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Benchmarking Marketing Productivity Using Data Envelopment Analysis: a Modified Approach

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Abstract. Data envelopment analysis (DEA) is now widely utilized as a method for assessing relative efficiency of a set of decision making units (DMUs). Along as evaluating relative efficiency DEA models are capable of to be improved for finding benchmark for inefficient units which can help managers for better making decision. Thus it is important to obtain accurate results from DEA models. In this paper the SBM model has been enhanced by incorporating two constraints. One of these constraints has been considered to deal with non-discretionary inputs that can affect production. The other helps to find acceptable targets where there exists variable that has an integer value. Also, with an example it has been shown how the proposed model works.

Keywords: Data Envelopment Analysis, Benchmarking, Efficiency, Non-Discretionary Inputs.

1. Introduction

The aim of the benchmarking process is to identify the best criterion in order to make the necessary changes to reach the highest level. As a mathematical tool, DEA was first developed by Charnes, Cooper, and Rhodes [3] and then extended by Banker, Charnes, and Cooper [1]. As Seiford [7] provided, DEA has become a popular tool for evaluating the relative efficiency of comparable firms. Also, an important key feature of DEA is that it obtains an efficiency frontier that those units located onto this frontier can be considered as benchmark for other DMUs not located onto it, which called inefficient DMUs. In the marketing literature, DEA was initially applied by Charnes et al. [4] More recent marketing applications include efficiency measurements of advertising campaigns as in Luo and Donthu [6] and benchmarking marketing productivity as in Donthu et al. [5] and Biehl, Cook and Johnston [2]. Benchmarking and target setting used in recognizing the leading units in managing an organization, thus here an attempt is made through presenting a modified DEA model for efficiency assessment by means of slack variables. As mentioned in literature benchmarking is ambiguous and error risking due to this fact that it is performed on basis of managers opinion and limitations.

By using slack-based measure of efficiency in DEA technique, it is possible to see the meaningful changes in efficiency scores through applying deduction in inputs and increase in outputs. Considering the proposed model in this paper, it can be seen that by imposing explicit variables in benchmarking process 26 homogeneous DMUs, those were used in benchmarking marketing productivity written by Donthu et al., [5] have been assessed more efficiently. We enhance SBM model by incorporating two constraints, one constraint is for dealing with non-discretionary inputs that can affect production. The new model allows measurement of efficiency in production process characterized by the influence of factors that managers can have α percent control on them. The other constraint helps to find acceptable targets where there exists variable that has an integer value and therefore must have an integer value in corresponding element of benchmark unit. This is the difficulty that has been overcome in this paper.

The paper unfolds as follows: in section 2, data envelopment analysis will be briefly reviewed. In section 3, the proposed model will be presented.

2. Data Envelopment Analysis

Data envelopment analysis (DEA) is powerful method based on mathematical programming problem for assessing relative efficiency of a set of decision making units and it was first proposed by Charnes et al. [3]. DEA models identify an efficient frontier. The important fact is that this frontier can be considered as a benchmark frontier. All the units onto this frontier are referred to as efficient and those which are not on this frontier are referred to as inefficient. As one of the aim of benchmark analysis is to found the information to set up target process DEA technique can be utilized. The slack-based measure of efficiency is introduced by Tone [8] in DEA literature. This model is non-radial thus individually deals with slacks of each input/output in an independent manner. The relative efficiency obtained through solving this model is the integration of input/output slacks. It should be noted that the slack based measure of efficiency considers both technical and composite inefficiency which is the key feature of this model, Tone [8]. Let DMU_o be the unit under assessment from a total of n units being evaluated. Also, assume $x_o \in R^{m\geq\circ}$, $y_o \in R^{s\geq\circ}$ as the inputs and outputs of DMU_o. One way to characterize production technology is production possibility set T_c, which is defined with a set of semipositive (x,y) as:

$$T_c = \{(x,y) \mid y \leq \sum_{j=1}^{n} \lambda_j y_j, \quad x \geq \sum_{j=1}^{n} \lambda_j x_j, \quad \lambda \geq 0, j = 1,\ldots,n\}$$

