Research on Technological Innovation Performance of New Energy Enterprises Based on DEA Model

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Abstract: By the national policy and macroeconomic environmental impact, new energy enterprises are actively changing their business strategies to enhance their competitiveness. The evaluation of enterprise innovation performance is of great significance for managers to find out the problems and causes of enterprise innovation, optimize the allocation of enterprise resources, and further improvements of the innovation performance of enterprises. 34 new energy listed enterprises were selected as research objects, and use DEA method to analyse the innovation performance of new energy listed companies in 2019.

1 Background

Under the new normal of economy, continuously upgraded consumer demand, increasingly intensified market competition and other factors promote enterprises to carry out technological innovation, so as to gain sustained competitive advantages. The report of the 19th National Congress put forward that innovation is the first driving force to lead development. The Outline of the National Strategy for Innovation-Driven Development emphasizes that innovation-driven is the fate of the country, the general trend of the world, and also is asked from the development. Technological innovation promotes social development and is also the fundamental guarantee for enterprises to maintain their competitive advantages. Technological innovation is seen as a key driver of productivity growth. Enterprise is the main body of market economy, as well as the main body of all kinds of technology innovation activities. Through independent innovation, the enterprise develops new products, improves production technology, enhances production and operation efficiency, expands market share, and continuously creates benefits. The effectiveness of technological innovation activities needs to be judged by the market. The ability of technological innovation is an important part of the value of enterprises. The continuous and effective technological innovation activities are profitable to improving the core competitiveness and thus the value of enterprises.

The influence factors of technology innovation and economic consequences related research has been the educational world attention topic, especially the research on the relationship between technological innovation and enterprise innovation performance has made some achievements. Increasing factor input is the key factor to improve the innovation ability, and then improve the performance of enterprises' technological innovation. Generally speaking, the innovation performance of enterprises will increase with the improvement of technological innovation ability, especially for high-tech enterprises. However, studies have found that the technological innovation ability and efficiency of high-tech industries are lower than the average of the industry. Therefore, for new energy enterprises, they need to pay more attention to how to rationally optimize resource allocation. The resource of an enterprise is limited, so how to rationally utilize the resource allocation is the key.

2 Sample Selection and Source of Data

2.1 Principle of Selecting Samples

This paper selects new energy listed companies as samples, and the research period is 2019. Considering the high growth rate, fast technology update speed and short product life cycle of this industry, the data indicators related to innovation input and financial performance in the current year are selected for the research, regardless of the time lag problem. After eliminating the listed companies in the sample whose data are not fully disclosed, 34 listed companies in this industry are finally selected as samples.

2.2 The Source of Data

The data in this paper mainly include the R&D intensity, proportion of R&D personnel, the sales growth rate, the number of patents applied by enterprises, the labour productivity and the asset-liability ratio of 34 listed manufacturing enterprises in 2019. The specific situation of all enterprises is carried out in the DEA analysis section.

Most of the data came from CSMAR database, and some of the missing data were collected manually from listed companies' annual reports, cninfo Information Network, and the trading website of Shenzhen Securities Regulatory Commission, etc. Among them, the number of patents applied by enterprises in that year came from China Intellectual Property Network established by Intellectual Property Publishing House of the State Intellectual Property Office.

The indirect data and calculation methods are as follows:

R&D intensity = R&D funds of the enterprise in the current year/sales revenue of the enterprise in the current year

Proportion of R&D personnel = number of R&D personnel/number of active employees

Total labour productivity = industrial added value/average number of all employees

3 Data Analysis

3.1 Establish the Innovation Performance Evaluation System

Table 1. Enterprise Innovation Performance Evaluation Index System

First Level Evaluation Index	Second Level Evaluation Index	Third Level Evaluation Index
Innovation Input	Human Input	Proportion of R&D Personnel X_1/%
	Financial Input	R&D Intensity X_2/%
Innovation Output	Patent Output	Number of Patents Y_1
		Sales Growth Rate Y_2/%
	Other Output	Total Labour Productivity Y_3
		Asset-liability Ratio Y_4

Enterprise independent innovation is a complex and comprehensive process, and the founding of evaluation index system is the basis of enterprise innovation performance evaluation. A scientific evaluation system can analyse the innovation performance concretely and quantitatively to avoid one-sidedness in the investigation. The construction of new energy enterprises' innovation performance evaluation system needs to reveal the internal relationship between enterprise innovation activities and output so as to ensure that enterprises can adjust innovation input according to the results.

