A Kernel Function DEA Method for Efficiency Evaluation of Technological Innovation in Scientific Research Institutions

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Abstract. To improve the efficiency of technology innovation is to improve the important way of innovation output. Therefore, this paper presents a kind of kernel DEA method, designs the index system of inputs and outputs, maps input indicators to a new dimension space by kernel function. Combined with BCC model to evaluate the method, the experiment proves the effect of this method in efficiency evaluation for technological innovation in scientific research institutions.

Introduction

The theory of technological innovation comes from the innovation theory proposed by Pete in 1912, which has been a hot issue for economists, sociologists and real workers at home and abroad since then [1, 2]. In Pete defined innovation as a transfer of production function, or a new combination of production function, whose purpose is to obtain the potential excess profit. Because the innovation resources of the scale of investment is often affected by the constraints of regional economic development level, regional knowledge base of objective conditions. Therefore, within investment scale of established innovation resources, improving the efficiency of the input and output of technology innovation have become an important way to improve the innovation output. And in the process of improving the efficiency of technological innovation, we must first solve the problem of how to evaluate the technological innovation efficiency of high-tech industries.

DEA (data envelopment analysis, DEA) method is a non-parametric statistical method which is to the concept of relative efficiency as the basis, to the convex analysis and linear programming as a tool for evaluation a prolific DMU (decision making unit, DMU) whether has the same type of multi input is the "technology" or not [3]. DEA model is the important tool for efficiency evaluation [4], the traditional DEA model in the evaluation of technology innovation efficiency. First, we construct a possibility set by a sample set, and then through the relationship between each sample point and the front surface of the projection point defines the efficiency of technological innovation. Concerning problems in the traditional DEA-BCC, and the needs of research institutions to technology innovation efficiency evaluation, we have proposed a DEA method based on kernel function mapping. The kernel function, will be put index mapping into a new dimension. Through the DEA-BCC evaluation method, the effect of the application of this method is verified by experiments.

Input and output index design

For the innovation of the input indicators, the views of foreign scholars are more consistent. Generally scholars put capital and talent input as the two basic input elements and use two indicators: the operation of the use of R&D costs and scientists [5]. At the same time, the number of patents is regarded as a major innovation output indicators [6], and the examination of the relationship between patent and R&D [7, 8], studies has shown that there is significant correlation between the R&D expenses and patent. The fact, R2 more than 0.9, indicates that for the research data on the U.S. Patent Office, the patent on the R & D of elastic is between 0.3-0.6 [9].

According to research institutions for technical innovation practice, design of input index includes R&D expenditures, scientific research personnel, and scientific research equipment (large).

Output indicators, in addition to the patent number, also contain the number of research projects, and work completion. The completion of the work is a weighted combination, including strong for the vertical project completion, the cooperation of the horizontal scientific research, basic pre research project completion of three categories. The purpose of this package is to form a complete description of the innovation output. The input-output index system is shown in Table 1.

Tab.1. The investment and output index

Investment index			Output index		
number of scientific researcher	R&D funding	research equipment	the number of scientific research subjects	achievement award	work completion score

Kernel function mapping DEA method

Step1:

There are n decision making units, DMU_j ($j=1,...,n$), their input and output vectors are respectively:

$X'_j=(x'_{1j},x'_{2j},...,x'_{mj})^T>0$, $Y_j=(y_{1j},y_{2j},...,y_{sj})^T>0$, $j=1,...,n$.

The weight vectors of input and output are respectively $v=(v_1,v_2,...,v_m)^T$, $u=(u_1,u_2,...,u_s)^T$.

Step2:

The weight vector of input $X'j$ is mapped to the data analysis space X_j.

$$X_j = \Phi(x'_{mj} - c) = e^{-(x'_{mj}-c)^2/2\sigma^2} \tag{1}$$

$$c = \frac{1}{n*m}\sum_{k=1}^{n}\sum_{l=1}^{m} x'_{lk} \tag{2}$$

$$\sigma = 1\Bigg/\sqrt{\frac{1}{m*n}\sum_{j=1}^{n}\sum_{i=1}^{m}(x'_{ij} - c)} \tag{3}$$

Step3:

Get BCC model.

$$\begin{aligned} &\textit{Maximize} \quad \frac{\sum_{r=1}^{s} u_r y_{ro}}{\sum_{i=1}^{m} v_i x_{io}} = \theta_o \\ &\textit{subject to} \quad \frac{\sum_{r=1}^{s} u_r y_{rj}}{\sum_{i=1}^{m} v_i x_{ij}} \le 1,\ j = 1,2,\cdots,n, \\ &\qquad u_r \ge 0, v_i \ge 0,\ \forall r,i. \end{aligned} \tag{4}$$

Step4:

The linear programming model is obtained by using the Charnes-Cooper transform.

$$\begin{aligned} &\textit{Maximize} \quad \sum_{r=1}^{s} \mu_r y_{ro} - u_o, \\ &\textit{subject to} \quad \sum_{i=1}^{m} \omega_i x_{io} = 1, \\ &\qquad \sum_{r=1}^{s} \mu_r y_{rj} - \sum_{i=1}^{m} \omega_i x_{ij} - u_o \le 0,\ \ j = 1,\ldots,n, \\ &\qquad \mu_r, \omega_i \ge 0, \qquad r = 1,\ldots,s;\ i = 1,\ldots,m. \end{aligned} \tag{5}$$

Step5:

According to the basic theory of linear programming, get the form of the dual problem of the model (5).

