Assessment and Forecast of Operating Efficiency of Power Generation Industry in the Context of Electricity Marketization

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Abstract. The current research on the impact of electricity market reform on the power generation industry lacks comparative studies and targeted measures under the expected scenario. To fill this gap, this paper presents a micro-level analysis of 62 power generators from both static and dynamic perspectives based on the DEA-BCC model and the Malmquist index. In addition, on the basis of China's macro energy data collected, the TIMES model was used for scenario prediction, and a comparative analysis was made with the benchmark reference scenario, thus exploring the main factors affecting total factor productivity and making reasonable predictions on the energy structure and industry development prospects under the two scenarios. It can be seen from the results that carrying out the electricity marketization reform will effectively reduce the average electricity cost and share of coal power generation. Finally, on the basis of the analysis of the results, policy recommendations and development strategies have been proposed in a targeted manner.

1. Introduction
In 2015, China officially launched the second round of electricity marketization reform, which promotes the upgrading of power enterprises development and provides structural opportunities for the power industrial development[1]. Although the supply-demand relationship in China is relatively loose, the regional supply and demand are uneven: the structural power supply is surplus in the power rich generation resources regions in the northwest, and the structural power supply in the power-intensive regions in the southeast is temporarily tight. At the same time, Chinese power generation enterprises mainly use traditional coal-fired power generation. In order to meet the requirements of economic and social development, power enterprises should give strengths to their comparative advantages and increase the proportion of new energy power generation[2]. Under the background of Chinese energy structure transformation and power marketization reform, it has significance for the long-term development of China's power generation industry to analyze the changes of power generation industry operation efficiency[3]. The existing research on the impact of electricity marketization reform on the power generation industry is less focused on the dynamic efficiency evaluation and cost under the expected scenario[4]. In view of that, this paper aim to analyze the financial situation of Chinese power generation enterprises, model and evaluate the operation efficiency of Chinese power generation
industry from the meso and micro level, and draws conclusions and suggestions for the development of the power generation industry.

2. Methodology

In this paper, we select the high applicability method, data envelopment analysis model (DEA)[5], to measure the operational efficiency of power generation enterprises. Based on the annual report data of 62 listed companies from 2013 to 2018, the DEA-BCC model is selected to carry out a static comprehensive evaluation of their operational efficiency and the corresponding technical efficiency value, pure technical efficiency value, scale efficiency value and a series of associated values. Malmquist index and DEAP2.1 software are used to carry out dynamic comprehensive evaluation, quantitatively analyze financial influencing factors and operational efficiency of power generation enterprises, in which technical efficiency change = pure technical efficiency change × scale efficiency change, the growth rate of total factor productivity = technical efficiency change × technological progress. And scenario analysis based on TIMES model can be utilized to assess cost to make the results more comprehensive and reliable.

3. Results and Analysis

3.1. Static Operating Efficiency Assessment of Power Generation Industry

3.1.1. Technical Efficiency Analysis. By analyzing the technical efficiency (TE) of 62 listed power generation enterprises during 13-18 years, it can be found that the value is between 0.736 and 1, with an average value of 0.909. It shows that around 9.01% of the factor inputs in this industry have not brought benefits under certain production technology level. The overall operational efficiency of the power generation industry is in the medium-effective area. From the perspective of enterprises, 14 enterprises are located in the technical efficiency effective area, 41 enterprises are located in the medium effective area and 7 enterprises are at the low effective area. Among them, the actual production capacity of 14 effective DMUs has reached the maximum production capacity, and the technical efficiency (TE) is ahead of the production efficiency, reaching the optimal solution in both pure technical efficiency and scale efficiency. During 6 years, the number of enterprises with 1 of TE was 14 during 2013 to 2016, rising to 17 in 2017 and falling to 12 in 2018. Only 19.35%~27.42% of the total sample companies achieved effective TE.

3.1.2. Pure Technical Efficiency Analysis. There are 3 enterprises with pure technical efficiency (PTE) less than 0.8, which technical efficiency (TE) is also less than 0.8. The number of enterprises with the 1 value of pure technical efficiency (PTE) is in the interval of 20 ~28 during 2013~2018, among which 28 enterprises reached the maximum in 2014 and 20 enterprises decreased to the minimum in 2018. Statistics show that from 2013 to 2018, the percentage of sample companies achieving pure technical efficiency (PTE) is 38.71%, 41.94%, 33.87%, 40.32%, 33.87%, 32.26% of the total sample respectively.

