

Performance Evaluation of Technique Progress with Data Envelopment Analysis

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Abstract. This article employs the data envelopment analysis to evaluate performances of technique progress. Some representative index stands for technique progress are taken as objects in the research. Comprehensive assessments are made by setting up and output index to find the relatively efficient model in the technique progress. Resource distribution efficiency of the technique progress is analyzed at the same time. A method for optimizing resource distribution and improving the investment is proposed.

Keywords: Date envelopment analysis, Performance evaluation, Technique progress

1. Introduce

With the continuous development of science and technique in our country, technique progress perform more and more impotent function in economical development, and the significance of the technique progress evaluation is coming out. The evolution of technique progress performance is not single target calculation and measurement, it need considerate comprehensive evaluation of many index. With the future study of the measurement, a lot of new evaluation methods continuously flow out, such as BP neural network system.

This article apply DEA (data envelopment analysis) to evaluate the effect of technique progress by the date from 2008 to 2010 < CHINA STATISTICAL YEARBOOK>, 2010<china new technique industry statistical yearbook>, 2010<china 60years statistical compilation>.in order to impel the development of economy, it classify the effect of technique progress and offer some useful information to government.

2. Research Techniques

DEA is a model to evaluate relative efficiencies of DMU (decision-making unit). It has been applied to evaluate performance of business in different professions [1~3] since 1978 (Charnes.ete). In those applications the inputs and outputs are fixed, but during evaluating future performance of business, the inputs and outputs are randomly, and they can be changed with market situation. So it is more difficult to evaluate randomly inputs and outputs. The paper analyzes randomly inputs and outputs; present a multiple criteria random DEA model to solve the problem. There are two sections: section 1 is the building of multiple criteria random DEA model; section 2 is an application of the model investment evaluation [1].

Multiple criteria random DEA model is on the basis of classic DEA of Charnes in 1978. The classic DEA is

$$\min d_0$$

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$$\begin{aligned} \sum_{i=1}^m v_i x_{ij0} &= 1 \\ \sum_{k=1}^s \eta_k y_{kj} - \sum_{i=1}^m v_i x_{ij} + d_j &= 0, j=1, \dots, n \\ \eta_k, v_i, d_j &\geq 0 \end{aligned} \quad (1)$$

where j is the symbol of DMU, $j=1,2,\dots,n$; k is the output, $k=1,2,\dots,s$, i is the input $i=1,2,\dots,m$; y_{kj} quantity the k th output for j th DMU, x_{ij} quantity i th input for j th DMU; η_k weight of k th output, v_i weight of i th input, d_j is the deviation. If and only if $d_0=0$, DMU₀ is relative efficient.

During evaluating the efficiencies of DMU by classic DEA model, how to select the best is difficult when there are a lot of efficient DMU. Xiao-Bai Li [4] give a multiple criteria DEA model, the model add two criteria. It is:

$$\begin{aligned} \min d_0 \\ \text{Min } M \\ \text{Min } \sum_{j=1}^n d_j \end{aligned}$$

$$\begin{aligned} \text{s.t. } \sum_{i=1}^m v_i x_{ij0} &= 1 \\ \sum_{k=1}^s \eta_k y_{kj} - \sum_{i=1}^m v_i x_{ij} + d_j &= 0, j=1, \dots, n \\ M - d_j &\geq 0 \\ \eta_k, v_i, d_j &\geq 0 \end{aligned} \quad (2)$$

In the two models, the inputs and outputs are fixed, that's to say, x_{ij}, y_{kj} are determined. But to future business, x_{ij}, y_{kj} are randomly, so those models can not be used to evaluate business performance with random inputs and outputs. In reality, to evaluate the performance including random inputs and output is very important, such as project evaluation, the inputs and outputs change with market situation. Even the same inputs, the outputs are different in different DMU [2].

3. Example

Two DMU (DMU1, DMU2) that use one input to produce one output are compared. DMU1 use one unit of input to produce two units of output. DMU2 also use one unit input, but its production is subject to random influence. There is 50% chance its output will be 1.5 units, the other 50% of the time it will produce 2.5 units, the expected output of DMU2 is also two units. If the evaluator accepts the expected output as a certainty, both DMU perform equally well. Sometime evaluator may tend to prefer DMU1 to DMU2 to avoid uncertainty, vice verse to risk-seeking evaluator [3].

