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Efficiency evaluations with context-dependent and measure-specific data envelopment approaches: An application in a World Bank supported project☆

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ABSTRACT

We evaluate the efficiency of decision making units (DMUs) in a World Bank supported Social Risk Mitigation Project (SRMP) in Turkey through context-dependent and measure-specific data envelopment analysis (DEA) approaches. The results suggest that the efficiency evaluations with context-dependent and measure-specific DEA play various roles in an organization such as setting attainable targets to DMUs, setting long and short term targets to DMUs separately, grouping of DMUs, and improving internal competition between DMUs. Four main contributions of this study can be summarized as follows. Firstly, the study shows the applicability of context-dependent and measure-specific DEA methodologies in a World Bank supported large scale project to increase the effectiveness of the project. Secondly, it outlines some important managerial conclusions of context-dependent DEA clustering approach. Moreover, we propose an alternative approach for attractiveness scores computations in case of exogenous group formations. Finally, the study proposes and applies measure-specific version of context-dependent DEA approach.

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1. Introduction

Data envelopment analysis (DEA) is a non-parametric approach for identifying relative efficiency of "decision making units" (DMUs) when there are multiple inputs and outputs [1–3]. DEA models have been widely applied for the efficiency evaluation throughout different industries, including public and private sectors. Recent applications can be found in Hua et al. [4], Gutiérrez-Nieto et al. [5], Kao and Hung [6], Yu and Lin [7], Erbetta and Rappuoli [8], Eilat et al. [9], Botti et al. [10], Wu et al. [11], Das et al. [12].

When the relative efficiency of the DMU set is evaluated using DEA approach, DMUs are differentiated into two groups: efficient DMUs and inefficient DMUs. Efficiency scores of inefficient DMUs can be distributed between 0 and 1 at all levels. This widespread distribution is particularly occuring in situations where the DMUs do not perform identical activities or in situations where the input–output compositions exhibit great variations due to exogenous factors. In a DEA based efficiency evaluation study performed by Zhu [13] for Fortune 500 companies, 75% of DMUs had efficiency scores below 0.5. When reference sets and efficiency targets for inefficient DMUs are determined using this approach, one often ends up with targets that are very difficult or are impossible to achieve. Therefore, it is important to determine achievable targets for inefficient DMUs. Otherwise, DEA approach will become useless for such problems. This is the main research subject of this paper. In such cases, there could be two alternatives to determine realistic input–output improvement for an inefficient DMU.

One alternative could be to ask DMU gradually improve its input–output values and become efficient over time. However, this approach would lead to subjectivity in the determination of sub-targets that would gradually approach the efficient frontier over time. On the other hand, when the inefficient DMUs are large in number it would not be possible and convenient to determine separate sub-targets for each inefficient DMU, nor would it be realistic to assign the same sub-target for each inefficient DMU. As a result, such an approach would negate the strongest feature of DEA analysis, namely, objective performance evaluation in multiple input–output cases.

Second alternative that is developed by Charnes [14] is based on dividing DMUs into homogenous sub-groups and then applying DEA analysis to this sub-groups separately. Major deficiency of this approach is difficulties during group formation process. Sometimes a DMU could belong to more than one group. In addition to this, reference set of an inefficient DMU would be only from its sub-group. To top all these, even though the sample can be separated into homogeneous sub-groups, it is still possible to end up with the DMUs that would have impossible to achieve sub-targets.

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In this study, we utilize a DEA based clustering methodology that enables assigning achievable goals to inefficient DMUs based on their own cluster reference set to solve the above mentioned problem. Although there are several studies in the literature that are dealing with ranking issues in data envelopment analysis [15–17] the number of studies that concentrate on clustering through DEA is limited. The context-dependent DEA concept presented by Zhu [18] can be, in a manner, counted as one of these studies.

The context-dependent DEA approach starts with clustering the DMUs and obtaining several performance levels. For this purpose, an algorithm is developed to remove the best-practice frontier to allow the remaining (inefficient) DMUs to form a new second-level best-practice frontier. If this new second frontier is removed, a third-level best-practice frontier is formed, and so on, until no DMU is left [18]. Each evaluation level represents an efficient frontier composed by DMUs in a specific performance level. Using this methodology, it is possible to cluster DMUs into groups with a non-parametric approach. The next step of context-dependent DEA approach after clustering the DMUs to several levels is the calculation of attractiveness and progress scores to produce a ranking at every performance level [19,20].

In this study, we examine the level-by-level improvement part of context-dependent DEA. We particularly concentrate on some significant managerial conclusions of this approach. Because context-dependent DEA clustering methodology enables assigning achievable goals to inefficient DMUs based on their own cluster reference.

On the other hand, in some cases, it may be impossible for a DMU to improve all of the inputs or outputs proportionally at the same time. For these types of situations, measure specific data envelopment models can be used [13,21,22]. Measure-specific models take sets of specific inputs or outputs of interest and give the target values for only those factors. The use of these models can be appropriate for the situations where only one or some of the inputs or outputs can be intervened. At this point, we also applied the measure-specific DEA model in order to obtain more achievable targets for DMUs. In addition to this, we applied measure-specific version of context-dependent DEA model.

