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Assessing the Environmental Efficiency of China's Power System: A Spatial Network Data Envelopment Analysis Approach

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Abstract : The climate issue has aroused global concern. Achieving sustainable development is a good path for countries to mitigate environmental and climatic pressures, although there are many difficulties. The first step towards sustainable development is to evaluate the environmental efficiency of the energy industry with proper methods. The power sector is a major source of CO2, SO2, and NOx emissions. Evaluating the environmental efficiency (EE) of power systems is the premise to alleviate the terrible situation of energy and the environment. Data Envelopment Analysis (DEA) has been widely used in efficiency studies. However, measuring the efficiency of a system (be it a nation, region, sector, or business) is a challenging task. The classic DEA takes the decision-making units (DMUs) as independent, which neglects the interaction between DMUs. While ignoring these inter-regional links may result in a systematic bias in the efficiency analysis; for instance, the renewable power generated in a certain region may benefit the adjacent regions while the SO2 and CO2 emissions act oppositely. This study proposes a spatial network DEA (SNDEA) with a slack measure that can capture the spatial spillover effects of inputs/outputs among DMUs to measure efficiency. This approach is used to study the EE of China's power system, which consists of generation, transmission, and distribution departments, using a panel dataset from 2014 to 2020. In the empirical example, the energy and patent inputs, the undesirable CO2 output, and the renewable energy (RE) power variables are tested for a significant spatial spillover effect. Compared with the classic network DEA, the SNDEA result shows an obvious difference tested by the global Moran' I index. From a dynamic perspective, the EE of the power system experiences a visible surge from 2015, then a sharp downtrend from 2019, which keeps the same trend with the power transmission department. This phenomenon benefits from the market-oriented reform in the Chinese power grid enacted in 2015. The rapid decline in the environmental efficiency of the transmission department in 2020 was mainly due to the Covid-19 epidemic, which hinders economic development seriously. While the EE of the power generation department witnesses a declining trend overall, this is reasonable, taking the RE power into consideration. The installed capacity of RE power in 2020 is 4.40 times that in 2014, while the power generation is 3.97 times; in other words, the power generation per installed capacity shrank. In addition, the consumption cost of renewable power increases rapidly with the increase of RE power generation. These two aspects make the EE of the power generation department show a declining trend. Incorporation of the interactions among inputs/outputs into the DEA model, this paper proposes an efficiency evaluation method on the basis of the DEA framework, which sheds some light on efficiency evaluation in regional studies. Furthermore, the SNDEA model and the spatial DEA concept can be extended to other fields, such as industry, country, and so on.

Keywords : spatial network DEA, environmental efficiency, sustainable development, power system
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