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Identifying the best university educational departments using data envelopment analysis

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A B S T R A C T

Selecting the best performer departments can be a difficult task when there are many applicants for comparison. Data envelopment analysis (DEA) representative a non parametric tool can be used as a fair technique to support the decision making process .Considering the fact that competition and dependency always exist between two real DMUs, a DMU must only be compared with real DMUs lying at different efficiency levels. This paper applied a context-dependent DEA to determine the best candidate relative to the others, evaluate the degree of excellence of best candidates' performance and then clusters them.

1. Introduction

Data Envelopment Analysis (DEA) pioneered by Charnes et.al (1978) and developed by Banker et.al (1984) is a linear programming method that measures the efficiency of DMUs applying multiple settings of inputs and outputs. In other words, DEA extends the theoretical discussion of technical efficiency of

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Farrell into direct measurability by enveloping the observed data to determine a best-practice frontier. If a decision making unit (DMU) is evaluated to have a best possible relative efficiency of unity, then it is said to be DEA efficient. Otherwise, it is said to be DEA inefficient. However, the standard DEA models evaluate each DMU against a set of efficient DMUS and cannot identify which efficient DMU as a better option with respect to the inefficient DMU. This is because all efficient DMUs have an efficiency score one. Notably, the performance of efficient DMUs is not only influenced by the inefficient DMUs but also by the context. In the context-dependent DEA developed by Seiford et.al (2003), Chen et.al (2005) and Morita et.al (2005) and the evaluation contexts are obtained by partitioning a set of DMUs into several levels of efficient frontiers. What's more, the context-dependent DEA provides several benchmark targets by setting evaluation contexts. On the other hand, when DMUs in a specific level are viewed having equal performance, the attractiveness measure allows us to distinguish between the equal performances based upon the same evaluation context. Considering the fact that competition and dependency always exit between two real DMUs the obtained efficiency levels must not be a combination of real DMUs. As a result, selecting the "best" candidate seems a bit difficult task. Since, DEA has been widely used as a performance evaluation framework in many application frameworks such as banking (Ataullah and Le (2006) and Luo and Yao(2010)); energy and environmental studies(Zhou et.al (2008)), healthcare(Chang(1998)) , so the attention is paid to select the best performer DMU in educational area. In this study, we consider the measurement of efficiency of educational departments from DEA perspective. As far as we are aware educational departments are the fundamental parts in an educational system. However, each department plays by its own contexts, but the competition is always exits among different departments; consequently, one should know how dependent a department is upon the change in the present situation of other DMUs in a whole educational system. As a result, the selection of "best" candidate among different educational departments seems important for the competition. In this paper, a context-dependent DEA is introduced to measure the relative attractiveness of a particular DMU when compared to the others. Then following the similar procedure presented by Johnson and Zhu (2003) the evaluation contexts are obtained by partitioning these DMUs into several levels of efficient frontier. The reminder of the paper is unfolded as follows. The next section introduces the basic notation of the original context –dependent DEA. Section 3 explains the research methodology and demonstrates how to choose the best performance DMU. Section 4 illustrates the process in one of the branches of Islamic Azad University. Conclusion will end the paper.

2. Research background

2.1. Context-Dependent DEA

Assume that there are n $DMUs$ to be evaluated and each DMU utilizes m inputs x_{ij} $(i=1,...,m)$ to produce s outputs y_{rj} $(r=1,...,s)$. The values of inputs and outputs of DMU_j $(j=1,...,n)$ are known and positive. Let J^1 be the set of all DMUs and J^k and E^k interactively defined $J^{k+1}=J^k-E^k$, where E^k consists of all radial efficient DMUs by following linear programming:

$$
\begin{aligned}
&\phi_o^*(k) = \max\ \varphi_o(k)\\
&\quad s.t.\\
&\quad \sum_{j\in F(J^k)} \lambda_j X_j \le X_o\\
&\quad \sum_{j\in F(J^k)} \lambda_j Y_j \ \ge \varphi_o(k) Y_o \qquad (1)\\
&\quad \lambda_j \ge 0 \quad , \ j \in F(E^k)
\end{aligned}
$$

