Research on the Evaluation of Innovation Efficiency of Electricity Listed Enterprises Based on Three-Stage DEA

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Abstract: With the development of the times,large state-owned enterprises put forward a major strategic development layout, this paper takes the technological research and development in the strategic layout as an entry point, and proposes a set of index system to measure the technological innovation efficiency of the sample electric power enterprises. In this paper, the three-stage DEA method is used to evaluate the efficiency, and the research results show that: the enterprise's establishment years, gearing ratio, government subsidies and gross regional product all positively affect the redundancy of R & D inputs, and the impact of total assets is not significant, and after removing environmental noise and random interference terms, the Pure technical efficiency of sample enterprises is improved and scale efficiency is decreased, after adjustment, the scale reward of each enterprise reaches incremental or optimal scale status during the sample period.

Keywords: Electricity Listed Companies ; R&D efficiency; Three-stage DEA

1. Introduction

The report of the 20th Party Congress focuses on the issue of carbon peak carbon neutral, requiring the energy supply industry to accelerate the construction of a new type of energy system, the large-scale power grid companies take up the mission to bear, deepen the strategic objectives, put forward the important position of technology research and development in the strategic development of enterprises. Therefore, this paper investigates the impact of R&D investment on the efficiency of listed electric power companies.

2. Literature Review

At present, there is a large amount of literature using total factor productivity to evaluate the efficiency of regions[1-3], industries[4-7] and enterprises[8-10]. Evaluation of electric power enterprise strategy should use scientific and effective methods. Some scholars study from a qualitative perspective, such as Chen Jiabing[11] and others used factor analysis, Liang Haifeng[12] fuzzy comprehensive evaluation method, as well as Zhu Jie[13], Zhang Jing[14] and others analyze the company's strategic path from a theoretical perspective, and there are also scholars who

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determine the efficiency of the electric power industry in a quantitative way, such as Ye Yingjin[15], Lei Xiyang[16], Miao Bin[17] and others used DEA methodology to determine the operational efficiency of electric power enterprises, Qi Huibo[18], Zhu Qingyuan[19] and others used the DEA-Malmquist index method, Cao Xuelu[20], Li Cunbin[21], Wang Chan[22] used a special DEA method, and in this paper, we use the three-phase DEA method to measure the innovation efficiency of the company, to overcome the static approach of the traditional DEA, and to exclude the influence of environmental factors.

3. Research methodology

This study adopts the three-stage DEA method,expecially in Stage 2: Stochastic Frontier Model SFA. Frdied et al. propose the idea of focusing on the slack variable. This variable consists of environmental factors, managerial inefficiencies, and statistical noise and reflects initial inefficiencies.In this paper, we take input orientation as an example and construct the following SFA regression function:

$$s_{ni} = f(z_i;\beta_n) + v_{ni} + \mu_{ni} \tag{1}$$

To measure the true efficiency of each DMU, the formula is adjusted as follows:

$$\hat{x}_{ni} = x_{ni} + \left[\max\left(f(z_i;\hat{\beta}_n)\right) - f(z_i;\hat{\beta}_n)\right] + \left[\max(v_{ni}) - v_{ni}\right] \tag{2}$$

The flowchart of the algorithm for the three-stage DEA is shown in Figure 1:

