

Ranking DMUs by Ideal PPS in Data Envelopment Analysis

*V.Rezaie^a, M.Khanmohammady^b

Abstract—An original DEA model is to evaluate each DMU optimistically, but the interval DEA Model proposed in this paper has been formulated to obtain an efficiency interval consisting of Evaluations from both the optimistic and the pessimistic view points. DMUs are improved so that their lower bounds become so large as to attain the maximum Value one. The points obtained by this method are called ideal points. Ideal PPS is calculated by ideal of efficiency DMUs. The purpose of this paper is to rank DMUs by this ideal PPS. Finally we extend the efficiency interval of a DMU under variable RTS technology.

Keywords— Data envelopment analysis (DEA), Decision making unit (DMU), Interval DEA, Ideal points, Ideal PPS, Return to scale (RTS).

I. INTRODUCTION

DEA is a non-parametric technique for measuring the efficiency of DMUs with common input And output terms [1,2]. The DEA models may be generally classified into radial and non-radial Models. Russell [7] discussed four conditions that are desirable in measuring “technical efficiency”. Fare and Lovell [6] proposed an analytical model that aggregates both output and input efficiencies in the framework of a radial measure, the efficiency measure of the model is called the “Russell measure(RM)”. RM has a major difficulty in efficiency measurement, because its objective function is formulated as a nonlinear programming problem. Cooper and Pastor [14] have, therefore, considered this problem and have proposed an adjustment to the Russell measure. Since DEA is a model for evaluation from the optimistic viewpoint, Entani and Tanaka [11] have already proposed the interval DEA model to obtain the efficiency interval. The efficiency interval is represented by its upper and lower bounds. The upper and lower bounds of the efficiency interval denote the evaluations from the optimistic and pessimistic viewpoints, respectively. The problem that obtains the upper bound of the efficiency interval is formulated as follows:

$$\Theta_o^u = \max_{U,V} \frac{U^T Y_0}{\max_j \frac{U^T Y_j}{V^T X_j}} \quad (1)$$

$$s.t U \geq 0, V \leq 0.$$

Where X_j and Y_j are the input and output vectors of DMU_j , respectively, whose elements are all positive and the decision variables are the weight vectors U and V .

Authors are with Islamic Azad University, Yasooj Branch. Iran.
e-mail:vahidehrezai@yahoo.com

Also, the lower bound of the Efficiency interval for DMU_o can be determined as follows:

$$\Theta_o^L = \max_{U,V} \frac{\frac{U^T Y_0}{V^T X_0}}{\max_{U,V} \frac{U^T Y_j}{V^T X_j}} \quad (2)$$

$$s.t U \geq 0, V \geq 0.$$

According to [11], Model (2) can be changed to the following problem:

$$\theta_o^L = \max_{r,i} \frac{y_{ro}}{\max_j \frac{y_{rj}}{x_{ij}}} \quad (3)$$

Where the i th element of the input weight vector V and the r th element of the output vector U are One and the other elements are all zero. Theorem 1. The optimal value of (2) and (3) are equal. Proof: The proof of the theorem is provided in [11]. DMUs are improved so that their lower bounds become so large as to attain the maximum value One. The points obtained by this method are called ideal points. The i th input element and the R th output elements of the ideal point for DMU_o are denoted as follows:

$$\bar{x}_{io} = \min_r \left\{ \frac{y_{ro}}{\max_j \frac{y_{rj}}{x_{ij}}} \right\} \quad i = 1, \dots, m. \quad (4)$$

$$y_{ro}^- = \max_i \left\{ \max_j \frac{y_{rj}}{x_{ij}} \bar{x}_{io} \right\} \quad r = 1, \dots, s. \quad (5)$$

When DEA models are used to calculate the efficiency of DMUs, a number of them may have an equal efficiency score of one. Many methods have been proposed in order to rank best performers; Andersen and Petersen (AP) [8] and Mehrabian et al. [9] (MAJ) presented two most popular of these methods. These methods would fail if data have certain structures. There are some methods based on norms. Jahanshahloo et al. [4] introduced an l_1 -norm approach that removes some deficiencies arising from AP and MAJ, but that cannot rank non-extreme DMUs.