Where X_o and Y_o are the input and output of DMU_o respectively and $j \in F(J^k)$ means that $DMU_j \in J^k$. In other words, $F(.)$ represents the correspondence from a DMU set to the corresponding subscript index set. When $k=1$, Model (1) becomes the original output oriented CCR model and $DMUs$ in set E^1 defines the first-level efficient frontier. When $k=2$, Model (1) gives the second-level efficient frontier after exclusion of the first- level efficient $DMUs$, and so on. In this manner, we identify several levels of efficient frontiers. Then the set E^k is called the $k-th$ level efficient frontier. The DEA stratification Model (1) partitions the set of $DMUs$ into different efficient levels characterized by $E^k \ (k=1,...,K)$.Based upon these evaluation contexts, the relative attractiveness measure for DMU_o can be obtained with respect to the $k-th$ level efficient frontier by solving the following context-dependent DEA model:

$$
\begin{aligned}
&H_o^*(k) = \max\ H_o(k) \qquad k=1,....,K-k_o\\
&\quad s.t.\\
&\quad \sum_{j\in F(E^{k+k_o})} \lambda_j X_j \le X_o\\
&\quad \sum_{j\in F(E^{k+k_o})} \lambda_j Y_j \ \ge H_o(k) Y_o \qquad (2)\\
&\quad \lambda_j \ge 0 \quad , \ j \in F(E^{k+k_o})
\end{aligned}
$$

Here $j \in F(E^{k+k_o})$ means that $DMU_j \in E^{k+k_o}$, i.e., $F(.)$ represents the correspondence from a DMU set to the corresponding subscript index set. Then $A_o^*(k) = \frac{1}{H_o^*(k)}$ is called the (output oriented) attractiveness of DMU_o from a specific level E^k. In Model (2) we set $k=1,...,K-k_o$ in order to consider E^{k_o} as evaluation context for $DMU_o \in E^{k_o}$.

2.2.Identifying the Best Performer

The first step in DEA approach presented in the literature is identifying inputs and outputs associated with the peer DMUs being assessed. In special academic case we are seeking to determine the efficiency with which academic department met the performance criteria relative to the candidate. After determining inputs and outputs and applying the classic context-dependent variable returns to scale DEA model which is referred to as DEA model (I) in process (I) the non dominated group will be identified solving a linear program for each DMU as follows:

$$
\begin{aligned}
& DEA \ \text{model (I)} \\
& \phi^*(k) = \max \ \phi(k) \\
& s.t. \\
& \sum_{j\in F(J^l)} \lambda_j y_j \geq \phi(k) y_k \qquad (3) \\
& \sum_{j\in F(J^l)} \lambda_j x_j \leq x_k \\
& \sum_{j\in F(J^l)} \lambda_j = 1 \\
& \lambda_j \geq 0 \quad j \in F(J^l)
\end{aligned}
$$

The optimal solution of above model assists to determine whether each group exhibited “best” performance relative to their peers. To further prioritize the performance levels of the” best” groups, we use the optimized DEA weights in DEA model (I). Additionally, benchmarking share is identified to measure the frequency the specific best candidates' performance level as follows:

$$\Delta_j = \frac{\sum_{d\in N} \lambda_j^{d*}}{I_N}$$

Where j represents a" best" candidate's performance level, and d represents a dominated performance level. N Is the set of dominated performance levels and I_N is the number of dominated performance levels in set N .

After obtaining the benchmarking share for each DMU, for further analyzing the applicant's performance levels, second set of DEA models referred as process (II) can be applied to applicant data. In process (II) the constant return to scale context-dependent DEA model is used also the degree of the first level applicant's performance levels is evaluated. The mathematical formulation of the DEA model employed to select best performers in CRS version for each candidate is as follows:

$$
\begin{aligned}
& DEA \ \text{model(II)} \\
& \phi^*(k) = \max \ \phi(k) \\
& s.t. \\
& \sum_{j\in F(J^l)} \lambda_j y_j \geq \phi(k) y_k \qquad (4) \\
& \sum_{j\in F(J^l)} \lambda_j x_j \leq x_k \\
& \lambda_j \geq 0 \quad j \in F(J^l)
\end{aligned}
$$

In DEA model (II), the resulting frontier is a ray that refers to the “best” group. In fact, if the convexity constraint is dropped, from a screening point of view, the use of DEA Model (II) results in fewer none dominated group. On the other hand, this context dependent DEA models enables a decision maker to catch the degree of excellence in order to categorize the best performance level. In this case the smaller the context dependent DEA score the better performance of the candidate. In the both model above $j \in F(J^l)$ indicates $DMU_j \in J^l$ shows the correspondence from a DMU set to the corresponding (subscript) index set. The best performance can be expressed as $E^1 = \{DMU_k \in J^l, \phi^*(k) = 1\}$.