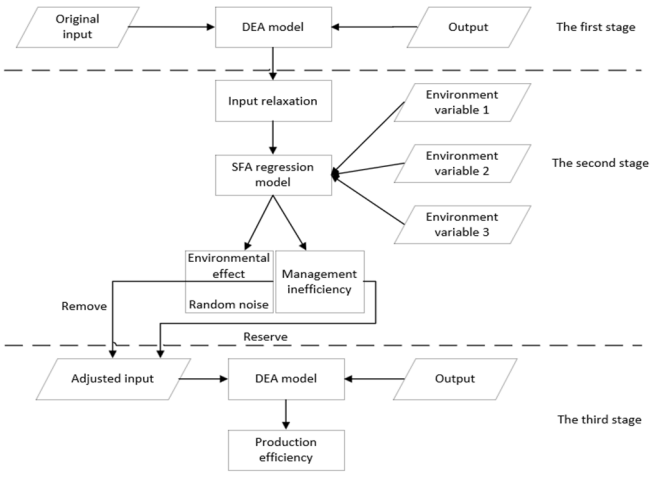

Figure 1 Flowchart of the algorithm

Based on the input-output indicators in the first stage, the slack variables are obtained for the SFA regression in the second stage, and the adjusted inputs are obtained by removing the effects of environmental variables, which are used in the DEA analysis in the third stage to generate the final production efficiency.

4. Indicators and data

(1) Indicator Selection

This paper measures the R&D efficiency of 14 listed electric power companies, taking into account standardization as well as the limitations on the number of indicators to be measured by the three-phase DEA method, this section combines the nature of the electric power industry and the strategically oriented indicator system library, and selects the input-output indicator system shown in Table 1.

Table1 Indicator System

Type of indicator	Name	Description
Input indicators	R&D expenditures	Amount of R&D expenditure invested
	Number of R&D staff	Total number of R&D personnel
Output indicators	Revenue from main operations	Difference between total operating income and other operating income
	net profit	Profit after tax, feedback on the profitability of the business
	Number of patents	Number of Patent Applications
environment variable	Founding Years	Length of time in existence
	total assets	Total assets at the end of the year
	gearing	Total liabilities/total assets
	government grant	Amount of government subsidy
	gross regional product	Reflecting regional economic conditions

(2) Data Selection

The data period for the input indicators of this paper's research is from 2017 to 2021, and the data interval for the output indicators is from 2018 to 2022. The indicator data come from Choice and the State Intellectual Property Office.Because part of the indicator data does, for this paper refer to the study of Chen Yansheng[23] according to its growth rate projected to make up the data, the specific calculation method is:

$$\partial_t = (\partial_{t-1} + \partial_{t+2}) / 2 \tag{3}$$

5. Analysis of results

5.1 Correlation tests of input and output indicators

Table2 Correlation tests

	Revenue from main operations	net profit	Number of patents
R&D expenditures	0.199	0.108	0.176
Number of R&D staff	0.271*	-0.012	0.308*

This paper applies SPSS to do correlation test on input and output indicators, and the results are shown in Table 2. As can be seen from Table 2, the input and output indicators have the characteristic of moving in the same direction, so the selected indicators are reasonable.

5.2 Three-stage DEA results analysis

According to the research methodology chosen in this paper, the empirical part consists of three stages, and the following are the empirical results of each stage.

(1) The results of the first stage: traditional DEA empirical results

The first stage uses DEAP software to analyze the input-output data from 2017 to 2021, and there are two enterprises with a comprehensive efficiency value of more than 0.8 in the sample enterprises in 2017, one of which has reached validity, three enterprises with a comprehensive efficiency value of more than 0.8 and all of them have reached validity in 2018, and there are five enterprises with a comprehensive efficiency value of more than 0.8.Most enterprises have increasing returns to scale in 2017 and 2018, and most enterprises have decreasing returns to scale in 2019-2021, and the distribution of the results of the comprehensive efficiency measurements of the sample enterprises is shown in Figure 2:

