Efficiency analysis:
A multi-output nonparametric approach

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Executive summary

Benchmarking is a technique used by Decision Making Units (DMUs) to enable continuous quality improvement. Benchmarking includes almost any activity that compares a DMU's performance with some standard. Benchmarking offers the possibility of optimizing the DMU’s processes, services, outcomes and products through these comparisons. Quite often, benchmarking is understood to be an act of imitating or copying but in reality benchmarking proves to be a concept that helps in innovation rather than imitation. Though benchmarking is not new, it has become popular both as an analytical research instrument and a practical decision-support tool. To some, benchmarking is not a choice; it is a necessity. Indeed, the penalty for neglecting proper benchmarking is loss of competitive edge, which is the key to survival and profitability.

Usually, benchmarking involves four distinct phases. **Phase I**: determine the set of comparison partners. There are three types of benchmarking procedure: internal benchmarking (i.e. the benchmark is chosen within the same organization), functional benchmarking (i.e. the benchmark is chosen regardless of which industry they are) and competitive benchmarking (i.e a competitor is used as the benchmark). **Phase II**: collect the data. Much information is already in the public domain (financial reports, newspaper reports, analysts’ reports) but it is unlikely to provide all the information required for a successful benchmarking exercise. **Phase III**: analyze the collected information which results in the creation of a model and an identification of performance gaps. The model will have huge influence on the results. It is crucial to motivate all assumptions made in that phase. The model could be specific to the benchmarking exercise. **Phase IV**: the action phase. Analyzing the reasons for the performance differentials and use the findings to redefine goals, redesign processes, and change expectations regarding the evaluated DMU’s own functions and activities.

Amongst the models chosen in **Phase III**, Data Envelopment Analysis (DEA) has received more and more attention in the benchmarking literature. The goal of such analysis is to evaluate the efficiency of a DMU by comparing its input-output performance to that of other DMUs operating in a similar technological environment. The increasing attention for DEA could be explained by two main reasons. On the one hand, DEA does not resort to any unverifiable parametric/functional specifications of the production technology but rather lets the data speak for themselves by reconstructing the production possibilities using the observed inputs and outputs and imposing some technology axioms (such as monotonicity, convexity, returns-to-scale). Consequently, DEA is nonparametric in nature. On the other hand, deviation from efficiency, which is measured as the distance to the reconstructed production possibilities, is very easily computed. Indeed, the computation of the efficiency
measures merely requires solving simple linear programming problems.

Recently, Cherchye et al (2008, 2013) argued that standard DEA models provide a black-box treatment of efficiency production behavior since they ignore the links between inputs and outputs, i.e. they implicitly assume that all the inputs produce all the outputs simultaneously. This assumption is not plausible in several applications (e.g. employees that are allocated to different productions processes, specific capital which is used to produce only one type of goods). These authors suggested a multi-output nonparametric efficiency measurement technique, based on a cost minimization condition, which uses available information on the allocation of inputs to outputs. The new methodology characterizes each output by its own production technology while accounting for interdependencies between the different output-specific technologies giving rise to scope economies. This methodology provides a more realistic modelling of the production process and has a bigger ability to detect inefficient behavior (i.e. has more discriminatory power) than standard DEA techniques.

In this thesis, we extend the method suggested by Cherchye et al (2008, 2013) in several directions. Firstly, we incorporate bad outputs (in contrast to good outputs). This extension deals in a natural way with several limitations of existing DEA approaches to treat undesirable outputs. As demonstrated with our application to the electricity sector. Next, we extend the methodology to allow for output-specific returns-to-scale assumptions. This allows for a more flexible model that does not force the practitioners to choose the same returns-to-scale assumption for all the outputs (as it is the case for the standard DEA model). This simultaneous choice could be difficult to defend in several settings but it is surely the case when undesirable outputs are present in the production process, as demonstrated in our application. Next, we extend the methodology for multi-output producers by considering a dynamic context. We suggest a new productivity index which takes the form of a Malmquist Productivity Index. Finally, we also generalize the method of Cherchye et al (2008, 2013), based on a cost minimization condition, to a profit maximization condition. This establishes a novel DEA toolkit for profit efficiency assessments in situations with multiple inputs and multiple outputs. We apply this new model to the case of electricity plants.