which assumes constant returns to scale technology. The constant returns to scale of SBM model is as following:

$$\begin{aligned}
\min \quad & \left(1 - \frac{1}{m}\sum_{i=1}^{m}\frac{s_i^-}{x_{io}}\right)\left(1 + \frac{1}{s}\sum_{i=1}^{s}\frac{s_r^+}{y_{ro}}\right) & \\
s.t. \quad & \sum_{j=1}^{n}\lambda_j x_{ij} - s_i^- = x_{io}, & i = 1,\ldots,m, \\
& \sum_{j=1}^{n}\lambda_j y_{rj} - s_r^+ = y_{ro}, & r = 1,\ldots,s, \\
& \lambda_j \geq 0, & j = 1,\ldots,n. \\
& s_r^+ \geq 0, \quad r = 1,\ldots,s, s_i^- \geq 0, & i = 1,\ldots,m.
\end{aligned}$$

In the following we give a brief explanation about variables.

n: total number of units that being assessed.

x_{ij} : ith input of the j th DMU, $i = 1,\dots,m$, $j = 1,\dots,n$.

y_{rj} : rth output of the j th DMU, $r = 1,\dots,s$, $j = 1,\dots,n$.

s_i^- : slack variables for inputs, for the unit under assessment it shows the additional amount of inputs need to be contracted to reach the optimal level of efficiency.

s_r^+ : slack variables for outputs, for the unit under assessment it shows the amount of outputs need to be increased to reach the optimal level of efficiency.

ε : a small positive real number.

As mentioned in Tone [8], for ρ_o depends merely on s_i^- , s_r^+ and it can be easily verified that $0 < \rho_0 < 1$ and satisfies the properties of units invariance and monotone. A DMU $(x_0, y_0) \in PPS$ is referred to as CRS efficient if any solution of the system

$$x_0 = x\lambda + s^-, \quad y_0 = y\lambda - s^+, \quad \lambda \geq 0, \quad s^- \geq 0, \quad s^+ \geq 0$$

has $s^- = 0$ and $s^+ = 0$; otherwise, (x_0, y_0) is referred to as CRS-inefficient, that means there exist semi-positive slacks for the above system. Solving CCR model and identifying efficient units now it is possible to set target. The CRS-efficient DMUs can be considered as targets for inefficient DMUs. As Tone [8] has been provided, in any optimal solution for DMU_0 those units with $\lambda^*_j > 0$ are targets for that inefficient DMU_0 .

3. Modified Approach

In this section the SBM model enhanced by incorporating two constraints. One for dealing with non-discretionary inputs that can affect production and the other one helps to find acceptable targets. The new model allows measurement of efficiency in production process characterized by the influence of factors that managers can have _ percent control on them. Also, it takes into account the situations where there exists variable that has an integer value and therefore must have an integer value in corresponding element of benchmark unit. This is the difficulty that has been overcome in this paper and for the illustrative example the data that were used in benchmarking marketing productivity written by Donthu et al. [5] have been considered which were collected from 26 fast food outlets. There exist some difficulty in the obtained results through running their model. Donthu et al. have considered number of employee as one of the input factors but they have not paid attention to this fact that this number is integer and in the corresponding element of target unit must remain integer, as well. Also, manager experience has been considered as one of the input factors but manager, who finally decide how the improvement actions should be performed, can not have a hundred percent control over this factor indeed. In the following, modified slack-based measure of efficiency will be presented in which these failures have been handled. Constraint (a) helps to find acceptable targets where there exists variable that has an integer value and must have an integer value in corresponding element of benchmark unit, for instance the number of employee. Also, constraint (b) has been considered which deals with non-discretionary inputs that allows measurement of efficiency in production processes characterized by the influence of factors that managers can have percent control on factors. In the following model, this constraint is written for input factors. The linear form of SBM model is as follows in which constraints (a) and (b) are imposed to capture the idea of setting targets precisely and allow the managers to have _ percent control on inputs.