The method we propose in this paper, ranks such DMUs, and does not have the above-mentioned problems.

The current paper is organized as follows. The next section addresses proposed model. In section 3 we give a proposed ranking and compare it with other models and, we consider the interval DEA with variable return to scale. End the paper concludes in section 4.

II. PROPOSED MODEL

We are dealing with n DMUs with the input and output matrices $X = (x_{ij}) \in R^{m \times n}$ and $Y = (y_{rj}) \in R^{s \times n}$, respectively. The data set is positive, i.e. $X > 0$ and $Y > 0$. The production possibility set (PPS) of n DMUs is as follows:

$$T_c = \{(X, Y) | X \geq X \lambda, Y \leq Y \lambda, \lambda \geq 0\}$$

First we obtain efficiency DMUs by adjusting Russell measure DMUs become divided into two categories:

- 1) Efficiency (E)
- 2) Inefficiency (F)

Inefficiency DMUs that have higher Θ^* Russell than they will have better Rank.

We know all DMUs that belong into E set:

$$\forall j \in E \Theta^*_{Russell} = 1$$

For ranking efficiency DMUs, we do on aspect following:

- 1) We calculate the ideal points of efficiency DMUs (E) by models (4), (5).
- 2) We calculate ideal PPS by Ideal of efficiency DMUs, and already DMUs.

$$Ideal \ PPS = \{ (x_1, \dots, x_m, y_1, \dots, y_s) | x_i \geq$$

$$\sum_{j=1}^n \lambda_j x_{ij} + \sum_{j \in E} \lambda'_j \bar{x}_{ij}, y_r \leq \sum_{j=1}^n \lambda_j y_{rj} + \sum_{j \in E} \lambda'_j \bar{y}_{rj}, i = 1, \dots, m, r = 1, \dots, s \}$$

Theorem 2. Ideal of strong efficiency DMUs are not dominated with any DMUs. ($(\overline{DMU}_0, \theta \in \{1, \dots, n\})$)

Proof: To prove the theorem, it is sufficient to show that the following inequalities are true.

$$\bar{x}_{io} \leq x_{ij}, i = 1, \dots, m, j = 1, \dots, n. \tag{6}$$

$$\bar{y}_{ro} \geq y_{rj}, r = 1, \dots, s, j = 1, \dots, n. \tag{7}$$

Recall that, in the beginning of this paper, we assumed that all of elements of the input and output vectors of DMU_j ($j = 1, \dots, n$) are positive. Furthermore, we assume that

$$\min_r \left\{ \frac{y_{ro}}{\max_j \frac{y_{rj}}{x_{ij}}} \right\} \text{ will happen in index } r', \text{ that is:}$$

$$\max_r \left\{ \frac{y_{ro}}{\max_j \frac{y_{rj}}{x_{ij}}} \right\} = \frac{y_{r'o}}{\max_j \frac{y_{r'j}}{x_{ij}}} \tag{8}$$

Also, we assume that $\max_j \frac{y_{r'j}}{x_{ij}}$ will happen in index k:

$$\max_j \frac{y_{r'j}}{x_{ij}} = \frac{y_{r'k}}{x_{ik}} \text{ as a result } \forall j \frac{y_{r'j}}{x_{ij}} \leq \frac{y_{r'k}}{x_{ik}} \tag{9}$$