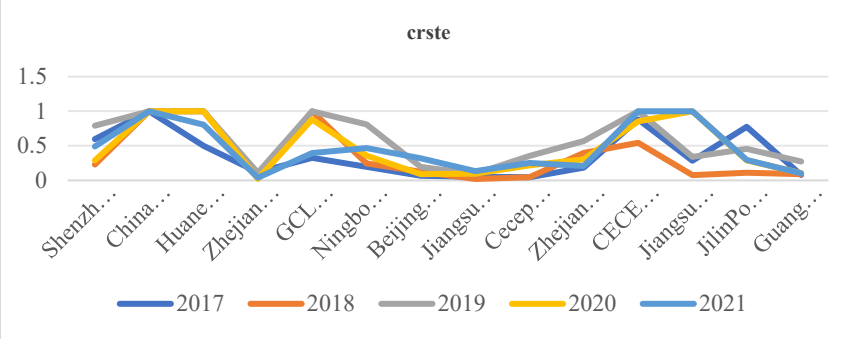

Figure 2 Phase 1 analysis

Table 3 Phase I DEA analysis

	2017		2018		2019		2020		2021	
	P1	P3	P1	P3	P1	P3	P1	P3	P1	P3
Shenzhen Energy Group Co., Ltd.	irs	irs	irs	irs	drs	-	drs	irs	drs	-
China Yangtze Power Co.,Ltd.	-	-	-	-	-	-	-	-	-	-
Huaneng Lancang River Hydropower Inc.	irs	irs	-	irs	-	irs	-	irs	drs	-
Zhejiang Fuchunjiang Environmental Thermoelectric Co.,Ltd.	irs	irs	irs	irs	drs	irs	drs	irs	drs	irs
GCL New Energy Holdings Limited	irs	irs	-	irs	-	-	drs	irs	drs	irs
Ningbo Shimao Energy Co.,Ltd.	irs	irs	irs	irs	drs	irs	drs	irs	drs	irs
Beijing Jingyuntong Technology Co.,Ltd.	irs	irs	irs	irs	drs	irs	drs	irs	drs	irs
Jiangsu Linyang Energy Co., Ltd	irs	irs	irs	irs	drs	irs	drs	irs	drs	irs
Cecep Solar Energy Co., Ltd.	irs	irs	irs	irs	drs	irs	drs	irs	drs	irs
Zhejiang Sunoren Solar Technology Co.,Ltd.	irs	irs	irs	irs	drs	irs	drs	irs	drs	irs
CECEP Wind-Power Corporation	irs	irs	irs	irs	-	irs	drs	irs	-	irs

Jiangsu New Energy Development Co., Ltd.	irs	irs	irs	irs	irs	irs	-	-	-	irs
JilinPowerShareCo.,Ltd.	irs	irs	irs	irs	drs	irs	drs	irs	drs	irs
Guangdong No.2 Hydropower Engineering Company, Ltd.	irs	irs	irs	irs	drs	irs	drs	irs	drs	irs

(2) Results of the second stage: SFA regression analysis results

The regression results are shown in Table 4 in the year of 2021, for example:

Table 4 SFA estimates for 2021

environment variable	Redundancy in research and development expenditures	Total R&D staff redundancy
constant term	-9358042.900	-307.126
Founding Years	1756166.300	6.146
total assets	0.000	0.000
gearing	-778889.600	1.295
government grant	0.551	0.000
gross regional product (GDP)	-48.193	0.000
σ^2	835939600000000.000	54252.373
γ	0.811	1.000
Log Likelihood	-255.835	-87.155

Based on the analysis, the following conclusions can be drawn:

In most years, the number of years of enterprise establishment is positively correlated with the redundancy of R&D expenditure and R&D personnel, indicating that the longer the time of establishment, the enterprise gradually scales up, and the enterprise rapidly expands and has a large market scale and share, which at this time will lead to insufficient motivation of enterprise R&D and reduce the efficiency of R&D. In the sample of enterprises studied, the impact of total assets on innovation efficiency is not significant, indicating that the expansion of enterprise scale in a short period of time does not bring about the enhancement of technological R&D efficiency, and the scale advantage is not reflected in technological transformation.2021 Asset-debt ratio is negatively correlated with the redundancy of R&D expenditures, indicating that there is a great impact of the enterprise's financial situation on the enterprise's tendency to engage in R&D activities,Except for 2021 when the increase in regional GDP reduces innovation efficiency, all other years promote innovation efficiency.