In the index system, the selection of each index has a direct effect on the scientificity, accuracy and practicability of results, and is more related to the adjustment of the innovation direction of enterprises. Specifically, the design of the index system should be based on rigor, objectivity, comparability and feasibility.

Based on the above principles, the following innovation performance evaluation index system is built, it's shown in Table 1. After examining the innovation input and output, the innovation input is divided into human input and financial input, of which the index of human input is the proportion of R&D personnel, and the index of financial input is the R&D intensity. Innovation output is divided

into patent output and others. The index of patent output is the number of patents applied by the enterprise during 2019, and the index of other output is the sales growth rate, the total labor productivity and the asset-liability ratio in the research year.

3.2 DEA Method

Data envelope analysis (DEA) model is a non-parametric method for evaluating the relative effectiveness of the same type of decision-making unit, without pre-estimating the form of production functions, It does not need to estimate the production function form in advance, but only according to the input and output of each decision-making unit of the original data can be relatively evaluated on efficiency. Therefore, it has strong objectivity. It mainly includes CCR model and BCC model. The main function of CCR model is to calculate the comprehensive or technical efficiency value of the technology and scale of the decision making unit, while BCC model can calculate the pure technical efficiency value, also can calculate scale efficiency value based on the division of comprehensive efficiency value by pure technical efficiency value.

In data envelopment model with constant return to scale, namely the C2R model, it is assumed that there are N department units (called "decision making units", abbreviated as DMU). DMUj (j = 1, 2,... ,n) represents the JTH decision unit. In the evaluation index system, each DMU contains M input index and T output index, which respectively represent "input resource" and "output utility". Xij stands for the input of the jTH decision unit to the iTH input index, and Yrj symbolizes the output of the JTH decision unit to the r output index.

$X_{ij} = (X_{1j}, X_{2j}... , X_{mj})$ T>0, $Y_{rj}= (Y_{1j}, Y_{2j}... , Y_{tj})$ T>0, S_i^-, S_r^+ are relaxation variables, and ε is non-Archimedian infinitesimal quantity, usually 10^{-6}, which are all parameters to be estimated. On the basis of CCR model, a constraint condition is added to obtain DEA-BCC model with variable return on scale.

$$\begin{cases} \min\theta - \varepsilon(\sum_{i=1}^{m} S_r^+ + \sum_{i=1}^{m} S_i^-) \\ s.t.\sum_{j=1}^{n} \lambda_j x_{ij} + S_i^- = \theta x_{j0} \\ \sum_{j=1}^{n} \lambda_j y_{rj} - S_r^+ += y_{jo} \\ \sum_{j=1}^{n} \lambda_j = 1 \\ S_i^-, S_r^+ \geqslant 0 \\ \lambda_j \geqslant 0 \\ j = 1,2...n \end{cases} \tag{1}$$

To solve the linear programming problem, let θ be the optimal value.

(1) If θ=1 and all the relaxation variables are 0, that is, Si-=0 and Sr+=0, then DMU is overall effective, that is, the decision making unit is both scale effective and pure technology effective.

(2) If θ=1 and the slack variables are not all 0, that is, Si-=0 or Sr+=0, then DMU is effective for weak DEA, it means the comprehensive efficiency is effective, but the input-output needs to be adjusted to some degree;

(3) If θ=1 and all the relaxation variables are not 0, then the DMU is invalid as a whole, indicating that DMUs are neither scale efficient nor purely technical efficient.

In recent years, the application of data envelopment model and its methods in technology innovation efficiency and innovation system efficiency has been further developed, which extends and deepens the theory and application of DEA model. Technological innovation input of enterprises has typical characteristics of knowledge economy, which is different from the law of diminishing marginal returns of traditional production function, resulting in certain uncertainty of enterprise performance of output. Therefore, this paper adopts the input-oriented DEA-BCC model to evaluate the changes of the comprehensive technical efficiency, pure technical efficiency, scale efficiency and scale return of the innovation performance of new energy enterprises, so as to put forward the improvement goals and plans for the enterprises that are not effective with DEA.

3.3 Empirical Analysis

On the basis of the enterprise innovation performance evaluation index system, this paper collects and collates the financial statements of 34 listed new energy enterprises, and obtains the data of innovation input and output of enterprises in 2019. By using DEAP2.1 software, the data of input and output of enterprises in 2019 are brought into the BCC model, and the evaluation results of innovation performance of listed new energy enterprises in 2019 are obtained.