That is to say, the relative efficiency of DMU relies on the utility of evaluator. Given a random variable z (input or output) and utility function $u(z)$, the certainty equivalent $c_u(\cdot)$ of z can be defined as

$$C_u(z) = u^{-1}(E[u(z)]) \quad (3)$$

where $E(\cdot)$ is the expectation of a random variable, and u^{-1} the inverse function of utility function $u(z)$. In example, if a evaluator holds a utility function $u(z) = z^{3/4}$ for the output, we have output of DMU2 $E(y) = \frac{1}{2}(1.5)^{3/4} + \frac{1}{2}(2.5)^{3/4} = 1.984$, DMU 2 is relatively less efficient. Obviously if z is constant, $C_u(z) = u^{-1}(E[u(z)]) = u^{-1}(u(z)) = z$. When z is variable, the difference between certainty equivalent and expectation a random variable is

$$r_u(z) = c_u(z) - E(z) \quad (4)$$

If $r_u(z) = 0$ a utility function is said to be risk-neutral, risk-seeking if $r_u(z) < 0$. If we extend (4) to multiple DMU, the every certainty equivalent of inputs and outputs is

$$\begin{aligned}
c_u(X, Y) = & (E(x_1) + r_u(x_1), \dots, E(x_j) + r_u(x_j), \\
& \dots, E(x_n) + r_u(x_n)); \\
& E(y_1) + r_u(y_1), \dots, E(y_j) + r_u(y_j), \dots, \\
& E(y_n) + r_u(y_n))
\end{aligned} \tag{5}$$

x_j is the input of j th DMU; y_j is the output of j th DMU.

Because of most risk-averse evaluators often under evaluate inputs, from the paper [5] (see Linguo.Gang and Bruce Sury, 1998) we turn (5) into (6)

$$\begin{aligned}
c_u(X, Y) = & (E(x_1) + r_u(x_1), \dots, E(x_j) + r_u(x_j), \\
& \dots, E(x_n) + r_u(x_n); \\
& E(y_1) + r_u(y_1), \dots, E(y_j) + r_u(y_j) \\
& , \dots, E(y_n) + r_u(y_n))
\end{aligned} \tag{6}$$

Given the certainty equivalent of inputs and outputs of multiple DMU, if there are a lot of inputs and outputs, the paper suppose utility function of inputs and outputs are $u(z) = 1 - \exp^{-2/\theta}$ (where θ is the parameter changed with different evaluators). If z has normally distribution $N(\mu, \sigma^2)$, then

$$\begin{aligned}
u^{-1}(z) &= -\theta \ln(1 - z) \\
u^{-1}(E[u(z)]) &= -\theta \ln(1 - E(1 - e^{-2/\theta})) \\
&= \mu - \sigma^2 / (2\theta)
\end{aligned}$$

when θ is subject to a uniform distribution in a district, we can deduce

$$\begin{aligned}
E(z) &= \mu, r_u(z) = -\sigma^2 / (2\theta), \\
C_u(x_{ij}) &= \mu_{xij} \sigma^2 / (2\theta) \\
r_u(x_{ij}) &= -\sigma_{xij}^2 / (2\theta), E(x_{ij}) = \mu_{xij}
\end{aligned}$$

Then the multiple criteria random DEA model is

$$\min d_0$$

$$\min M$$

$$\min \sum_{j=1}^n d_j$$

$$s.t \sum_{i=1}^m [\mu x_{ij0} + \sigma_{xij0}^2 / (2\theta)] = 1$$

$$\sum_{k=1}^s \eta_k [\mu y_{kj} - \sigma_{yjk}^2 / (2\theta)] - \sum_{i=1}^m v_i [u_{xij} + \sigma_{xkj}^2 / (2\theta)] + d_j = 0$$

$$M - d_j \geq 0$$

$$\eta_k, v_i, d_j \geq 0$$

4. Apply DEA to Our Economy

4.1 Choosing Variable and Decision Unit

The data chose comes from 2008 to 2010 year “China Statistical Yearbook”, 2010 year “China High-tech industries Yearbook”, and “New China 60 years statistical collection”. The input and output index of DEA evaluation model is as follows:

Input index: ①the average annual number of all practitioners of industry enterprises ② the average annual balance of current assets ③ the average annual balance of fixed assets ④scientist and engineer ⑤the outlay for research and examination

Output index: ① industry production value ② the earning of main operation ③ total amount of profit ④ the revenue from new goods sold ⑤the warranty number of patent application

4.2 The Evaluation Result

First, we make validity evaluation between national level, which we take as a DMU evaluation unit and twenty-nine provinces in mainland except Qinghai province, and Tibet province. Second, we take twenty-nine provinces in mainland except Qinghai province and Tibet province as a DMU evaluation unit to make DEA grading validity evaluations. Evaluation results as table 1:

The first estimated result of technique advancement's EDA classification validity, which was put up in 30-provinces/ municipalities/ cities. Then the second estimation was put up on the area except Beijing, Tianjin and Hebei. Finally the third estimation, which eliminates second effective area, was put up. So, every area was effective and elimination was finished.