3.1.3. Scale Efficiency Analysis. Based on the data of average value from 2013 to 2018, the scale efficiency (SE) average value of 62 listed power generation companies is 0.975, and none of them with DMU has scale efficiency value (SE) less than 0.8, which indicates that the overall industry scale efficiency has good effect. Further analysis shows that there are 17 DMU companies with effective scale efficiency (SE), of which 14 companies have effective integrated technical efficiency (TE), which means that the ineffectiveness of the other 3 companies’ integrated technical efficiency (TE) is caused by the ineffectiveness of their pure technical efficiency (PTE). Technical efficiency factors restrict the overall operating efficiency of these three companies, resulting in a significant reduction of their overall efficiency.
3.1.4. Return to Scale Analysis. There are 26 companies with decreasing returns to scale, 17 companies with constant returns on scale and 19 companies with increasing returns to scale. The overall return to scale of the power generation industry is not obvious. Among the 48 companies with ineffective overall technical efficiency (TE), there are 26 companies with decreasing returns on scale accounting for 54.17%, which should improve output efficiency by reducing factor input. There are 19 companies with increasing returns to scale, accounting for 39.58%, which should improve their output efficiency by increasing factor input. The number of companies with constant returns to scale, accounting for 6.25%, which should strive to improve the overall efficiency (TE) of enterprises by improving the pure technology efficiency (PTE).

3.1.5. Effective DMU Analysis: based on industry perspective. By dividing the total sample DMU according to the industry, it can be found that the percentage of new energy power generation enterprises, hydroelectric power generation enterprises, thermal power generation enterprises and heat power generation enterprises account for 19%, 35%, 39%, 7% of the total DMU respectively. The relative stability ranking of effective DMUs is clear. Among them, the reference frequencies of the first three Long-source electric power, CNTC and NEW China Electric are 26, 23 and 20, respectively, which has relatively stable business and operation. The reference frequencies of Zhaoxin Stock and Datang Power Generation are 1 and 2 respectively with the low relative stability of business and operation.

3.1.6. Slack Variable Analysis. In all sample of DMUs, there is no input redundancy or insufficient output for effective DMU enterprises, while ineffective DMU enterprises exist such phenomenon. Taking China nuclear power as an example, this invalid DMU has both input redundancy and insufficient output situation. In terms of input, the input redundancy value of the total operating cost element is 0.024, of the total asset element is 0.071. Therefore, it is necessary to reduce operating costs and reduce the total asset scale in the future. The investment redundancy value of the equity element attributable to shareholders of the parent company is 0.022, which means that the debt-equity structure needs to be adjusted. In terms of output, the output value of the EPS element is 0.099, and the output value of the operating profit element is 0.105. So the company's operating efficiency and management quality should be improved to enhance operating profitability.

From the improvement percentage of the overall average value of the power generation industry, on the input index, the improvement percentage of the total operating cost is 10.43%, of the total assets is 10.28%, and of the equity improvement percentage attributable to the shareholders of the parent company is 10.50%. On the output index, the percentage improvement of EPS is 35.70%, and of operating profit is 52.19%.

From different industries, the existence of input redundancy and insufficient output of the 9 ineffective DMUs in the new energy power generation industry is significant and has a lot of space for improvement. From the perspective of the average improvement percentage of the new energy power generation industry, in terms of input indicators, the improvement percentage of total operating costs is 12.89%, of total assets is 12.77%, and of equity attributable to shareholders of the parent company is 12.99%. In terms of output indicators, the improvement percentage of EPS is 30.72%, which is slightly lower than the overall level of the power generation industry; the improvement percentage of operating profit is 52.19%, which has reached the average level.

