Reinhard Madlener, Carlos Henggeler Antunes and Luis C. Dias

COMBINING DATA ENVELOPMENT AND MULTI-CRITERIA ANALYSIS FOR ASSESSING THE PERFORMANCE OF COGENERATION PLANTS

Reinhard Madlenera: German Institute for Economic Research (DIW Berlin), Königin-Luise-Straße 5, 14195 Berlin, Germany, and Centre for Energy Policy and Economics (CEPE), Department of Management, Technology, and Economics, ETH Zurich, Zurichbergstrasse 18 (ZUE E), 8032 Zurich, Switzerland
Email rmadlener@ethz.ch
Carlos Henggeler Antunes: Department of Electrical Engineering and Computers, University of Coimbra and INESC Coimbra, Rua Antero de Quental, 199, Coimbra, Portugal
And Luis C. Diasc: Faculty of Economics, University of Coimbra and INESC Coimbra, Rua Antero de Quental, 199, Coimbra, Portugal

Overview

This paper compares multi-criteria decision aiding (MCDA) and data envelopment analysis (DEA) approaches for assessing renewable energy conversion plants, in order to determine their relative performance in terms of economic, environmental, and social criteria and indicators. The case is for a dataset of 41 agricultural biogas plants in Austria. The results indicate that MCDA constitutes an insightful approach that can be used in a complementary way to DEA, namely in situations requiring a meaningful expression of managerial preferences concerning the relative importance of evaluation aspects to be considered in performance assessment.

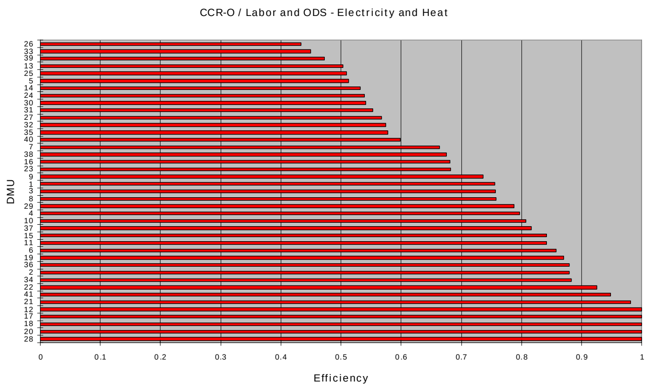
Methods

DEA is a non-parametric performance measurement technique, based on linear programming (LP), for assessing the relative efficiency of DMUs (e.g. Cooper et al., 2000). DMUs are homogeneous entities (such as sales outlets, electricity distribution companies, bank branches, schools, etc.) with some decision autonomy, operating a production process that converts a set of inputs into a set of outputs. DEA models use these inputs and outputs to compute an efficiency score for a given DMU when this particular DMU is compared with all the other DMUs considered. The relative efficiency of a DMU is defined as the ratio between the sum of its weighted output levels to the sum of its weighted input levels. The weights are chosen by the LP model such that a DMU is ‘shown in its best light’, i.e. that its efficiency score is maximized.

In assessments of the performance of DMUs in which technical, economic and environmental aspects are at stake, it is often important to use known standards (or theoretical maxima) and efficiency profiles. Also, there are situations in which DMUs must be appraised for efficiency on an “as they come” basis, i.e., they are not included in a given set of DMUs. This required capability of evaluating each DMU in absolute terms, and not just in comparison with other peers, as well as the need to include evaluation aspects expressed in different units, and even measured qualitatively (i.e. allowing for independence towards scales), can be achieved using the ELECTRE TRI method (Yu, 1992). ELECTRE methods are based on the construction and exploitation of a so-called outranking relation between courses of action (here: DMUs). In our analysis four efficiency categories are defined to classify the DMUs according to their efficiency (poor, fair, good, very good). The aim is to assign each plant to one of these ordered categories according to the multiple evaluation criteria considered. After the performance data of the DMUs for the different criteria have been introduced, the reference profiles are required, which define the limits between each category (we define the profiles such that about one fourth of the plants falls in each category according to each indicator individually). Classification results can be shown for different rules that have to be obeyed (i.e. a minimum number of indicators that place a particular DMU in a specific category).

Results

Figure 1 depicts the outcome of the DEA for two different model specifications (CCR and BCC, both output-oriented). In each of the model specifications reported, we have used substrate and labor as factor inputs and the amount of net electricity and external heat as (desirable) outputs (i.e. the electricity and heat supplied outside the biogas plant). Methane emissions have been considered as well in these first models, as an undesirable output to be minimized.



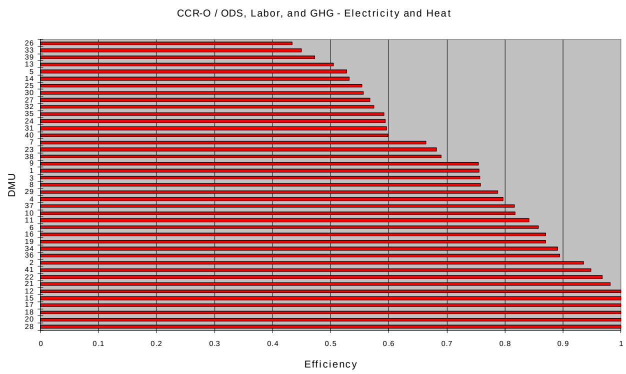


Fig. 1: DEA results, CCR-O model (with and without methane emissions as undesirable output)

Table 1. Classification results for different rules (excerpt)

DMU	Optimistic	50% majority	Pessimistic	DMU	Optimistic	50% majority	Pessimistic
1	3	2	1	22	4	4	1
2	4	3	2	23	3	3	2
3	4	4	3	24	4	2	1
4	4	3	1	25	4	2	1

Conclusions

DEA is a data-oriented approach that requires no *a priori* specification of the functional form of the production model converting inputs into outputs. Units are then free to choose their most favorable weights for becoming efficient when compared with their peers. On the other hand, this can present a disadvantage whenever over-specialization must be avoided in the consumption of inputs or the production of outputs, which amounts to practically ignore some inputs and outputs. Moreover, managerial preference information is often required, since inputs and outputs do not generally have the same importance in assessing the efficiency of operational units. Therefore, models for efficiency evaluation must explicitly incorporate meaningful techniques to take weights into account, understood as coefficients of relative importance of inputs and outputs. This has been the main motivation for the use of MCDA techniques, in order to assess the extent by which these could overcome those characteristics of DEA, and what adaptations would be needed to improve the quality of the assessment. Therefore, we are not proposing MCDA as an approach to replace DEA as a performance evaluation tool, but rather as a complementary technique, namely as far as the meaningful introduction of managerial preferences is concerned.

References

Cooper, W.W., Seiford, L.M., Tone, K., 2000. Data Envelopment Analysis: A Comprehensive Text with Models, Applications, References and DEA-Solver Software, Kluwer Academic Publishers, Boston/Dordrecht/London.

Yu, W., 1992. ELECTRE TRI: Aspects méthodologiques et manuel d'utilisation. Document du LAMSADE 80, Université Paris-Dauphine.