DEA-based Achievements Estimate of Technology Investment

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ABSTRACT
In recent years, domestic R&D funding has maintained rapid growth, and scientific and technological innovation has achieved fruitful results. However, compared with the world's technological powers, the technological foundation is still weak. Science and technology R&D activities are a typical input-output process, and this process is also a complex process. This study takes Dalian's science and technology investment as the research object, and establishes a science and technology investment achievements estimate index system from two sides: scientific research input and scientific research output. This study collected data on the input and output of science and technology based on the Science and Technology Yearbook. Then use the DEA method to evaluate the effectiveness of these outputs. The DEA calculation model is established, and the input-output efficiency is calculated using DEAP software. This can lay a good foundation for the subsequent achievements estimate of science and technology investment.

Keywords: *Data Envelopment Analysis, Achievements Estimate, Scientific and Technological Investment*

1. INTRODUCTION

In recent years, our country's R&D investment has maintained rapid growth, and scientific and technological innovation has achieved fruitful results. However, compared with the world's scientific and technological powers, our country's scientific and technological foundation is still weak, and there is still a large gap in scientific and technological innovation capabilities, especially original capabilities. The situation that core technologies in key areas are controlled by others, and it has not been fundamentally changed. By strengthening the effective management of scientific research project funds, the role of limited financial funds in promoting scientific and technological progress can be better played, which will help to enhance the transformation power of scientific and technological achievements to productivity, maximize the performance of local financial investment in science and technology, and promote rapid economic development. Therefore, it is of great significance to evaluate the performance of science and technology projects and related science and technology investment.

Data Envelopment Analysis (DEA) compares the comparative performance of decision-making units (DMU) and evaluates the effectiveness of decision-making units. It has been widely used in the achievements estimate of scientific and technological achievements, reflecting its unique advantages in evaluating the opposite availability of multiple input and output index.

The Data Envelopment Analysis method is a method that uses mathematical programming to evaluate the opposite availability of comparable units of the same type, based on multiple input and output index. Mathematical programming includes linear programming, multi-objective programming, stochastic programming, etc. It is a nonparametric method for quantitative analysis. By evaluating and analyzing the technical efficiency of multiple decision-making units, the DEA method can obtain the relatively effective situation between DMU. The DEA is suitable for operations in complex situations with multiple input and output index.

There are no strict requirements on the measurement unit of input and output index, which eliminates the influence of subjective factors in the operation process. Therefore, this article uses DEA method to analyze the financial skillfulness investment performance of Dalian City.

2. RELATED WORK

At present, there are a large number of researchers discussed that government should play in contributing to technological and R&D investment. This research is related to the literature on government technology and R&D investment performance evaluation. Several researchers have studied the inverted U-shaped correlation between scientific output and growth [1]. Dai & Cheng assessed the impact of different levels of government financial investment on the technology sector[2]. Their research shows that public subsidies

have an S-shaped relationship with firms' total R&D expenditures, based on a U-shaped relationship with firms' private investment curves. Thus, Callaghan finds that R&D investment may strengthen a country's patent growth association in a faster-growing country [3]. The approach of Novikova explores the correlation between project participants due to government technology and financial investment [4]. According to Novikova, the significant excess of economic benefits mainly depends on the indirect interests of indirect participants who use the results of the invested projects but are not direct participants in the projects. The research conducted by Oleg & Ekaterina found that the impact of technological investment on GDP dynamics and overall technological level is not synchronized. They suggested that the government should change the macroeconomic policy, which is not only aimed at stimulating investment as a driver of growth, but also allocate investment in such a way that it will lead to the improvement of the economy and technology and the change of insufficient technological investment [5].One of the studies showed that market-oriented scientific research has a relatively high probability of government invention and innovation. However, current research on the impact of government R&D investments are mainly focused on western countries, few researchers are investigating this in Asian countries, especially in China. From this perspective, Kai, Meng and Andrea studied the impact of government R&D investments including government and government R&D programs can significantly influence the number of patent technology transfer contracts [6]. In Asian countries, local R&D investment has a huge impact on technological development. As a result, research infrastructure assessments attract most of the Asian academic attention associated with local companies. For example, Lee, Choi & Seo used Slack-Based Model Data Envelope Analysis (SBM-DEA) to examine the performance of research and development (R&D) investments at the local government level in South Korea [7]. Likewise, Chen, Gu & Luo revealed that Chinese companies that did not disclose their R&D spending were less innovative [8].

These studies have provided a broader research horizon and laid a research foundation for the research on the performance of fiscal science and technology expenditures.