From the perspective of the average improvement percentage of the hydropower industry, in terms of investment indicators, the improvement percentage of total operating costs is 10.45%, the of total assets is 10.15%, and of equity attributable to shareholders of the parent company is 10.42%, which are almost the same as the level of the power generation industry. In terms of output indicators, the improvement percentage of EPS is 29.76%, which is lower than the overall level of the power generation industry; the improvement percentage of operating profit is 37.60%, which is significantly lower than the overall level of the power generation industry.

From the perspective of the average improvement percentage of the thermal power industry, in terms of investment indicators, the improvement percentage of total operating costs is 9.37%, of total assets is
9.23%, and of equity attributable to shareholders of the parent company is 9.24%. All three indicators are lower than the overall level of the power generation industry. In terms of output indicators, the improvement percentage of EPS is 41.02%, which is higher than the overall level of the power generation industry; the improvement percentage of operating profit is 55.57%, which is slightly higher than the overall level of the power generation industry.

From the perspective of the improvement percentage of the average value of the heat power industry, in terms of investment indicators, the improvement percentage of total operating costs is 7.29% and of total assets is 7.86%. The improvement space of the first two investment indicators is less than 8%, which is significantly lower than the overall level of the power generation industry. The improvement percentage in equity attributable to shareholders of the parent company is 9.29%, which is slightly lower than the overall level of the power generation industry. In terms of output indicators, the improvement percentage of EPS is 59.76%, which is higher than the overall level of the power generation industry; the improvement percentage of operating profit is 52.19%, which is slightly lower than the overall level of the power generation industry.

In addition, in the improvement percentage of input indicators, the improvement percentage of total operating cost, total assets and equity attributable to shareholders of the parent company have same proportion in each industry and table relative improvement situation. Among them, the improvement percentage of the three input indicators of the new energy power generation industry is ahead of all other industries, indicating that the new energy industry can expand the scale of assets and equity within its affordable range and achieve certain scale benefits.

In the percentage improvement of output indicators, the average improvement range of operating profit and EPS is relatively large, indicating that the whole industry should pay more attention to output management. From the perspective of the improvement percentage of EPS, the output index of the heat power industry is slightly higher than the overall level of the industry. Invalid DMU should proceed from the income side to balance the level of net profit and the proportion of equity. From the perspective of the percentage improvement of operating profit, this indicator of the new energy power generation industry is significantly higher than the overall level of the power generation industry. New energy power generation companies can start with operating profit, strengthen profit management and reasonably control the balance of revenue and expenditure.

3.2. Dynamic operation efficiency evaluation and scenario prediction of energy structure

3.2.1. Total factor productivity Change Analysis According to the results, the average value of total factor productivity is 1.010 from 2013 to 2018, which represents the overall increasing trend of total factor productivity, with an average annual growth rate of 1.0%. Specifically, the year with a larger growth rate of total factor productivity is 2013-2014 and 2016-2017, while 2014-2015, 2015-2016, 2017-2018 show a decline with 18.0%, 6.4% and 7.6% respectively. The number of companies with the change of total factor productivity (TFP) more than 1 is 39, of which the two companies with the largest increase had a change in total factor productivity of 13.6% and 12.4% respectively, which both belonged to the hydroelectric power industry. The two companies with the largest decline belong to the new energy power generation industry, whose total factor productivity changes are 12.5% and 8.9%, respectively.

3.2.2. Total factor productivity Change Decomposition Analysis From the technological progress (TECH), the average value from 2013 to 2018 is 1.022, which represents the overall growth trend of technological progress, with an annual average growth rate of 2.2%. In 2014 and 2017, there is a large increase in technological progress, up to 16.4% and 25.4% respectively. However, there were declines in 2015, 2016 and 2018, which reached 15.9%, 4.9% and 4.7%, respectively. Specifically, there are 44 companies (71% of the total sample) whose TECH change is greater than 1, among which the two companies with the largest increase belong to the hydropower and power generation industry. The two
companies with the largest declines belong to the new energy power generation industry and the hydroelectric power generation industry respectively.