DMU₀ is strong efficiency so we have:

$$\forall i \forall_j x_{io} \leq x_{ij} \text{ Therefore } \frac{y_{r'j}}{x_{ij}} \leq \frac{y_{r'o}}{x_{io}}$$

$$\text{If we set } j = 0 \text{ in (9) then we will have: } \frac{y_{r'o}}{x_{io}} \leq \frac{y_{r'k}}{x_{ik}}$$

$$\text{So we have } \frac{y_{r'o}}{x_{ij}} \leq \frac{y_{r'k}}{x_{ik}} \text{ as a result } \frac{x_{ik} \cdot y_{r'o}}{y_{r'k}} \leq x_{ij}$$

$$\text{According to (8): } \min_r \frac{x_{ik} \cdot y_{ro}}{y_{rk}} \leq x_{ij} \text{ as a result}$$

$$\max_r \frac{y_{ro}}{y_{rk} / x_{ik}} \leq x_{ij}$$

$$\text{According to (9): } \min_r \left\{ \frac{y_{ro}}{\max_j \frac{y_{rj}}{x_{ij}}} \right\} \leq x_{ij}$$

$$\text{According to (4): } \bar{x}_{io} \leq x_{ij}$$

Inequality (6) is thus proved to be true.

For proving inequality (7), we assume that

$$\left\{ \left(\max_i \frac{y_{rj}}{x_{ij}} \right) x_{io} \right\} \text{ will happen in index } i', \text{ that is:}$$

$$\max_i \left\{ \max_j \frac{y_{rj}}{x_{ij}} \right\} x_{io} = \left(\max_j \frac{y_{rj}}{x_{ij}} \right) x_{i'o} \tag{10}$$

Also, we assume that $\max_j \frac{y_{rj}}{x_{ij}}$ will happen in index l:

$$\max_j \frac{y_{rj}}{x_{ij}} = \frac{y_{rl}}{x_{il}} \text{ as a result } \forall_j \frac{y_{rj}}{x_{ij}} \leq \frac{y_{rl}}{x_{il}} \tag{11}$$

DMU₀ is strong efficiency so we have:

$$\forall_r, \forall_j \quad y_{rj} \leq y_{ro} \quad \text{Therefore} \quad \frac{y_{rj}}{x_{ij}} \leq \frac{y_{ro}}{x_{i'o}}$$

If we set $j = 0$ in (11) then we will have: $\frac{y_{ro}}{x_{i'o}} \leq \frac{y_{rl}}{x_{i'l}}$

So we have $\frac{y_{rj}}{x_{i'o}} \leq \frac{y_{rl}}{x_{i'l}}$ as a result $y_{rj} \leq \frac{y_{rl}}{x_{i'l}} \cdot x_{i'o}$

By (10): $y_{rj} \leq \max_i \frac{y_{rl}}{x_{ij}} \cdot x_{i'o}$

$$\text{By (11): } y_{rj} \leq \max_i \left[\max_j \frac{y_{rj}}{x_{ij}} \right] \cdot x_{i'o}$$

By (5): $y_{rj} \leq y_{ro}$.

Inequality (7) is hence proved true.

For ranking efficiency DMUs, we calculate efficiency their ideal DMUs in ideal PPS with the following problem:

$$\Theta^*(\bar{X}_o, \bar{Y}_o) = \min \left(\frac{1}{m} \sum_{i=1}^m \theta_i \right) / \left(\frac{1}{s} \sum_{r=1}^s \theta_r \right)$$

$$\text{s.t.} \quad \sum_{j=1}^n \lambda_j x_{ij} + \sum_{j \in E} \lambda'_j \bar{x}_{ij} \leq \theta_i \bar{x}_{io} \quad i=1, \dots, m.$$

$$\sum_{j=1}^n \lambda_j y_{rj} + \sum_{j \in E} \lambda'_j \bar{y}_{rj} \geq \phi_r \bar{y}_{ro} \quad r=1, \dots, s,$$

$$\lambda_j \geq 0, \quad j=1, \dots, n$$

$$0 \leq \theta_i \leq 1, \quad i=1, \dots, m$$

$$\phi_r \geq 1, \quad r=1, \dots, s.$$

The performance of a DMU will be better if its Θ^* has lower than others, because $\Theta^*(\bar{x}_o, \bar{y}_o)$ is efficiency of

$\overline{DMU}_o = (\bar{x}_o, \bar{y}_o)$ in ideal PPS. The Performance of a

DMU_o will be better if it's Θ^* ideal point has a smaller. Because, if DMU_o has further output then DMU_o will have more input and if DMU_o has less input then DMU_o will have less output i.e. if DMU_o have better performance then its ideal point is closer to own DMU, as a result DMU_o is far from frontier Ideal PPS. To elaborate, we apply our proposed model in the following example. Example1: We consider 7 DMUs with two inputs and two outputs. The data and the adjusting Russell measure Θ^* of the DMUs are shown in Table 1.