This study also examines context-dependent DEA based efficiency evaluation approach to measure the relative efficiency of DMUs in a World Bank supported Social Risk Mitigation Project (SRMP) in Turkey. Two main components of the SRMP, namely "Conditional Cash Transfers" and "Local Initiatives" components, were extensively carried out by Social Solidarity Foundations in all provinces of Turkey. We developed both the context-dependent DEA and the measure-specific context-dependent DEA based efficiency evaluation methodology of these Social Solidarity Foundations to determine their performance rankings. The context-dependent DEA methodology determines the efficient Social Solidarity Foundations, as well as targets need to be attained to become efficient and efficiency layers of DMUs.

The results suggest that context-dependent DEA and the measure-specific context-dependent DEA approaches can effectively be used as a performance evaluation methodology in large scale projects. In addition to this superiority, the performance measure plays different roles in an organization such as setting attainable targets to DMUs, setting long and short term targets to DMUs separately, grouping of DMUs, and improving internal competition between DMUs.

Eventually, four main contributions of this study can be summarized as follows. Firstly, the study shows the applicability of context-dependent and measure-specific DEA methodologies in a World Bank supported large scale project to increase the effectiveness of the project. Secondly, it outlines some important managerial conclusions of context-dependent DEA clustering approach. Moreover, we propose an alternative approach for attractiveness scores computations in case of exogenous group formations. Finally, the study proposes and applies measure-specific version of context-dependent DEA approach.

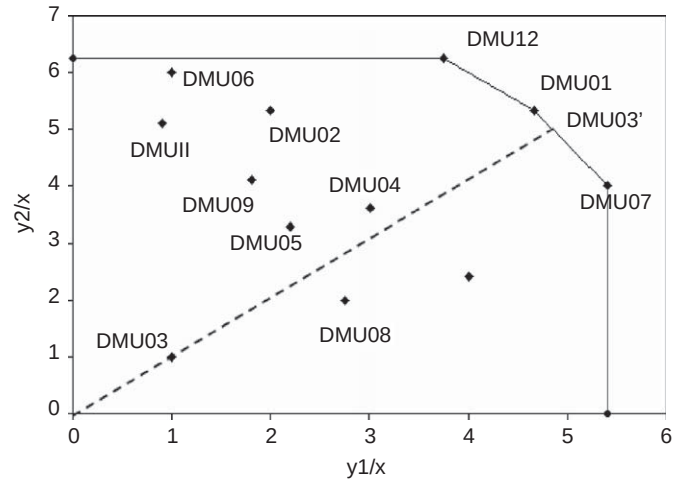

Fig. 1. Output oriented standard DEA efficient frontier for hypothetical example.

The rest of the paper is arranged as follows. Second section of the study explains context-dependent DEA approach. Third section proposes mathematical foundation of measure- specific version of context-dependent DEA model. Fourth part summarizes the managerial conclusions of the context-dependent DEA approach. Social Risk Mitigation Project in Turkey is briefly explained in fifth part. We also present the data and the dimensions of the application in this section. An application of both the context-dependent and the measure specific context-dependent DEA methodologies in a World Bank supported large scale project is performed in the sixth part.

2. Context-dependent DEA

2.1. Clustering the DMUs

Zhu's clustering approach [18] in context-dependent DEA can be summarized as follows. Assume that there are n DMUs which have k outputs and m inputs. We define the set of efficient DMUs as E and set of all DMUs as $\boldsymbol{N}$. Then the DMUs in set $\boldsymbol{E}^1$ define the first-level efficient frontier in set $\boldsymbol{N}^1$. The sequences of $\boldsymbol{N}^{\boldsymbol{b}}$ and $\boldsymbol{E}^{\boldsymbol{b}}$ are defined as $\boldsymbol{N}^{\boldsymbol{b}+1} = \boldsymbol{N}^{\boldsymbol{b}} - \boldsymbol{E}^{\boldsymbol{b}}$. The DMUs in set $\boldsymbol{E}^1$ define the first-level efficient frontier and this set is identical to classical DEA efficient DMU set. Second-level efficient frontier is obtained for $b = 2$ after the keeping out of the first-level efficient DMUs. Using this process, several levels of efficient and sub-efficient frontiers are obtained until the last DMU remains. To obtain efficient DMUs following output oriented constant returns to scale (CRS) linear programming model is solved for each level separately.

$$\begin{aligned} &\max \quad \phi \\ &st \quad \sum_{j\in N} \lambda_j x_{ij} \le x_i \quad i = 1, \ldots, m \\ &\qquad \sum_{j\in N} \lambda_j y_{rj} \ge \phi y_r \quad r = 1, \ldots, k \\ &\qquad \lambda_j \ge 0 \quad j \in N \end{aligned}$$

where x_{ij} and y_{rj} are ith input and rth output of DMU j.

It might be impossible to I/O improvement for DMU3 using its reference sets for a hypothetical example with two outputs and one input in Fig. 1. Using aforementioned approach, sub-efficient frontiers could be formed for inefficient units to obtain achievable targets for inefficient units.

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