. This paper uses the methods of DEA (Data Envelopment Analysis) and selects 14 industries' data from the state taxation investigation jointly carried out by the Ministry of Finance and the State Taxation Administration in 2007 as samples. It appraises the Hi-tech companies' competitiveness from three aspects: asset deployment status, profit-making capability and innovation ability, and in this way, gets rid of the assessment's non-objectivity and non-fairness induced by the inadequate objective requisites. This paper improves the rationality and accuracy of the Hi-tech companies' competitiveness assessment from the aspects both of the model and the index.

Keywords: Hi-Tech Companies, Competitiveness, Assessment

1. Introduction

In 21st century, the economy globalization and scientific development bring some new characteristics of high-tech companies' competitiveness. The characteristics are highlighted in the way that companies' competitiveness is transforming from the cost-quality management of industry economy era to the innovation efficiency management of knowledge economy era. These claim that the high-tech companies are geared to the needs of the market, stress technological innovations, borrow and assimilate the advanced technology internally and externally, carry out derivative R&D, realize the commercialization and industrialization of innovation fruits, implement the art innovation and procedures optimizing, construct a more effective, more efficient and less consumable system, increase the products' additional value. In this way, they are able to increase their market share, strengthen their competitive ability, and make more economy profit. It is thus evident that nowadays high-tech companies gain their competitive advantages depending on technology innovation and efficiency improvement. Through the competitiveness evaluation, the high-tech companies can understand their own survival status, analyze the main factors that influence their technology innovation and efficiency improvement, moreover, optimize their management systems, increase the efficiency of resource deployment and utilization, implement more effective strategies of technology innovation and efficiency improvement, strengthen competitive advantages, and gain more economic and social benefits.

2. Methods

Data Envelopment Analysis, DEA, raised by A. Charnes, W. W. Cooper and E. Rhoden, is an effectiveness comprehensive assessment method with multi-index inputs and multi-index products, which is mainly used to assess the relative effectiveness of similar companies, therefore, it is also a method of appraising the relative efficiency of decision-making unit with multi-input and multi-product. Its basic idea is to spread the single-input and single-output engineering efficiency concept to the effectiveness assessment of decision-making unit with multi-input and multi-output, to apply the mathematics planning to assess the relative effectiveness of multi-input and multi-output "unit". It decides whether the DMU is effective by the means of its observation data, essentially, it
decides whether the DMU is located in the leading edge of production possible anthology. Therefore, DEA is in fact a non-parameter evaluation method.[1] The advantages of DEA lie in the following: ① Each weighing coefficient is decided by the model automatically and optimally, in this way, subjectivities are avoided as much as possible. ② Even if one input is linked with one or more outputs, and there is certain relationship between inputs and outputs, the DEA method will unnecessarily confirm the dominant formula of this relationship. ③ DEA holds its advantage when dealing with issues of the production function and scale economy.[2] However, the traditional DEA method faces some disadvantages. Since it regards each decision-making unit as a “black box”, more emphasis is placed on the relative efficiency of the transforming between initial inputs and final outputs, and less emphasis is placed on the influence of the internal process on its relative effectiveness. Therefore, network DEA method is extended from the traditional DEA, it decomposes the complex production system (DMU) into several production phrases (sub-units), and after analyzing each sub-DMU, it decides whether the DMU is located in the effective leading edge of production possible anthology.

At present, the DEA method is increasingly applied in the study of high-tech companies' competitiveness, however, some issues are still in the need of consideration:

Most of the current studies are still lingering at the traditional DEA concept. However, the high-tech company production is a typical two-phase process: firstly, human, material and financial resources are put in; secondly, through R&D, high-tech products are put out so as to make profits. Any evaluation study that only regards the production process as a whole “black box” without reasonably factorizing the production process or analyzing the internal structure and R&D will not be scientific or objective.