$$
\begin{aligned}
&\textit{Maximize}\quad \theta_{\mathbf{o}} - \varepsilon\left(\sum_{i=1}^{m} s_i^- + \sum_{r=1}^{s} s_r^+\right) \\
&\textit{subject to}\quad \sum_{j=1}^{n} x_{ij}\lambda_j + s_i^- = \theta_o x_{io},\ i = 1,\ldots,m \\
&\qquad \sum_{j=1}^{n} y_{rj}\lambda_j - s_r^+ = y_{ro},\quad r = 1,\ldots,s \\
&\qquad \sum_{j=1}^{n} \lambda_j = 1 \\
&\qquad \lambda_j, s_i^-, s_r^+ \geq 0,\quad \forall i, j, r
\end{aligned}
\tag{6}
$$

Experiment and Results

We select high technology industry technology development activities in five research institutions within 6 years, 2010-2015, as subjects, and view high technology industry technology development activities decision in eight research institutions within 6 years as 48 decision units by panel data. Set *i* (*i=1, 2, ..., 5*), *t* (*t=1, 2, …, 6*) the input index and output index of the year 6 are respectively set as X_{it} and Y_{it}, which are denoted as DMU_{it}. Taking the input index *X* as the horizontal coordinate, the output index *Y* the vertical coordinate, the coordinate of the decision element DMU*it* in the two-dimensional coordinate system is (*Xit*, *Yit*). During 2010-2015, scientific research institutions in the technology development phase of the input index and output index values, lined a total of 18 frontier points in the coordinate system of distribution. When amplify the near the region of origin of the initial frontier, as shown in Figure 2. The 48 decision units are shown in Figure 1.

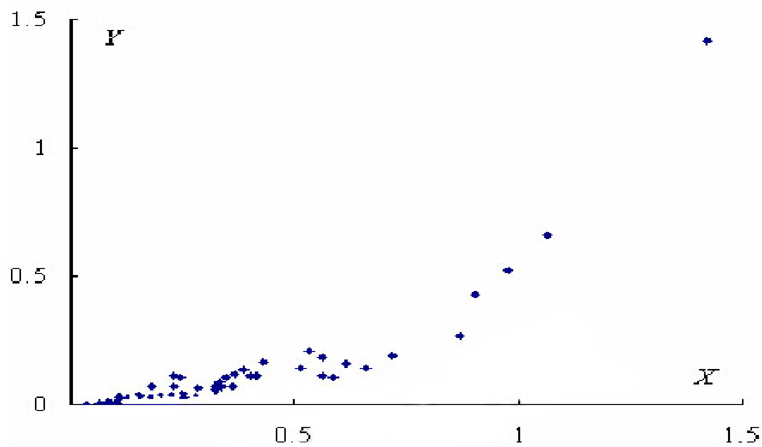

Fig.1. The input-output distribution at technology development stage for 8 research institutions from 2010 to 2015

According to the characteristics of the initial front surface and decision making unit, it is relatively easy to determine the situation: when high technology industry technology development stage in the investment scale is small (B10 left interval [0, 0.2303]), marginal revenue is constant; when investment in large scale B10 right interval [0.2303 1.4219] keeps increasing , marginal revenue increase is an the obvious phenomenon.

The experimental results well explain the problems in the technological innovation of scientific research institutions, which need a lot of investment in the process of high technology research and development, including funds and talents. If there is no certain scale of financial security and high quality of security personnel, some high technology R & D activities are difficult to carry out, not to mention to ensure the rate of the success in the high technology research and development, which means that the marginal revenue keeps unchanged on the low scale of high technology industry technology development activities. When technology development investment reaches a certain scale, R & D team grows, and the quality of personnel of research continuously improves and develops, the experimental conditions receive an great improvement. Then technical reserves will continue to increase by technological advancement. When the difficulty of technology breakthrough is relatively degraded, namely when the investment scale is bigger, the high technology industry technology development activities of the marginal revenue will present incremental phenomenon.

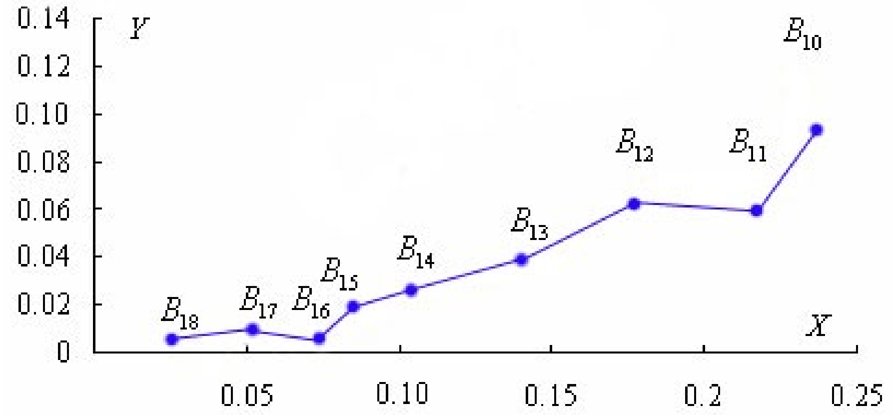

Fig.2. The initial frontier near origin at technology development stage

Conclusion

Improving the efficiency of technology innovation is an important way of innovation output. Therefore, this paper presents a kind of kernel DEA method, designs the index system of inputs and outputs, maps input indicators to a new dimension space by kernel function. Combined with BCC model to evaluate the method, the experiment proves the effect of this method in efficiency evaluation for technological innovation in scientific research institutions.

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