(3) Stage 3 results: DEA measurements after adjusting inputs

The results are shown in Figure 3:

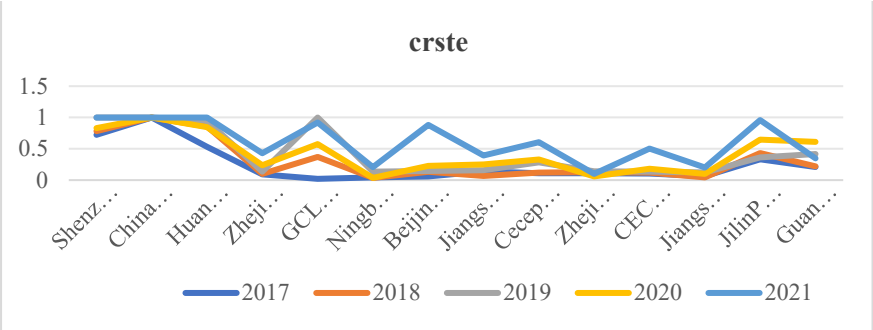

Figure 3: Phase II analysis

In terms of efficiency analysis, the average value of comprehensive efficiency from 2017 to 2020 have declined, indicating that the efficiency of R&D expenditure and R&D personnel inputs have been overestimated, and the average value of comprehensive efficiency in 2021 has improved, indicating that the efficiency of its R&D inputs is better than it looks.DEA effectiveness refers to achieving both technical efficiency effectiveness and scale efficiency effectiveness, and the sample of enterprises that have achieved DEA effectiveness in stage 1 There are 13 enterprises in the period, and 9 enterprises in the third stage that reach the effectiveness in 5 years, indicating that the resource allocation of these 9 enterprises is relatively effective, and the innovation efficiency is at the optimal level. As can be seen from Table 3, after adjusting the input variables, there is a significant increase in the number of firms with increasing returns to scale, indicating that the vast majority of the sample firms have not yet reached the maximum size. Therefore, such enterprises should reasonably increase the investment of R&D resources, rational deployment, improve the utilization rate of resources, make corresponding decisions on R&D investment in the light of their own situation, and avoid blind expansion.

6. Conclusions and recommendations

This paper uses DEA model and SFA model to analyze the innovation efficiency of 14 listed electric power companies from 2017 to 2021, and after excluding environmental noise and random interference, the following conclusions are drawn: (1) the overall innovation efficiency of listed electric power companies is not high, the years of establishment and asset-liability ratio aggravate the redundancy of R&D expenditures, and the governmental inputs and the GDP of the region sometimes reduce the redundancy of R&D expenditures; except that the total assets do not have a significant effect on R&D investment redundancy, all other environmental variables increase R&D redundancy and limit the improvement of corporate innovation efficiency. (2) After removing environmental noise and random interference terms, the pure technical efficiency is significantly improved, leading to a decline in the comprehensive innovation efficiency. The results indicate that the lower innovation efficiency of listed electric power companies is mainly due to scale inefficiency. (3) After adjusting the input values, the sample enterprises are all in the optimal production scale or increasing returns to scale, and these sample enterprises can appropriately expand their production scale in order to obtain better scale efficiency and innovation efficiency.

Based on this, this paper puts forward the following suggestions:

(1) From the perspective of enterprises, expanding the scale is still the key to improve the innovation efficiency, and at the same time, enterprises should also rationally plan the resources to reduce the phenomenon of redundancy and waste of resources; in addition, enterprises should also actively implement the innovation strategy while improving the level of asset management and technology management. (2) From the government's point of view, the government should pay attention to the protection of intellectual property rights, improve the corresponding legislation on property rights, universities and research institutes, and enhance the enthusiasm of the main body of the enterprise in research and development; secondly, improve the government's subsidy policy, taking into account the reasonableness and social benefits, lastly, establish and improve the mechanism of talent flow to promote the orderly flow of talents. orderly flow of talents.

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