The present studies prefer to choose profits, revenues, etc. as output index, which makes studies outcomes too simple. It seems neither scientific nor reasonable. Firstly, high-tech companies have features of high level input, high level risk and high level return. There is a dilemma between the risk and return. The above indexes do not include the risk factor, they can only reflect the quantity differences among the high-tech companies' outputs, but can not reflect the level of their competitiveness. Secondly, the present indexes do not mirror high-tech companies' innovation ability. Innovation ability is an important symbol reflecting high-tech companies maturate, meanwhile, the maturate is an important reference expressing high-tech companies' competitiveness. Therefore, it is necessary to find out the output indexes reflecting high-tech companies' innovation capacity and to embody the role of innovation capacity in their competitiveness.[3]

This paper will make a deep discussion and supplementation aiming at the above problems. In the first phase of high-tech companies' production, the mid-outputs (implementation indexes) are derived from the overall inputs. In the second phase, the overall outputs are derived from the mid-outputs. When choosing the output indexes, this paper puts the risk-value index and innovation-ability index into the evaluation index system.

3. Evaluation model

Based on the new assumption, this paper establishes a relative effectiveness production leading edge: firstly, based on the second-phase efficiency evaluation, a DEA model based on the inputs is established, and the minimum value of the second-phase mid-output in the assumption of the constant second-phase outputs (DEA overall outputs) is derived. Then, another DEA model is established to derive the minimum value of first-phase inputs, in this way, a certain number of (number of i) ideal production systems are built up. Afterwards, the “effective surface” is decided, so the DMU efficiency value is equal to their real production ability divided by the production ability of i number of ideal production systems.[4]

We assume that the scale return is stable, there are i number of DMU, m number of input indexes, h number of mid-product indexes, n number of output indexes.)

The input vector : $X_j = (x_{1j}, x_{2j}, \ldots, x_{mj})^T, j = 1, \ldots, i$

The mid-product vector: $W_j = (i_{1j}, i_{2j}, \ldots, i_{hj})^T, j = 1, \ldots, i$

The output vector: $Y_j = (y_{1j}, y_{2j}, \ldots, y_{nj})^T, j = 1, \ldots, i$

Step 1, the model evaluating the second-phase efficiency is as following:
\[
\begin{align*}
\min & \quad \theta_2 \\
\text{s.t.} & \quad \sum_{j=1}^{\infty} W_j \lambda_{2j} + n_2^{-} = \theta_2 W_0 \\
\sum_{j=1}^{\infty} Y_j \lambda_{2j} & = Y_0 \\
\lambda_{2j} & \geq 0, j = 1, 2, \ldots, i \\
n_2^{-} & = (n_1^{-}, n_2^{-}, \ldots, n_h^{-}) \\
n_2^{-} & \geq 0 
\end{align*}
\]

( I )

Step 2, the model evaluating the first-phase efficiency is as following:

\[
\begin{align*}
\min & \quad \theta_1 \\
\text{s.t.} & \quad \sum_{j=1}^{i} X_j \lambda_{1j} + n^1_1 = \theta_1 X_0 \\
\sum_{j=1}^{i} W_j \lambda_{1j} & = W'_0 \\
\lambda_{1j} & \geq 0, j = 1, 2, \ldots, i \\
n^1_1 & = (n^1_1, n^1_2, \ldots, n^1_m) \\
n^1_1 & \geq 0 \\
W' & = \theta_1 W - n^2_1 
\end{align*}
\]

( II )

Step 3, the optimal inputs \( X' = \theta_2 X - n^1_1 \) are derived from (I) and (II), i number of optimal production systems are identified, and the “effective production leading edge” is built up. Further, each DMU is compared with i number optimal DMU, and its relative efficiency is obtained. Therefore, the model evaluating the whole system relative efficiency is as following:
4. Empirical study