$$
\begin{aligned}
\min \quad & q - \frac{1}{m}\sum_{i=1}^{m}\frac{s_i^-}{x_{io}} \\
s.t. \quad & \sum_{j=1}^{n}\mu_j x_{ij} - s_i^- = x_{io}, \qquad i = 1,\dots,m, \\
& \sum_{j=1}^{n}\mu_j y_{rj} - s_r^+ = y_{ro}, \qquad r = 1,\dots,s, \\
& q + \frac{1}{s}\sum_{i=1}^{s}\frac{s_r^+}{y_{ro}} = 1, \\
& q x_{io} - s_l^- = z_l, \qquad l \in L \qquad (a) \\
& q x_{to} - s_t^- \geq (1-\alpha)x_{to}, \quad t \in T \qquad (b) \\
& \mu_j \geq 0, \quad j = 1,\dots,n, q > 0, \ z_l \in Z \\
& s_r^+ \geq 0, \quad r = 1,\dots,s, s_i^- \geq 0, \quad i = 1,\dots,m.
\end{aligned}
$$

Where L is the set of inputs which must have an integer value and T is the set of inputs that managers can not have a hundred percent control over them, such as manager experience. As indicated above, $z_l \in Z$, z_l is confined to get integer values. α in constraint (b) is a predefined constant, which implies that the element of target unit is at least $(1-\alpha)$ percent of corresponding element of input. It should be noted that 0 < α _ < 1. Considering $\mu_0 = 1$ and $\mu_j = 0$, $j = 1,\ldots,n$, $j \neq o$, $s^- = 0$, $s^+ = 0$, $z_l = 1$, $\forall\, l \in L$ is a solution of model (2), therefore; model (2) is always feasible.

4. Benchmark Illustration

Consider the example used in benchmarking marketing productivity written by Donthu et al. [5]. Input/Output data are gathered in Table 1. As indicated in Donthu et al. [5] input variables included advertising and promotion expenses, manager experience, and number of employees. Output variables included customer satisfaction and sales, respectively.

As mentioned above, the number of employee was included as an explicit input but it should be considered that number of employee is an integer number. Therefore, in corresponding element of target unit it must remains integer as well. Also, since store manager experience was included, we get use of constraint (b) in order to empower managers to have _ percent control on manager experience because it is impossible for managers to have a hundred percent control over manager experience. As an instant, we consider α to be 0.2 in constraint (b), which implies that the element of target unit is at least eighty percent of corresponding element of input. Noted that utilizing this model useful information about each DMU can be provided such as slack variables, efficiency scores or input excess and output shortfall which use by managers for setting out guidelines for improving the efficiency of inefficient units.

Taking into account the proposed model the efficiency scores are shown in the first column of Table 1.

Table 1. Inputs and outputs

DMU #	p*o	Input1	Input2	Input3	Output1	Output2
1	1	3.5	7	24	4.1	3.6
2	1	2.2	9	32	4	3.2
3	0.81	3.9	12	30	4.4	4.2
4	0.85	4.1	5	35	4.4	4.4
5	1	2.5	6	25	3.6	4
6	0.94	3.3	10	24	3.9	4.2
7	0.76	5	12	33	4.5	4.5
8	1	2.1	5	32	3.6	3.7
9	1	2.8	11	20	3.6	3.8
10	0.77	4.3	16	36	4.5	4.6
11	1	4	2	33	4	4.1
12	0.87	3.5	6	32	4.2	4.2
13	0.89	4	10	26	4.3	4
14	0.79	3	14	38	3.9	4
15	0.81	4.6	12	30	4.6	4.5
16	0.92	3.5	7	28	4.2	4
17	0.85	3.5	9	29	4.2	4.2
18	0.91	2.6	16	30	3.7	3.9
19	1	3	5	24	3.5	3.7
20	0.86	3.5	11	25	4	4
21	0.82	4.2	12	30	4.3	4.6
22	1	3.8	3	32	4.3	4.4
23	1	3	5	35	4.5	4.6
24	0.85	3.4	7	30	4	4.1
25	0.91	3.8	9	24	3.9	4
26	0.82	2.9	13	28	3.7	3.6

In the above example unit 7 is considered to be the least efficient unit with the efficiency score of 0.76. So, units 5 and 9 are its group of benchmarking targets that it can imitate from them to become efficient. Considering s-_ and s+_ as the amount by which the corresponding input or output of under evaluation units must be improved. Managers can determine what changes need to be made in an inefficient units to performs efficiently.