3.3.1 Efficiency Value Analysis

According to the calculation results and combined with the above theories, the average comprehensive efficiency, average pure technical efficiency and average scale efficiency of 34 listed enterprises in 2019 are analyzed. Comprehensive efficiency refers to whether the input and output of the decision making unit have reached an effective state on the optimal production scale. The greater the value of comprehensive efficiency, the better the effect of resource allocation and the greater the efficiency of resource use. Pure technical efficiency is the relative efficiency of input and output under the assumption of constant return to scale. Efficiency of scale is the gap between the size and optimal size of the decision-making unit at the existing level of technology and management. The average DEA efficiency value in 2019 is presented in Table 2.

Table 2. 2019 DEA Efficiency Value of New Energy Listed Enterprises

Index Description	comprehensive efficiency	pure technical efficiency	scale efficiency
Average Value	0.465	0.673	0.702
Minimum Value	0.114	0.207	0.280
Maximum Value	1.000	1.000	1.000

According to Table 2, average comprehensive efficiency is relatively low, only 0.465, while the minimum value is only 0.114, which indicates that the innovation performance of sample enterprises is not ideal. To a certain extent, it shows the reliability of the research on the transformation of technological innovation investment into innovation performance measurement.

In 2019, the average pure technical efficiency was 0.673, higher than comprehensive efficiency 0.465, and the minimum value is only 0.207; also, the average scale efficiency is 0.702, indicating that the root cause of the overall low average comprehensive efficiency was that the low average pure technical efficiency. This also reflects that the new energy enterprises, as a whole have large-scale investment and expansion, but the actual technology and management level of the enterprises do not adapt to the scale of the enterprises.

3.3.2 Return of Scale Analysis

There are three different type of scale return: constant return, increasing return and decreasing return. The analysis of enterprise scale returns is conducive to the further study of the reasons for the low scale efficiency of enterprises. The concrete empirical situation is shown in Table 3.

Table 3. Scale Return of New Energy Listed Enterprises in 2019

Scale Return	Number	Proportion
Constant Return	7	20.59%
Increasing Return	4	11.76%
Decreasing Return	23	67.65%

As it's shown in Table 3, among the 34 listed enterprises, 7 enterprises have the same return on scale, accounting for 20.59% of the total number of enterprises, that is, 7 enterprises have reached scale efficiency and are at the optimal point of return on scale. The remaining 27 enterprises failed to reach scale efficiency, among which 4 enterprises have increasing returns to scale, accounting for 11.76% of the total, indicating the existence of excess capacity. There are 23 enterprises have decreasing returns, accounting for 67.65% of the total number of enterprises.

Among the 34 enterprises, most of them are in the situation of decreasing return, that is probably caused by the following reasons :(1) The enterprises blindly expand the scale. After the expansion of the scale, the reasonable division of labor within the enterprises is destroyed, and the production relations are difficult to coordinate, thus reducing the efficiency. (2) The increase of management. With the increasing production scale of the enterprise, the number of its management will be more and more, which will inevitably bring the problem of the enterprise's own production income. First of all, the increase in the number of managers leads to the waste of human resources and the increase in the salary to employees. Second, the number of managers will bring chaos within the enterprise. Finally, managers usually do not have the actual production capacity, which will also reduce the production efficiency of the enterprise.

In addition to the above reasons, due to the change of the macroeconomic situation, many enterprises blindly change their corporate strategies. A number of financial statements of enterprises in 2019 revealed that the substantial increase in expenses of enterprises was caused by the increase in R&D expenditure, but these enterprises only hoped to rapidly develop new products or improve the technological content of products by greatly increasing R&D personnel and R&D expenditure, but ignored the follow-up of relevant management.

4 Conclusion

The results show that increasing R&D investment, ensuring sufficient R&D funds and R&D personnel are the basis for improving enterprise technological innovation performance. On the basis of increasing resource investment, it is more important to adjust input structure and optimize resource allocation. Under the national innovation-driven development strategy, enterprises have increased their investment in technological innovation, but they have not fundamentally changed from scale to benefit. Technological innovation is a complex system and an open process. In addition to the technology itself, system, culture, strategy, organization and other factors can affect the performance of enterprises. For enterprises in the new energy industry, synergy among factors should be exerted according to the industry characteristics and their own actual situation to promote the all-round development of innovation-driven enterprises.

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