TABLE .1 EVALUATION EFFECTIVENESS

| District | First Evaluation Value | First Effectiveness | Second Evaluation Value | Second Effectiveness | Third Evaluation Value | Third Effectiveness |
|--------------|------------------------|---------------------|-------------------------|----------------------|------------------------|---------------------|
| Nation | 1 | effective | | | | |
| Beijing | 1 | effective | | | | |
| Tianjin | 1 | effective | | | | |
| Hebei | 1 | effective | | | | |
| Shanxi | 0.7340 | ineffective | 0.8877 | ineffective | 1 | effective |
| Neimen | 1 | effective | | | | |
| Liaoning | 0.8236 | ineffective | 1 | effective | | |
| Jilin | 0.8545 | ineffective | 1 | effective | | |
| Heilongjiang | 1 | effective | | | | |
| Shanghai | 1 | effective | | | | |
| Jiangsu | 1 | effective | | | | |
| Zhejiang | 1 | effective | | | | |
| Anhui | 0.7533 | ineffective | 0.9650 | ineffective | 1 | effective |
| Fujian | 1 | effective | | | | |
| Jiangxi | 0.9859 | ineffective | 1 | effective | | |
| Shandong | 1 | effective | | | | |
| Henan | 0.9563 | ineffective | 1 | effective | | |
| Hubei | 0.7390 | ineffective | 0.9496 | effective | 1 | effective |
| Hunan | 0.9664 | ineffective | 1 | effective | | |
| Guangdong | 1 | effective | | | | |
| Guangxi | 0.8806 | ineffective | 1 | effective | | |
| Hainan | 1 | effective | | | | |
| Chongqing | 1 | effective | | | | |
| Sichuan | 0.6989 | ineffective | 1 | effective | | |
| Guizhou | 0.7703 | ineffective | 1 | effective | | |
| Yunnan | 0.8920 | ineffective | 1 | effective | | |
| Shanxi | 1 | effective | 1 | effective | | |
| Gansu | 0.6623 | ineffective | 0.8792 | ineffective | 1 | effective |
| Ningxia | 0.8056 | ineffective | 1 | effective | | |
| Xinjiang | 1 | effective | | | | |

From the elimination result, we can found that the countryside holistic technique level is effective. In the first elimination, Beijing, Tianjin, Hebei, Niemen, Heilongjiang, Shanghai, Jiangsu, Zhejiang, Fujian, Shandong, Guangdong, Hainan, Chongqing, Shanxi and Xinjiang reach the technique level of the country. In the second elimination, effective areas were Liaoning, Jilin, Jiangxi, Henan, Hunan, Guangxi, Sichuan, Huizhou, Yunnan, Shanxi and Ninxia. Finally, effective areas were Shanxi, Anhui and Hubei. All the area that reaches the technique level of the country are areas inshore and along the Changjiang. This could reflect that the main economy force of our country is fastening on these areas. Areas inshore and along the Changjiang have better industrialization level, technique benefit and dimension manufacture benefit than areas inland. The conclusion that Inner Mongolia, Heilongjiang, Shaanxi, Xinjiang province achieved nation technical level errs from the reality observation. Analyzing its reason to lie in, one is that the strong science and technology strength of Heilongjiang and Shanxi enhanced their output level. Another is that the Commercial scale of these areas is small; the difference between investment and output is also small. So the

proportion between investment and output is also higher than other provinces. but when the Commercial scale become bigger , maybe the result is not that. The core idea of DEA analyses is analyzing the relative efficiency of evaluation unit with the proportion between investment and output. So we get this conclusion from Computed result. But according to this, we cannot make any judgment. The following tow reasons can account for it. These provinces already have high technology level and when National level can no longer be used as Appraisal unit, Shaanxi province does not have technology effectiveness. In a word, the china 's area which has technology effectiveness is still in Coastal area.

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6. References

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