Research on Operational Efficiency and Total Factor Productivity of Provincial Power Grid Enterprise

—Based on the analysis of panel data of Henan Power Grid in 2012-2016

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Abstract: In this paper, using the panel data of 18 grid enterprises in Henan Province from 2012 to 2016, based on data envelopment analysis (DEA) method and Malmquist index, the operational efficiency and total factor productivity(TFP) of power grid enterprises in Henan are measured. The method can be promoted and applied in other provincial power grid enterprises, providing a scientific basis for grid enterprises to optimize operational decisions and increase the proportion of technological progress in output.

1. Introduction

TFP is the ratio of total output to real input. Compared with traditional economic growth evaluation, TFP emphasizes efficiency growth caused by management and technological progress, and also underlines high quality and sustainable development[1,2]. In order to accurately reflect the effectiveness of management and technological progress, it is necessary to conduct research on the operational efficiency and TFP of grid enterprises.

2. Evaluation model

2.1 Model Introduction

DEA is a quantitative calculation method for economic efficiency analysis of several decision making units (DMUs) with multiple inputs and outputs[3,4]. The Variable returns to scale(VRS) model considers variable returns to scale and is more in line with objective facts[5]. Suppose there are M DMUs that need to evaluate economic efficiency, including K input indicators and L output indicators. The model is expressed as:

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$$\begin{cases} min\left(\theta - \varepsilon\left(\sum_{k=1}^{K} s_k^- + \sum_{l=1}^{L} s_l^+\right)\right) \\ st.\ \sum_{m=1}^{M} x_{mk}\lambda_m + s_k^- = \theta x_k^m \quad k = 1,2,3,\ldots,K \\ \sum_{m=1}^{M} y_{ml}\lambda_m - s_l^+ = y_l^m \quad l = 1,2,3,\ldots,L \\ \sum_{m=1}^{M} \lambda_m = 1 \\ s_k, s_l^+, \lambda_m \geq 0 \quad m = 1,2,3,\ldots,M \end{cases} \tag{1}$$

x_{mk}represents the input of the kth resource of the mth DMU; y_{ml}represents the lth output of the mth DMU. θ（$0<\theta\leq1$）is the comprehensive efficiency index; $\lambda_m$is the weight variable; s_k^-ands_l^+ are the relaxation variables; $\varepsilon$is the non-Archimedes infinitesimal quantity; the constraint condition is$\sum_{m=1}^{M}\lambda_m = 1$.

2.2 Construction of Evaluation Index System

In order to accurately measure the TFP of Henan Power Grid and truly reflect the effectiveness of management and technological progress, “Grid Engineering Investment” and “110 kV and above Public Transformer Capacity” were chosen as the input factors; “Maximum Power Supply” and “Power Sold” were chosen as the output factors. The data comes from “the compilation of Henan Province Power Statistics”.

Correlation coefficient test is performed between the selected input-output variable data, and the results are shown in Table 1 and Table 2. It can be seen from the results that the selected two input variables are highly positively correlated with the output variables in most years, and are significant at the 1% significance level.

Table 1. Spearman correlation coefficient between two inputs and output 1

output 1- Electricity Sales	input 1- Power Grid Engineering Investment	input 2- Substation Capacity
2012	0.8163***	0.9546***
2013	0.6412***	0.9293***
2014	0.4118*	0.8865***
2015	0.3787	0.8019***
2016	0.6264***	0.9360***

Table 2. Spearman correlation coefficient between two inputs and output 2

output 2- Maximum Load of Power Supply	input 1- Power Grid Engineering Investment	input 2- Substation Capacity
2012	0.8266***	0.9360***
2013	0.6656***	0.9484***
2014	0.5624**	0.9401***
2015	0.6883***	0.9567***
2016	0.7482***	0.9360***

Note: *** indicates significant at 1% significance level, ** indicates significant at 5% significance level, and * indicates significant at 10% significance level.

3. Operational Efficiency Evaluation

3.1 Evaluation of Comprehensive Efficiency (CRSTE)

In 2012-2016, the number of effective DMUs increased from 3 to 4, and fell back to 2; the

efficiency increased from 16.7% to 22.2% and fell back to 11.1%, which means that Henan Power Grid had been tortuous on the road of management and development. In terms of the average CRSTE, the highest value is 0.847 in 2014, and the lowest value is 0.776 in 2016. Overall, the average CRSTE value of Henan Power Grid is not high, basically fluctuating around 80% from the frontier of efficiency. It shows that the overall management level of Henan Power Grid is not ideal enough, and nearly 20% of the resources are underutilized.