From the perspective of the change of technical efficiency (TE), the average value from 2013 to 2018 is 0.988, which indicates that the overall trend of overall technical efficiency is decreasing, with an average decrease of 1.2%. Among them, the technical efficiency has an increase in 2013 and 2017, with an increase of 3.3% and 25.4% respectively. The technical efficiency has decreased in 2014, 2015, 2016 and 2018, with a decrease of 1.8%, 2.6%, 1.7% and 3.1%, respectively. Specifically, the variation of TE of 40 companies is less than 1. There are 5 enterprises with the largest decline, among them, 4 companies belong to the new energy power generation industry and one company belongs to the hydroelectric power industry. 7 enterprises have the largest increase, including 5 companies belong to the hydroelectric power generation industry and 2 companies belong to the new energy power generation industry.

3.2.3. Technical Efficiency Change Decomposition Analysis From the change of pure technology efficiency (PTE), the average value from 2013 to 2018 is 0.991, which represents that the overall change trend of pure technology efficiency is decreasing, with an average annual decrease of 0.9%. From 2014 to 2018, the pure technology efficiency showed a decreasing trend, with the decreases by 1.0%, 1.3%, 1.5%, 0.01% and 0.05% respectively. Specifically, 37 companies with less than 1 change in (PTE) have the largest decline. The two companies belonging to the new energy power generation industry have changes of 6.3% and 6.0% respectively. The two companies with the largest increase belong to the new energy power generation industry and the hydroelectric power generation industry, which increase by 4.9% and 4.2%, respectively.

From the change of scale efficiency (SE), the average value from 2013 to 2018 is 0.997, which represents that the overall scale efficiency is decreasing, with an average annual decrease rate of 0.3%. Among them, in 2017, the scale efficiency increased by 3.4%. The scale efficiency declined by 0.8%, 1.3%, 0.2% and 2.5% in 2014-2016 and 2018 respectively. Specifically, 31 companies had a change of less than 1.0 in scale efficiency (SE), of which the largest declining company had a change of 5.2% of SE, while the SE of largest increasing company had increased by 4.0%, which both belonged to the hydropower industry.

From the above analysis, the average total factor productivity (TFP) of 62 power generation companies from 2013 to 2018 was 1.010, with an average annual growth rate of 1.0%. The technological progress (TECH) under the total factor productivity split was 1.022, with an annual average growth rate of 2.2%. The technical efficiency (TE) was 0.988 with an average annual decrease of 1.2%. The pure technical efficiency (PTE) under the technical efficiency change split was 0.991, with an average annual decrease of 0.9%. The scale efficiency (SE) was 0.997, with an average annual decrease of 0.3%, which has extremely small change. It can be seen that the growth of technological progress (TECH) is the reason for the growth of total factor productivity (TFP) of power generation companies, which shows that listed power generation companies should pay attention to upgrading and transformation at the technical level.

4. Conclusions and Suggestions

4.1. Conclusion

The conclusions can be drawn as following. Statically, around 9.01% of the factors input in the industry do not have benefits and the overall technical efficiency of some enterprises has large difference. The return to scale of the power generation industry are not optimistic. In terms of input and output indicators, the improvement space is obviously. Dynamically, total factor productivity (TFP) shows an overall growth trend, in which the growth of technology progress (TECH) is the key factor for the growth of total factor productivity (TFP) of power generation companies, with the very little scale efficiency changes. From the reform of electrical market, the development of power marketization helps to reduce the average cost of electricity consumption, while it does not significantly promote the total power
The development of electricity market trading helps to reduce the share of coal power generation and increase the share of hydropower and photovoltaic power generation.

4.2. Suggestions
Power generation enterprises should use a forward-looking vision to rationalize their industrial layout. On the basis of adjusting the geographical location distribution of power supply towards rationalize, optimize the energy structure, enhance the timely response characteristics of demand-side management and ensure that the market share matches the original share of the enterprise. Strengthen the corresponding intensity of peak shaving and build a more information-based energy supply model. When the pure technical efficiency (PTE) of a certain decision-making unit (DMU) is less than 1 and the scale efficiency (SE) is 1, it is the best choice to improve corporate governance conditions and enhance company management capabilities. Companies with low scale efficiency should take specific conditions into consideration. If the returns to scale increase, they should devote themselves to expanding the scale of production to form returns to scale of the enterprise; if the returns to scale are diminishing, they should judge industry trends more carefully, control the scale of production, and the Integrate some low-efficiency production units, which are more conducive to the overall efficiency of the enterprise.

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