4.1 Choosing Samples

The samples in this paper are chosen from the 14 industries data of the joint taxation investigation taken by the National Ministry of Finance and State Taxation Administration in 2007. 1. Industry of petroleum processing, coking and nuclear fuel processing (abbr. industry of petroleum processing) 2. Industry of chemical material and chemical products (abbr. industry of chemical manufacturing) 3. Industry of pharmacy 4. Industry of chemical fabric manufacturing 5. Industry of rubber products 6. Industry of plastic products 7. Industry of non-metal mine products 8. Industry of nonferrous metals smelting and rolling processing(Abr. industry of nonferrous metals processing) 9. Industry of metal products 10. Industry of common equipment manufacturing 11. Industry of communications and transportation equipment manufacturing, (abbr. industry of transportation equipment manufacturing) 12. Industry of electric machinery and appliance manufacturing (abbr. industry of electric equipment manufacturing) 13. Industry of signal communication equipment, computer and other electric equipment manufacturing (abbr. industry of electric equipment manufacturing) 14. Industry of apparatus and instrument for measuring and office machinery manufacturing(abr. industry of apparatus and instrument for measuring manufacturing). Ten high-tech companies of each industry are chosen as samples, all of which are granted by the relevant state or provincial administration. In view of the secret nature of companies' information, this paper uses the relevant industry name instead of each company name, and regards each industry as one decision-making unit, DMU.

4.2 Choosing Indexes

Based on some initial indexes such as staff number, production and operation expenses, product's varieties, fixed assets net value, core technology capital, this paper calculates the following indexes as the first-phase input indexes, namely, the whose process input indexes: per capital production and operation expenses, per capital fixed assets net value, per capital core technology asset and average production and operation expenses. Indexes of per capital R&D input and per capital R&D output are taken as practicing indexes of high-tech companies competitiveness, namely, the first-phase outputs; Indexes of the weighted risk capital ratio, the average return ratio of total capital, the return ratio of weighted risk capital, productive value ratio of innovation products are taken as the second-phase

\[
\begin{align*}
\min \theta_s \\
\text{s.t.} \sum_{j=1}^{i} X' \lambda_{3j} + n^{3-} &= \theta_s X_0 \\
\sum_{j=1}^{i} Y \lambda_{3j} - n^{3+} &= Y_0 \\
\lambda_{3j} &\geq 0, j = 1, 2, \ldots, i \\
n^{3+} &= (n_1^{3+}, n_2^{3+}, \ldots, n_n^{3+}) \\
n^{3-} &= (n_1^{3-}, n_2^{3-}, \ldots, n_m^{3-}) \\
n^{3+} &\geq 0 \\
n^{3-} &\geq 0 \\
X' &= \theta_s X - n^{3-}
\end{align*}
\]
output indexes, namely, the overall production system output indexes. Accordingly, the competitiveness of high-tech companies is evaluated from three aspects: ① the asset deployment status; ② the profit-making capacity; ③ the innovation capacity.[5]

The index of weighted risk asset ratio is a reasonable index considering the risk factor, it reflects the quality of high-tech companies' assets. The index of average return ratio of total asset wholly describes high-tech companies' profit-making capacity by the application of asset. It can quickly test the relationship between high-tech companies' inputs and outputs, and herewith understand whether the interaction between the total profit and total asset is reasonable. The index of weighted risk asset return ratio evaluates high-tech companies' profit-making capability under certain risk-control situation, measuring the output level of unit economic capital. It combines the risk with the return, and works as an average return ratio of total assets including the risk value. The index of innovation product's output value ratio evaluates high-tech companies' innovation ability and maturate by the means of ratio of innovation product revenue to the total revenue. Accordingly, high-tech companies' competitiveness is evaluated.[6]

4.3 Collecting Data

This paper chooses 14 industries' data from the joint taxation investigation taken by the National Ministry of Finance and State Taxation Administration in 2007, and collects or calculates data of 10 sorts of indexes, including ① per capital production and operation expenses, ② per capital fixed assets net value, ③ per capital core technology capital, ④ average production and operation expenses, ⑤ per capital R&D input, ⑥ per capital R&D output, ⑦ the weighted risk asset ratio, ⑧ the average return ratio of total asset, ⑨ the earnings ratio of weighted risk asset, ⑩ productive value ratio of innovation products.[7] All of the data are from “the information table of the state taxation investigation in 2007” (Table 1).
## Table 1  Index of Selected 14 Industries' High-tech Companies