Table 3. Evaluation results of CRSTE of 18 power grid enterprises in Henan

	2012	2013	2014	2015	2016
CRSTE average	0.793	0.831	0.847	0.816	0.776
Maximum CRSTE	1	1	1	1	1
Minimum CRSTE	0.617	0.632	0.619	0.520	0.491
The number of effective DMUs	3	3	4	3	2
Effective rate /%	16.7	16.7	22.2	16.7	11.1

3.2 Analysis of the Returns to Scale(RTS)

The number of power grid enterprises with constant RTS has decreased, and about 85% of the enterprises have not yet reached the optimal scale. At the same time, the number of enterprises with increasing RTS is increasing, and the number of enterprises with decreasing RTS is decreasing, indicating that the most power grid enterprises is not effective mainly because the scale is too small, which has the potential to continue to expand.

The CRSTE reflects the overall level of business management, which is equal to the product of the pure technical efficiency(VRSTE) and the scale efficiency(SCALE). The SCALE is in a state of fluctuating change, and the VRSTE is declining year by year, indicating the resource utilization capacity of the 18 power grid enterprises has declined over time.

Table 4. Evaluation results of RTS of 18 power grid enterprises in Henan

Year	The number of DMUs			Efficiency means		
	Constant RTS	Decreasing RTS	Increasing RTS	CRSTE	VRSTE	SCALE
2012	3	6	9	0.793	0.910	0.880
2013	3	5	10	0.831	0.901	0.927
2014	4	5	9	0.847	0.883	0.961
2015	3	3	12	0.816	0.860	0.951
2016	2	2	14	0.776	0.838	0.928

3.3 Regional Comparison of Operational Efficiency

In terms of CRSTE from 2012 to 2016, the average efficiency of Central and North Henan is around 0.84, and is higher than the South Henan by about 0.07, indicating that the comprehensive management capability and resource utilization capacity of the Central and North Henan are generally better than South Henan. As for VRSTE, the difference between Central and North Henan is about 0.02, and the difference between North and South Henan is about 0.07. As for the SCALE, the average values of the three regions are all around 0.93, so there is little difference in scale. All of these indicate that the gap in CRSTE is mainly due to the gap in VRSTE.

Table 5. Evaluation results of regional comparison of operational efficiency

	Region	2012	2013	2014	2015	2016	5-year mean
CRSTE	North Henan	0.798	0.810	0.887	0.893	0.818	0.841
	Central Henan	0.846	0.838	0.858	0.846	0.829	0.843
	South Henan	0.745	0.843	0.812	0.736	0.699	0.767
VRSTE	North Henan	0.947	0.806	0.913	0.928	0.864	0.892
	Central Henan	0.951	0.884	0.911	0.911	0.920	0.915
	South Henan	0.848	0.921	0.838	0.769	0.749	0.825
SCALE	North Henan	0.847	0.911	0.970	0.965	0.951	0.929
	Central Henan	0.894	0.952	0.945	0.933	0.906	0.926
	South Henan	0.892	0.916	0.968	0.956	0.932	0.933

Note: North Henan includes: Anyang, Puyang, Hebi, Xinxiang and Jiaozuo; Central Henan includes: Sanmenxia, Luoyang, Jiyuan, Zhengzhou, Kaifeng and Shangqiu; South Henan includes: Xuchang, Luohe, Zhoukou, Zhumadian, Xinyang, Pingdingshan and Nanyang.

4. TFP Measurement

The output-oriented Malmquist index is used to measure the TFP of Henan Power Grid. In recent years, the values of Malmquist index are less than 1, indicating that the TFP of Henan Power Grid has gradually decreased.

The comprehensive technical efficiency change index (effch) is improving in 2012-2014, while the technological progress index（techch） is decreasing, which has a negative impact on TFP. The effch and the techch were all reduced in 2012-2014, which together lowered the TFP.

Table 6. TFP in Henan Province from 2012 to 2016

	Comprehensive efficiency change(effch)	Technological progress change(techch)	TFP & Malmquist index
2012-2013	1.048	0.985	1.032
2013-2014	1.017	0.924	0.939
2014-2015	0.962	0.949	0.913
2015-2016	0.950	0.862	0.819
mean	0.993	0.929	0.923

5. Conclusion

The DEA method is used to evaluate the operational efficiency of Henan Power Grid from the perspectives of CRSTE, VRSTE and SCALE, reflecting the trend and regularity of input and output efficiency of Henan Power Grid in 2012-2016.

First of all, from the perspective of CRSTE, the CRSTE of Henan Power Grid is in a state of volatility, and nearly 20% of the resources are not fully utilized. Secondly, from the perspective of the RTS, about 85% of grid enterprises have not yet reached the optimal scale. The most power grid enterprises is not effective due to the small scale. So these enterprises have potential for continued expansion. Thirdly, the comprehensive management capacity, resource utilization capacity of the Central and North Henan power grids are generally better, while the South of Henan is worse. The gap in CRSTE is mainly caused by the gap in VRSTE.

Finally, the Malmquist index is used to measure the TFP of Henan Power Grid. Under the current evaluation system, the TFP of Henan Power Grid in 2012-2016 is gradually decreasing. It is necessary to strengthen management, optimize power grid scale and input-output ratio, and achieve balanced development of 18 power grid enterprises by means of differentiated policies.

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