3. COMBINING THE COMPREHENSIVE EVALUATION INDEX METHOD TO CONSTRUCT AN INDEX SYSTEM

3.1 Establish Achievements Estimate Index

The technological investment of enterprises is obviously different from traditional industrial investment. The first is to highlight economic and technological characteristics; the second is to take into account the economic benefits of research and development and the strategic benefits of the enterprise. The R&D activity of an enterprise is a typical input-output process which is complex.

Considering the characteristics of multiple output of technology input, combined with the comprehensive evaluation index method, determine the achievements estimate index of technology investment. From the two aspects of scientific research input and output, this study selects and establishes a scientific and technological input achievements estimate index system. The indicator system includes five aspects: personnel input capacity, capital input capacity, scientific and technological activity capacity, achievement output capacity and external environment, etc., as shown in Table 1.

Table 1. The Achievements estimate index of science and technology investment

Target Layer	Statistical Caliber	Statistical Index
Technology Investment	The High and New Tech Enterprises	The R&D Internal Expenditure
	The Local Government Expenditures on Technology	The Local Government Expenditures on Technology
	The Local Government Expenditures on Technology	The Proportion of Local Government Expenditure on Technology
	The High and New Tech Enterprises	The Internal Expenditure of Technological Activities
	The High and New Tech Enterprises	The Science and Technology Activity Staff
Technology Output	The High and New Tech Enterprises	The Product Sales Income
	The High and New Tech Enterprises	The Industrial Output
	The High and New Tech Enterprises	The Patent Granted in the Year
	The High and New Tech Enterprises	The Number of Technology Institutions Run by Enterprises

3.2 Select Data

This study combines the data report and processes the original data. The data reports include Technology Statistical Yearbook, China Torch Statistical Yearbook, Liaoning Province High and new Tech Industries, etc., as shown in Table 2. Due to the lack of data, part of the parameter data was selected in the DEA evaluation. Output parameters include product sales revenue, total industrial output value, authorized patents that year, and the number of technical institutions established by the company. Input parameters include internal expenditures of R&D funds, internal expenditures of technological activities, and personnel of technological activities.

Table 2. Original Data Sheet for Achievements estimate of Science and Technology Input

Statistical Index	Internal expenditure of R&D expenses	Local fiscal expenditure on science and technology	The proportion of local fiscal expenditures on science and technology in fiscal expenditures	Internal expenditures for scientific and technological activities	Technological personnel	Product sales revenue	Industrial output	Patent granted in the year	Number of scientific and technological institutions run by enterprises
	input1			input2	input3	output1	output2	output3	output4
unit	Thousand	10 thousand	%	Thousand	people	100 million	100 million	piece	piece
2011	5376421	331652	4.51	8293009	26094	1294.97	1337.75	1807	172
2012	4354482	392872	4.41	6476196	35759	1255.8	1518.41	2304	209
2013	4335231	462846	4.27	7899705	37531	1475.35	1488.81	1882	231
2014	6214647	430258	4.35	11347606	40998	1769.71	1916.53	1568	935
2015	4443529	182829	2.01	8943151	39256	1610.75	1491.59	2053	262
2016	6440611			8289461	41997	1665.41	1449.8	2541	336
2017	8758580			19411	43761	1754.75	1466.08	2877	339

4. DEA EVALUATION

In this paper, the DEA calculation software DEAP2 program, taught by Coelli, is used to calculate the data of Dalian's government technology input and output , which from 2011 to 2017 in Table 2 and Figure1 and Figure2. The model formulas are as follows:

$$\min\left[\theta - \varepsilon\left(\sum_j^n s_j^- + \sum_j^n s_j^+\right)\right] s.t. \quad (1)$$

$$\begin{cases} \sum_{\substack{j=1 \\ j=j_0}}^n \lambda_j x_j + s_j^- = \theta x_j \\ \sum_{\substack{j=1 \\ j=j_0}}^n \lambda_j x_j - s_j^+ = y_j \\ \lambda_j \gg 0, j = 1,2,\cdots,n, s_j^+ \gg 0, s_j^- \gg 0 \end{cases} \quad (2)$$

In the formula, θ is the efficiency value of the evaluation decision-making unit, ε is the non-Archimedean infinitesimal, λj (j = 1,2,...,n) is the planning decision variable, and X(x1,x2,...,xn) is the input Variable vector, Y(y1,y2,…,yn) is the output variable vector, S-=(s-1,s-2,…,s-n) and S+=(s+1,s+2,…,s+n) are the slack variable vectors of redundant input and insufficient output respectively.

$$TE = PTE \times SE \quad (3)$$

TE indicates whether DEA is effective or not;

PTE indicates whether the resource allocation is reasonable or not;

SE represents the scale or not;

Therefore, the TE looks at the overall effectiveness of the organization, the PTE looks at the input and output, and the SE looks at the return to scale.