<table>
<thead>
<tr>
<th>Industry</th>
<th>Input index (yuan)</th>
<th>Practicing index (yuan)</th>
<th>Output index (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. petroleum processing</td>
<td>143938</td>
<td>202468</td>
<td>51.60</td>
</tr>
<tr>
<td>2. chemical manufacturing</td>
<td>497925</td>
<td>146970</td>
<td>62.20</td>
</tr>
<tr>
<td>3. pharmacy manufacturing</td>
<td>498308</td>
<td>102911</td>
<td>43876</td>
</tr>
<tr>
<td>4. chemical fabric manufacturing</td>
<td>249564</td>
<td>135440</td>
<td>12001</td>
</tr>
<tr>
<td>5. rubber products</td>
<td>237492</td>
<td>149013</td>
<td>21798</td>
</tr>
<tr>
<td>6. plastic products</td>
<td>268890</td>
<td>101838</td>
<td>37749</td>
</tr>
<tr>
<td>7. non-metal mine products</td>
<td>384284</td>
<td>229466</td>
<td>7911632</td>
</tr>
<tr>
<td>8. nonferrous metals processing</td>
<td>204281</td>
<td>112120</td>
<td>4264436</td>
</tr>
<tr>
<td>9. metal products</td>
<td>281526</td>
<td>116798</td>
<td>3879007</td>
</tr>
<tr>
<td>10. common equipment manufacturing</td>
<td>186158</td>
<td>754072</td>
<td>38229</td>
</tr>
<tr>
<td>11. transportation equipment manufacturing</td>
<td>207515</td>
<td>164973</td>
<td>44875</td>
</tr>
<tr>
<td>12. electric equipment manufacturing</td>
<td>105894</td>
<td>123906</td>
<td>2917159</td>
</tr>
<tr>
<td>13. electric equipment manufacturing</td>
<td>529628</td>
<td>276532</td>
<td>1011934</td>
</tr>
<tr>
<td>14. apparatus and instrument manufacturing</td>
<td>308090</td>
<td>103064</td>
<td>17733</td>
</tr>
</tbody>
</table>

Footnote: The above ①-⑩ indicate separately: ① per capital production and operation expenses, ② per capital fixed assets net value, ③ per capital core technology capital, ④ average production and operation expenses, ⑤ per capital R&D input, ⑥ per capital R&D output, ⑦ the weighted risk asset ratio, ⑧ the average return ratio of total asset, ⑨ the earnings ratio of weighted risk asset, ⑩ productive value ratio of innovation products.

### 4.4 DEA Evaluation

We should realize that before putting the above 14 industries' indexes into the DEA model, we have to normalize them to meet the data monotonous requirement of DEA model.[8] The results of DEA assessment are shown in Table 2.
### Table 2  DEA Evaluation of Selected 14 Industries' High-tech Companies

<table>
<thead>
<tr>
<th>DMU</th>
<th>Technology efficiency</th>
<th>Pure technology efficiency</th>
<th>Scale efficiency</th>
<th>$\sum \lambda_j$</th>
<th>Scale return evaluation</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. industry of petroleum processing</td>
<td>0.93</td>
<td>0.93</td>
<td>1</td>
<td>1</td>
<td>stable</td>
</tr>
<tr>
<td>2. industry of chemical manufacturing</td>
<td>0.20</td>
<td>0.36</td>
<td>0.51</td>
<td>0.45</td>
<td>decreasing</td>
</tr>
<tr>
<td>3. industry of pharmacy manufacturing</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>stable</td>
</tr>
<tr>
<td>4. industry of chemical fabric manufacturing</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>stable</td>
</tr>
<tr>
<td>5. industry of rubber products</td>
<td>0.81</td>
<td>1</td>
<td>0.81</td>
<td>1.39</td>
<td>decreasing</td>
</tr>
<tr>
<td>6. industry of plastic products</td>
<td>0.56</td>
<td>0.67</td>
<td>0.87</td>
<td>0.55</td>
<td>increasing</td>
</tr>
<tr>
<td>7. industry of non-metal mine products</td>
<td>0.67</td>
<td>1</td>
<td>0.67</td>
<td>1.45</td>
<td>decreasing</td>
</tr>
<tr>
<td>8. industry of nonferrous metals processing</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>stable</td>
</tr>
<tr>
<td>9. industry of metal products</td>
<td>0.93</td>
<td>0.93</td>
<td>1</td>
<td>1</td>
<td>stable</td>
</tr>
<tr>
<td>10. industry of common equipment manufacturing</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>11. industry of transportation equipment manufacturing</td>
<td>0.99</td>
<td>1</td>
<td>0.99</td>
<td>1.45</td>
<td>decreasing</td>
</tr>
<tr>
<td>12. industry of electric equipment manufacturing</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>13. industry of electric equipment manufacturing</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>14. industry of apparatus and instrument for measuring manufacturing</td>
<td>0.24</td>
<td>0.32</td>
<td>0.79</td>
<td>0.68</td>
<td>increasing</td>
</tr>
</tbody>
</table>

