The Evaluation of R&D Investment and Output Efficiency in China

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Abstract: The purpose of this paper is to study the evaluation of R&D input-output efficiency of enterprises. The data of R&D activities of enterprises in 31 regions of mainland China, R&D funds and R&D personnel are used as input indicators, and new product output are used as input indicators. Output indicators, based on the DEA cross-evaluation model to evaluate the efficiency of R&D input and output of enterprises in China, are not ideal. Among more than half of the region, only Hainan Province is efficient. Finally, the rationalization of raising R&D input-output level of enterprises in China is put forward.

1. Introduction

The economic growth of a country depends on technological progress caused by innovation, which is driven by supply factors such as discovery of scientific knowledge, technological opportunities, R&D efficiency, opportunity cost of investment and demand factors such as demand scale and consumption structure of new products. Among them, R & D is the most important supply factor to promote technological innovation. R&D refers to the systematic and creative activities in the field of science and technology, including basic research, applied research and experimental development, in order to increase the total amount of knowledge and create new applications with these knowledge.

With the increasing importance of R&D activities, R&D investment has gradually become an important indicator to measure the competitiveness of a country or region in science and technology. However, R&D capitalization is conditional capitalization, not all R&D investment. Entry can bring innovation to our country, and it can be completely transformed into productivity so as to enhance our national economy.

2. Research status at home and abroad

Scherer (1967) found that when the R&D scale of an enterprise rises to a certain extent, the R&D scale and the innovation output of an enterprise will change from positive correlation to negative correlation or irrelevance. [1]Bound et al. (1984) found that the two were U shaped.[2] Anming Zhang (2003) found that enterprise ownership is another important factor affecting the efficiency of

enterprise R&D input and output. Non-state-owned enterprises have higher R&D input and efficiency level than state-owned enterprises. [3]The higher efficiency level comes from their high input, and at the same time brings about the improvement of productivity level.

There are two ways to evaluate R & D Efficiency: parametric method and non parametric method.[4] This paper will build a DEA cross-evaluation model, R&D funds and R&D personnel full-time equivalent as input indicators, patent applications and new product output value as output indicators to evaluate the efficiency of R&D input and output of 31 regional enterprises in China, and put forward rationalization for the improvement of R&D input and output level of enterprises.

3. The building of model function

The DEA cross-evaluation model adopted in this paper is a non-parametric analysis method.DEA uses linear programming method to construct a non-parametric piecewise linear envelope (or frontier) and envelop the data.[5] According to the envelope, the efficiency measure can be calculated.[6]

3.1 Construction of DEA model

There are I decision-making units. For each decision-making unit, there are N input and M output indicators. For the first decision-making unit, column vectors x_i and q_i are used to represent its input and output respectively. The efficiency value of each decision-making unit is expressed by the weight ratio of output to input, where u is a vector of Mx1, representing the weight of output; v is a vector of Nx1, representing the weight of input. The optimal weight value can be obtained by solving the following mathematical programming problems.

$$\max_{u,v}(u'q_i / v'x_i)$$
$$s.t. u'q_j / v'x_j \le 1,\ j = 1,2,\cdots, I$$
$$u, v \ge 0$$

The total efficiency measure must be equal to or less than 1: the values of u and V are found to maximize the efficiency of decision I. For this particular ratio modeling, one problem is that it may have numerous solutions. To avoid this situation, we can add a constraint. $v'x_i = 1$. Then there are

$$\max_{u,v}(\mu'q_i)$$
$$s.t. v'x_i = 1$$
$$\mu'q_j - v'x_j \le 0,\ j = 1,2,\cdots, I$$
$$\mu, v \ge 0$$

In this paper, the symbols u and v are replaced by μ and v, mainly to emphasize that this is a different linear programming problem. The above model is called the multiplier form of DEA model linear programming. Then using the duality of linear programming, we can get an equivalent envelope form:

$$\min_{\theta,\ \lambda}$$
$$s.t. -q_i + Q\lambda \ge 0$$
$$\theta x_i - X\lambda \ge 0$$
$$\lambda \ge 0$$

In the formula, θ is a scalar and λ is a constant vector of Nx1. This envelope form involves fewer constraints than the multiplier form (N+M<I+1), so it is more widely used. According to Farrell (1957), the θ value obtained is the efficiency value of the I decision making unit.If the value is 1, it means that the point is on the leading edge, that is the technology effective enterprise.

4. Indicators selection and empirical results analysis

4.1 Selection of indexes

The ultimate goal of R&D activities is to create new products, transform R&D patents and scientific papers into productivity, increase GDP and enhance competitiveness. Therefore, this paper selects the "new product output" as a key indicator to measure the output of R & D. It not only considers patents and papers related to R & D activities. At the same time, we also consider the value of transforming research and development achievements into products.

Selection of input indicators. R&D internal funds, which is the R&D input funds index used in this paper, refers to the total funds for implementing R&D activities in a certain statistical unit or economic department within a specified period of time, regardless of the source of funds. The funds accounting occurring outside the statistical unit or department but supporting the internal R&D activities. Internal R & D expenditure, daily expenditure and capital expenditure are also included.

