COMPARATIVE ANALYSIS OF OPERATIONAL EFFICIENCY OF LARGE-SCALE SOLAR POWER GENERATION COMPANIES

Nan CHEN, Department of Transdisciplinary Science and Engineering, School of Environment and Society, Tokyo Institute of Technology, chen.n.ac@m.tietch.ac.jp
Mika GOTO, Department of Innovation Science, School of Environment and Society, Tokyo Institute of Technology, goto.m.af@m.titech.ac.jp

Overview

Toward the carbon-neutral society, one of the promising renewable energy resources is a solar photovoltaic (PV) power generation whose cumulative installed capacity has been dramatically increasing over the globe, from approximately 40 gigawatts (GW) in 2010 to over 700 GW in 2020. Under the circumstance, the efficient operation of solar PV companies is a key to promoting the use of solar PV generation and achieving the green growth of the economy. However, information on operation and management, particularly on large-scale solar PV companies, has not been well accumulated in previous studies. This study assesses the operational performance of the large-scale solar PV power generation companies in the world and discusses management implications from the results.

Methods

This study applies data envelopment analysis (DEA) and Malmquist productivity index (MI) to evaluate the efficiency of 20 large-scale solar power generation companies in the world from 2011 to 2020. DEA, initiated with Cooper et al. (1978), is a popular non-parametric frontier method for the performance assessment of various organizations, which measures the holistic efficiency of different decision-making units (DMUs) by comparing their data to the most efficient ones as benchmarks. The constant returns-to-scale (CRS) model and variable returns-to-scale (VRS) model are the most common models in DEA. To clearly identify performance differences and analyze trends and regional features among companies, we use DEA super-efficiency model (SEM) and global Malmquist index (GMI), proposed by Pastor and Lovell (2005), for the measurement. The GMI is designed to overcome the disadvantages of the standard MI of non-circularity, infeasibility in linear programming, and multiple measures of productivity change. Further, we decompose the GMI to technical efficiency change (TECH) and best practice change (BPCH) components. Unlike the conventional CRS and VRS models, efficiency scores of SEM have stronger discriminating capability across DMUs. The MI and GMI enable us to deal with time-series performance assessments. This study uses six financial measures for the performance analysis, consisting of three inputs and three outputs. The three inputs are total assets, total operating expenses, and capital expenditures. The three outputs are total revenue, EBITDA, and total enterprise values. To conduct a comparative analysis, this study classifies the 20 solar power generation companies into four groups based on the following rules. Group 1 includes companies whose business area covers only one country/region; Group 2 includes companies whose business covers more than one country/region and the primary office is in North America; Group 3 is the same as Group 2 but the primary office is in Europe; Group 4 is the same as Group 2 but the primary office is in other areas.

Results

From empirical results, we obtain eight findings. First, Group 1 shows higher performance in operational efficiencies with CRS and VRS models over the study period, although they interact and change their relative efficiency levels. The decrease in 2012 and 2013 for CRS and that in 2016 and 2017 for VRS are evident and worth noting. Second, Group 3 constantly presents a lower level of efficiencies with CRS and VRS models. Third, Group 2 is the lowest in scale efficiency (SE) since 2015, showing a potential room for improvement of scale-related strategy. Fourth, the result of SEM shows more differences in DMUs with high efficiencies. For group 1, the average efficiency and median efficiency are still the highest among all groups though the volatility is higher than that of CRS model, which means that power producing companies focusing on one area are operating more efficiently in comparison to those that are doing business in different countries/regions. Fifth, the efficiency of Group 4 shows a feature of high average value and high volatility, meaning a large gap between maximum and minimum value. Sixth, the results of GMI show that operational efficiency of all four groups has grown varying from 2% for Group 3 to 7.9% for Group 4 over the 10 years of the study period. It is noted that Groups 1 and 4 have relatively large volatility and gap between extreme values. Seventh, by decomposing the larger changes of Groups 1 and 4 into TECH and BPCH, we can see that TECH of four groups is more distinguishing than BPCH. In particular, the major reason for the rapid increase in GMI of Group 1 in 2012 and 2013 is its TECH attaining high-level value. This indicates that companies transacting in only one country/region are doing better in operational performance than those transacting in various countries/regions. This is probably due to management efficiency arising from the adoption of a single country/region' institution to cope with. Eighth, the temporal development of BPCH indicates that compared with the best practice, companies' technology has improved in a steady way.

Conclusions

This study applied DEA and MI/GMI to evaluate the efficiency of 20 large-scale solar power generation companies in the world from 2011 to 2020. To clearly distinguish performance differences and analyze the trend and regional features among companies, we used SEM and GMI for the measurement. In addition, we decomposed the GMI to TECH and BPCH components. From empirical results, we revealed eight findings and discussed management implications. Input and output data expansion to incorporate not only financial but also technology variables would be a future extension of this study.

References

Charnes, A, Cooper, WW, Rhodes, E. 1978. Measuring the efficiency of decision making units. *European Journal of Operational Research* 2(6): 429-444.

Pastor, JT, Lovell, CAK. 2005. A global Malmquist productivity index. *Economics Letters* 88(2): 266–71.