5. **Analysis result**

5.1 **As far as the technology efficiency is concerned, 6 industries' high-tech companies are DEA effective.**

They are separately industry of pharmacy manufacturing, industry of chemical fabric manufacturing, industry of nonferrous metals processing, industry of common equipment manufacturing, industry of electric equipment manufacturing, industry of apparatus and instrument for measuring manufacturing. There exist three kinds of situations among the left DEA ineffective industries: (1) The pure technology is efficient, while the inefficient scale resulting in the technology inefficiency, such as industry of non-metal mine products, industry of rubber products, industry of transportation equipment manufacturing. (2) The scale is efficient, while the inefficient pure technology resulting in the technology inefficiency, such as industry of petroleum processing, industry of metal products. (3) The pure technology and scale are inefficient simultaneously, resulting in the technology inefficiency, such as industry of chemical manufacturing, industry of plastic products, industry of electric equipment manufacturing. Totally, operation efficiencies of China's 14 industries' high-technology companies are at a fairly high level, and there are no apparent differences among them, except for industry of chemical manufacturing and industry of electric equipment manufacturing.
5.2 As far as the pure technology efficiency is concerned, 9 industries’ high-tech companies are pure-technology efficient.

They are separately industry of pharmacy manufacturing, industry of chemical fabric manufacturing, industry of rubber products, industry of non-metal mine products, industry of nonferrous metals processing, industry of common equipment manufacturing, industry of transportation equipment manufacturing, industry of electric equipment manufacturing, industry of apparatus and instrument for measuring manufacturing. This indicates that nowadays, most of China's high-tech companies are able to fully make use of the available technology, and are trying to obtain the maximum output with fixed inputs. Comparatively, pure technology efficiencies of some industries' high-tech companies such as industry of chemical manufacturing, industry of plastic products, industry of electric equipment manufacturing, industry of petroleum processing, industry of metal products still need to be improved, since these companies’ input-output ratios are fairly low.

5.3 As far as the scale efficiency is concerned, scale return of 8 industries' high-tech companies are stable.

They are separately industry of petroleum processing, industry of pharmacy, industry of chemical fabric manufacturing, industry of nonferrous metals processing, industry of metal products, industry of common equipment manufacturing, industry of electric equipment manufacturing, industry of apparatus and instrument for measuring manufacturing. Among the left scale-inefficient industries, there exist two situations: (1) The scale return is decreasing, such as industry of non-metal mine products, industry of rubber products, industry of transportation equipment manufacturing, indicating that these companies are over-scaled and inefficient compared with the technology status, and their scales need to be decreased properly. (2) The scale return is increasing, such as industry of chemical manufacturing, industry of plastic products, industry of electric equipment manufacturing, indicating that these companies' are under-scaled, and their scales need to be increased properly.

6. Conclusion

To scientifically assess the Hi-tech companies’ competitive strength is the premise and foundation of effectively improving their competitiveness.[9] This paper uses the method of DEA and selects 14 industries' data from the state taxation investigation as samples. It appraises the Hi-tech companies' competitiveness from three aspects: asset deployment status, profit-making capability and innovation ability, and in this way, gets rid of the assessment's non-objectivity and non-fairness induced by the inadequate objective requisites. This paper improves the rationality and accuracy of the Hi-tech companies’ competitiveness assessment from the aspects both of the model and the index.

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