Full-time work equivalence (FTE) of R&D personnel is a true measure of the total amount of R&D. All Member States must insist on it to ensure international comparison. R&D activities may be some people's main work (e.g. R&D laboratory staff) or minor work (e.g. design and Testing Institute staff). It may also be an important part-time activity (e.g. university teachers or graduate students). If only R&D personnel are counted, it will be underestimated. R&D activities; and calculating the total number of people who spend a certain amount of time on R&D activities will overestimate R&D activities. Therefore, the number of people engaged in R&D activities should be counted according to a full-time work equivalent of R&D activities. A full-time work equivalent can be considered as a person's year. Therefore, if a person has 30% of R&D activities. Time spent on R & D activities is recorded as 0.3 FTE..

The data of all indicators in this paper come from China Statistical Yearbook and China Scientific and Technological Statistical Yearbook, and the number of samples is more than twice the sum of all indicators, which conforms to the rules of using DEA method.

4.2 Empirical results analysis

4.2.1 The overall efficiency of R&D input and output efficiency of Chinese enterprises is relatively low

Using R&D input in 2013 and R&D output in 2015, this paper considers that R&D input should bring its efficiency into full play within at least two years. This part evaluates and analyses the efficiency of R&D input and output of enterprises in different regions of China by using MATLAB software. The average efficiency of cross region evaluation is shown in Table 1.

From Table 1, it can be seen that only the R& D input and output of enterprises in Hainan in 31 regions of the mainland of China in 2011 are of high efficiency. The efficiency level of R& D activities of enterprises in other regions is not good, the average efficiency value is only 0.3819, and more than half of the regions are below the average level. The efficiency of R&D investment in Zhejiang, Guangdong and Shandong is below the average. It shows that blindly increasing R&D investment funds does not mean that it can be effectively utilized, and more funds have not been fully utilized. Although Hainan R&D investment funds are not much, but its efficiency level is high, and it can be fully utilized in a real sense.

Table 1 The average efficiency of DEA cross evaluation of R&D in different regions

ranking	region	R&D efficiency mean	ranking	region	R&D efficiency mean
1	HAINAN	1.0000	17	HUBEI	0.3305
2	ANHUI	0.7630	18	SHANDONG	0.3066
3	ZHEJIANG	0.7622	19	NINGXIA	0.2789
4	JIANGSU	0.5720	20	SICHUAN	-。2594
5	CHONGQING	0.5711	21	HENAN	0.2503
6	HUNAN	0.5697	22	SHANXI	0.2447
7	BEIJING	0.5635	23	HEBEI	0.2421
8	TIANJIN	0.5226	24	LIAONING	0.2331
9	GUIZHOU	0.4591	25	GANSU	0.2011
10	GUANGDONG	0.4531	26	XIZANG	0.1873
11	FUJIAN	0.4468	27	JIANGXI	0.1832
12	SHANGHAI	0.4289	28	SHANXI	0.1532
13	YUNNAN	0.3841	29	NEIMENGGU	0.1522
14	GUANGXI	0.3577	30	HEILONGJIANG	0.1416
15	XINJIANG	0.3550	31	QINGHAI	0.1172
16	JILIN	0.3489			

4.2.2 Analysis of the low efficiency of R & D output in China

The conversion rate of R&D results of Chinese enterprises is relatively low. In many developed countries in the world, R&D capital mainly comes from enterprise investment, supplemented by government financial expenditure. R&D investment fully reflects the operation law of market economy. However, Chinese enterprises' R&D dependence on the government is relatively high, their R&D capabilities are weak, their awareness of technological innovation is poor, and the main body of scientific and technological competitiveness development is absent, which leads to the disconnection between R&D and production and the difficulty in transforming scientific and technological achievements. This is an important issue affecting the international competitiveness of Chinese enterprises in science and technology. It is this unreasonable phenomenon that leads to the lack of scientific and technological resources and the weak scientific and technological strength of enterprises. When scientific research results are needed, it is often necessary to introduce some advanced technologies and achievements from abroad at a high price. R&D institutions and institutions of higher learning devote a lot of scientific research efforts to projects that are conducive to awards and titles, and the conversion rate of scientific research results is low.

China's R&D output is poor. In 2013, the total number of patents authorized in China was 815,000, of which 741,000 were domestic and 74,000 were foreign. However, only 80,000 patents were authorized for invention, accounting for 10.8%, which is in sharp contrast to 74.3% of foreign patents.

5. Conclusions

Since 2016, the intensity of R&D input in China has steadily increased, and input is for output. Therefore, while increasing R&D input, China should pay attention to the effective utilization of R&D resources and improve the efficiency of R&D input and output, so as to truly realize the enhancement of China's technological innovation ability. Therefore, it is necessary to improve R&D input of Chinese enterprises. This paper puts forward the following suggestions:

Increase R& D input to colleges and Universities. As the main body of research innovation, research institutes and institutions of higher learning bear the responsibility of basic research, which is an important link to achieve high efficiency of R&D investment.

Improving the conversion rate of R & D output of enterprises. At present, R&D investment

in China is mainly concentrated in the enterprise sector, and investment in research institutes and institutions of higher learning is relatively small. At the same time, as the main link of experimental development, enterprises should not neglect to improve the efficiency of R&D input and output. Therefore, enterprises should enhance the awareness of scientific and technological innovation and make full use of R&D input funds. At the same time, institutions of higher learning should actively strengthen links with enterprises and form technological alliances to promote the transformation of scientific and technological achievements into real productive forces.[7]

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