DYNAMIC ENVIRONMENTAL EFFICIENCY ANALYSIS ON CHINA'S GENERATION SECTOR: A GAME CROSS MALMQUIST APPROACH

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Overview

China's current electricity management mechanism has initially taken shape since 2003 as a result of the unbundling power reform introduced in 2002. In general, this reform has gained success in the generation sector by establishing quite many companies and intensifing the competitiveness among them in recent years. Despite of the management mechanism changes, the power industry has kept as a pillar of the economy. Benefiting from the fast development of China's economy, its power generation has leapt to the first in the world since 2010. Simutaneously, it is proved that the increasing power consumption is a double-edged sword as thermal power generation also leads to large amount of carbon dioxide (CO_2) emissions.

China issued "Greenhouse gas emissions control program during the 13th Five Year" in November 2016, which further confirmed the electric industry as one of the key industries in implementing carbon emission quota control mechanism. Not all the power generation groups performed as expected under the competitive market,especially when we take the environmental factors into consideration. In order to better reflect the dynamic environmental efficiency changes of generation groups, this study puts forward the concept of Game Cross-Malmquist Index which combines the Game Cross-efficiency and Malmquist Index to investigate the influence of the competitiveness on the power market during 2003-2013. The results may provide decision supports for the improvement of generation sectors' competitiveness and future power reforms.

Methods

Data envelopment analysis (DEA) is a popular approach in environmental efficiency studies. The Game Cross-efficiency is one appraoch incorporating DEA Cross-efficiency and game theory, which may take the competition among DMUs into consideration to give a specific ranking for them. For the DMU_j , $j = 1, 2, \cdots, n,$ which has m inputs and s outputs, the cross efficiency will be solved once for each $d = 1, 2, \cdots, n$, that is, it will be solved n times altogether. The game d-cross efficiency for each DMU_j can be defined as follows:

$$\alpha_{dj} = \frac{\sum_{r=1}^{s} \mu_{rj}^{d} y_{rj}}{\sum_{i=1}^{m} \omega_{ij}^{d} x_{ij}}, \qquad d = 1, 2, \cdots, n,$$

where μ_{rj}^{d} and ω_{ij}^{d} are optimal weights for $x_{ij}\left(i = 1, 2, \cdots, m\right)$ and $y_{rj}(r = 1, 2, \cdots, s)$ respectively when evaluating the performance of the DEA efficiency of DMU d .

The Malmquist Index, which is also based on DEA, is a popular tool to measure the dynamic Total Factor Productivity changes. Similar to traditional DEA approach, the results of Malmquist index model are always controversial due to its subjectiveness in choosing variables and inaccurateness of the results. Things become even worsen when there are quite a few DMUs lying on the frontier. To overcome these drawbacks, this study incorporates the cross efficiency approach for peer evaluationw with Malmquits index to discriminate the efficient DMUs, and proposes a Game Cross- Malmquist Index (GMI) approach to measure the environmental efficiency of generation groups under the competitive power market, which is well suited to the increasing competitiveness in China's generation sector. And the Game Cross-efficiency Malmquist Index can be written as follows:

$$GMI_k = \left[\frac{E_k^t\left(x_k^{t+1}, y_k^{t+1}\right)}{E_k^t\left(x_k^t, y_k^t\right)} \frac{E_k^{t+1}\left(x_k^{t+1}, y_k^{t+1}\right)}{E_k^{t+1}\left(x_k^t, y_k^t\right)} \right]^{\frac{1}{2}}$$

where $E_k^t\left(x_k^{t+1}, y_k^{t+1}\right)$ is the modified Game Cross-efficiency for DMU k in period $t+1$ under the production frontier of period t for the generation sector.

Results

With the exception of a slightly dynamic environmental efficiency decline at the end of the study period, there is no significant GMI changes, and the average efficiency has kept fluctuating around 1 over the period.

The efficiency change and technical progress shared the same trends with the GMI, which reached the highest point in 2011-2012 and then declined. The efficiency changes contributed more to the GMI than the technological progress.

There was a significant gap among generation groups in dynamic environmental efficiency. The ones with big share of hydro power have achieved a rising dynamic environmental efficiency while the efficiency of thermal power-dominanted ones showed a reversial trend.

Conclusions

The Game Cross-Malmquist Index approach may obtain more objective and reliable results in estimating the dynamic environmental efficiency since it can reflect the competitive relationship between generation corporations. The results indicate that China should continue to forward favourable policies to boost technology progress; furthermore, not all the clean power technology should be developed at the same pace, and the proportion of intermittent generation forms, such as wind power and solar power, should be confined to a suitable level to balance the environmental appeals and stable power supply.

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