The final activity after applying DEA involves combining results from the two DEA analyses. In order to have a fair reduced pool of candidates, it's better to incorporate preference information running DEA assurance Region (AR) model. Finally we could have the best educational group among the selected ones. Finally at the end of process (II) best performance will be more characterized. Equipped with performance level and benchmark share, different four categories can be identified. The first category which has the first priority to choose among the candidates includes DMUs with both large benchmarking share and efficient performance relative to frontier level2. The second or third category gets the second priority. But DMUs with excellent context dependent performance fall into category one and the rest of DMUs which obtain the large benchmarking share assign to the third category. The rest of candidates which need to explore more fall into category four. In other words, we have a reduced pool of candidate. Also only the first category is illegal to choose among.

3. An Empirical Study

We shall illustrate the before mentioned approach for efficiency measurement with the analysis of one branch of Islamic Azad University activities. The real data set consists of 7 academic departments. The data for this analysis are derived from operations in the first midterm 91-92. We use five variables from the data set as inputs and outputs. Inputs include the number of registered students in that midterm (x_1) for each educational group, average years of experience (x_2) in teaching and number of all professors for each group (x_3) and outputs include the number of working papers, publications and conference presentation (y_1) for each group in this midterm and the number of graduated student for that semis term (y_2). Table (1) contains list of departments and data sets in this period.

Table 1 Data of Numerical example

DMU	x_1	x_2	x_3	y_1	y_2
Civil	578	4.21	7	1	276
Electronic	372	4.97	6	2	262
Computer	247	5.47	6	0	151
Agriculture	435	8.5	6	1	345
Chemistry	85	5.5	3	1	63
Accounting	202	5.83	3	0	155
Architecting	90	5.5	2	0	61

By applying the process mentioned above, using the context-dependent model, the following levels of efficient frontier are as follows:

$E^1 = \{1,2,4,5\}$

$E^2 = \{3,6\}$

$E^3 = \{7\}$

Table (2) reports the efficiency score for the DMUs based upon Model (3) (ϕ^*) and benchmarking share (Δ_j) based on the VRS context dependent case.

Table 2 Context-dependent performance

DMU	ϕ^*	Δ_j
Civil	1	0
Electronic	1	1
Computer	1.20	-
Agriculture	1	1
Chemistry	1	1
Accounting	1	1
Architecting	1	0

Based upon Table (2), in an effort to categorize the "best" final candidate, we are able to group the candidate's performance levels into four categories as follows:

Category 1: unit #6 gets the first priority because of large benchmarking share and efficient performance relative to frontier level2.

Category 2: Units # 1,2,4,5 gets the second position because of excellent context dependent performance.

Category 3 includes the second priority but it contains only the units with large benchmarking share. Here in this example, unit #3 gets the priority.

Category 4: the units in this category will consider later because of an inefficient context dependent score. In our real example unit #7 falls into this category. In order to identify the best performer group through using these categories, the last two categories can be reserved for more consideration. The attention is paid to DMUs in category one and two. The priority is given to DMUs fall into category one. So, unit#6 in this example, Accounting Educational Department, catches the "best" candidate between the DMUs in that specific University branch. As it was clear, the preference was not incorporated in this evaluation, so the DEA assurance Region (AR) model was not running.

4. Conclusions

In today's business world, hiring the "best" employee for a specific aim can be a daunting task. This article is concerned with the measurement of efficiency of educational groups from DEA perspective. Context-dependent DEA as the selected process was developed to allow the decision makers and managers to focus on a smaller number of promising candidates who are better suited to specified goals. The scenario of the best educational department, based on both qualitative performance measures and quantitative data, facilitates the structure for managers to ensure a fair competition. Additionally, given this methodology, ensures consistency across candidates and performance measures.

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