Table 2 shows the benchmark unit for inefficient unit 7. According to what has been mentioned above about model (2), in target unit the third element of input is integer. Also, since store manager experience was included, therefore as indicated in Table 2, in target unit the second element of input, when α is considered to be 0.2, is at least eighty percent of its related input element.

Table 2. Target and peer group

DMU #	I1	I2	I3	O1	O2
7	5	12	33	4.5	4.5
target	3.11	9.6	28	4.11	4.69
peer group					
5	2.5	6	25	3.6	4
9	2.8	11	20	3.6	3.8

5. Conclusion

Data envelopment analysis used as a mathematical programming problem for performance evaluation of set of decision making units with multiple inputs and outputs. DEA methodology has many advantages that make it a strong tool. Also, DEA models have capability of being improved in different occasions. One of the significant feature of DEA is that non-discretionary input variables can be incorporated into the DEA models. In this paper by using DEA models while an efficiency scores of DMUs and target units for inefficient DMUs were found, some modifications also incorporated into model in order to reveal the reality of situations. To this end, in order to get use of significant features of non-radial models, slack-based measure of efficiency (SBM) has been considered. Here, this model utilized where there exist integer numbers such as number of employee, etc.

This modification helps to find acceptable targets where there exists variable that has an integer value and must have an integer value in corresponding element of benchmark unit. An other modification that has been considered in new model

deals with non-discretionary inputs that can affect production. The new method allows measurement of efficiency in production processes characterized by the influence of factors that managers can have _ percent control on factors.

For further investigation, attentive to this fact that benchmarking process highly depend on the senior managers decision it is suggested that a technique for collecting managers decision for preference or ranking input and output variables should be presented. Also, Since many of the variables influencing the efficiency score of a DMU in benchmarking process in marketing management are based upon the unobservable possessions, that means basically it is not be explored primarily or can hardly be explored, it should be considered that not to propose a technique which

(i) investigates variables,
(ii) compares their importance,
(iii) estimates their accuracy.

Furthermore, due to the dependency of output variables in benchmarking process to the recourses and they have been evaluated just from the viewpoint of customers, it seems that it will not be an accurate basis for recognizing the efficiency of DMUs. Therefore, in benchmarking process based on DEA technique which performed in SBM model separation of output based on financial or non-financial and customer based classification should be proposed.

References

[1] Banker, RD, Charnes A, Cooper WW. (1984) Some models for estimating technical and scale inefficiencies in data envelopment analysis, Management Science; 30(9), 1078-92.

[2] Biehl M, Wade Cook W, Johnston DA. (2006) The efficiency of joint decision making in buyer-supplier relationships. Ann Oper Res.; 145, 15-34.

[3] Charnes A, cooper WW. (1978), Rhodes E. Measuring the efficiency of decision making units.European Journal of operational research.; 2, 429-444.

[4] Charnes A, Cooper WW, Golany B, Seiford L, Stutz J. (1985). Foundations of data envelopment analysis for pareto-koopmans efficieny empirical production function. Journal of Econometrics; 30(1-2), 91-107.

[5] Donthua N, Hershberger EK , Osmonbekov T. (2005). Benchmarking marketing productivity using data envelopment analysis. Journal of Business Research; 58, 1474 1482.

[6] Luo X, Donthu N. Benchmarking advertising ef .ciency. Journal of Advertising Research 2001; 41, 7-18.

[7] Seiford LM. (1999). Data envelopment analysis. The evolution of the state of the art. Journal of Productivity Analysis; 7, 99-137.

[8] Tone K. (2001). A slack-based measure of efficiency in data envelopment analysis. European Journal of Operational Research; 130(3), 498-509.