SUMMARY OF OUTPUT TARGETS:

firm	output:	1	2	3	4
1		1294.970	1337.750	1807.000	172.000
2		1255.800	1518.410	2304.000	209.000
3		1475.350	1488.810	1882.000	231.000
4		1769.710	1916.530	1568.000	935.000
5		1610.750	1491.590	2053.000	262.000
6		1665.410	1449.800	2541.000	336.000
7		1754.750	1466.080	2877.000	339.000

SUMMARY OF INPUT TARGETS:

firm	input:	1	2	3
1		5376421.000	8293009.000	26094.000
2		4354482.000	6476196.000	35759.000
3		4335231.000	7899705.000	37531.000
4		6214647.000	11347606.000	40998.000
5		4443529.000	8943151.000	39256.000
6		6440611.000	8289461.000	41997.000
7		8758580.000	19411.000	43761.000

Fig.1 Running Result of DEAP2

Table 3. Dalian Science and Technology Input-Output Efficiency

Decision-making Unit (DMU)	Technical Efficiency (TE)	Pure Technical Efficiency (PTE)	Scale Efficiency (SE)
2011	1	1	1
2012	1	1	1
2013	1	1	1
2014	1	1	1
2015	1	1	1
2016	0.982	1	0.982
2017	1	1	1

4.1 Technical Efficiency ANALYSIS

It can be seen from Table 3, during the study year, Dalian Municipal Government's science and technology investment has a comprehensive efficiency value of 1 for 6 years (IDEA is effective), accounting for 86% of the total number of years, and 1 year for achieving an average comprehensive efficiency of 0.950. The overall efficiency in 2016 was less than 1, 0.982 respectively, which is not valid for DEA. As can be seen from Figure 2, that the comprehensive efficiency of Dalian Municipal Government's investment in technology is in a relatively stable state. This shows that the performance level of Dalian municipal government's science and technology investment from 2011 to 2017 was moderate.

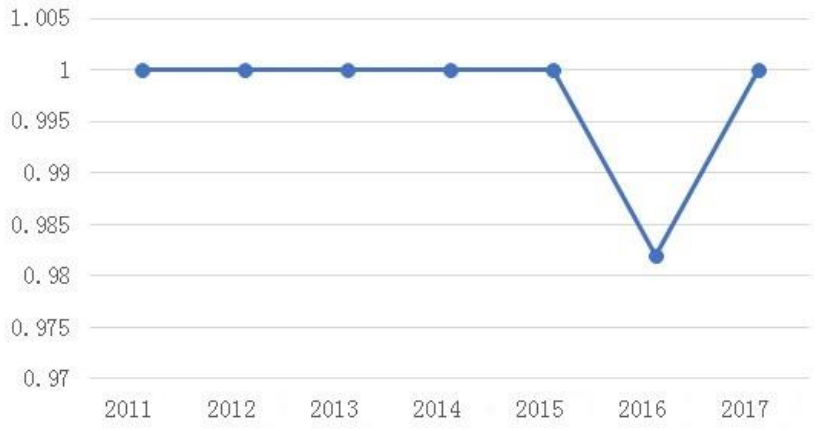

Fig.2 Distribution Map of TE

4.2 Pure Technical Efficiency Analysis

PTE refers to the maximum output that the decision-making unit can obtain under given input conditions [9]. It can be seen that the pure technical efficiency values from 2011 to 2017 both reached 1, indicating that the government's investment in technology is reasonable relative to the output of technology in the past few years.

4.3 Scale Efficiency Analysis

SE refers to the increase in technology input, and what will happen to the output [10]. Constant scale efficiency is an ideal state of production, which means that the growth rate of output and input are the same. Increasing scale is to increase input, and output will increase at a faster rate than input. Diminishing scale means that output will grow at a slower rate than input. For decision-making units that are in a state of increasing or decreasing in scale, they need to be adjusted and improved to achieve the desired state. In the Table 3, the synthesized efficiency, pure technical efficiency and scale efficiency outside of 2016 have all reached DEA effectiveness. The effective value accounts for 86% of the total number of years. The scale efficiency is also constant. This shows that the financial input in technology in the past six years has reached an ideal state. The overall efficiency and scale efficiency in 2016 are both less than 1. This shows that the amount of input has not been managed well in 2016, and the effect produced is limited.

5. CONCLUSIONS

In this paper, DEA is used to evaluate the opposite availability of Dalian's technology input and output performance. On this basis, other methods can be used to evaluate performance, and the efficiency of mining performance input-output is not high. Reason to help the government make the right decision.

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