TABLE I INPUTS, OUTPUTS AND Θ^* OF DMUS IN EXAMPLE 1

DM U	A	B	C	D	E	F	G
x_1	2	3	2	2	3	2	3
x_2	3	4	2	3	4	2	4
y_1	4	5	4	5	4	4	5
y_2	5	6	4	4	5	6	4
θ^*	0.335	0.648	0.800	1	0.530	1	0.507
	8	1	0		3		2

According to the results of the adjusting Russell measure model, DMU_D and DMU_F are evaluated as efficient. In order to rank the two DMUs by the proposed method, first we obtain their ideal point and ideal PPS then we calculate the distance of ideal point to Ideal PPS. According to the method, if DMU has a shorter distance, then it has better rank. The ideal points, and the ranking of DMUs are shown in Table 2.

TABLE II IDEAL POINTS AND RANKING OF EACH DMU

Ideal DMU	A	B	C	D	E	F	G
Input ₁	-	-	-	1.33	-	1.6	-
Input ₂	-	-	-	1.33	-	2	-
Output ₁	-	-	-	6	-	5	-
Output ₂	-	-	-	9	-	6	-
$d_j(x_j, y_j)$	-	-	-	4.7368	-	2.6420	-
RANK	4	5	3	2	6	1	7

The important property of this method is its ability to rank extreme and non-extreme DMUs. We show this property with the following example.

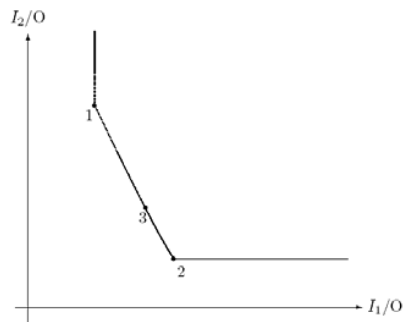


Fig. 1: Farell frontier for three DMUS.

Example2: We consider the three DMUs with two inputs and one output. The Farell frontier for These DMUs is shown in Fig 1. As can be seen in Fig 1, DMU₁ and DMU₂ are extreme efficient DMUs and DMU₃ is non-extreme. The data, ideal points and ranking of DMUs, as well as their Efficiency results by model (12) are shown in Table 3. It can be seen that this method ranks all of DMUs.

TABLE III DATA AND IDEAL POINTS AND RANKING

DMU ₃	DMU ₁	DMU ₂	DMU ₃	DMU1	DMU2	DMU3
Input ₁	1	3	2	1	1	1
Input ₂	4	1	2.5	1	1	1
Output ₁	1	1	1	4	3	2.5
$d_j(x_{j1}, y_{j1})$	-	-	-	14	10.50	8.75
Bank	3	2	1	-	-	-

III. EFFICIENCY INTERVAL UNDER VARIABLE RTS TECHNOLOGY

Entani et al. [11] improved the efficiency intervals of a DMU by adjusting its given inputs and outputs under constant RTS technology. We want to develop their model under variable RTS technology.

Lemma 1. For

$a, b, c, d > a', b', c', d' > 0, t_1, t_2, t'_2 \geq 0, (t_1 + t'_1 \neq 0), (t_2 + t'_2 \neq 0)$, if

$$\frac{d}{b} \leq \frac{d'}{b'} \text{ and } \leq \frac{a'}{c'}$$

Then:

$$\frac{ad}{bc} \leq \frac{(t_1 a + t'_1 a')(t_2 d + t'_2 d')}{(t_2 b + t'_2 b')(t_1 c + t'_1 c')}$$

Proof. The proof of the theorem is provided in [10]. The upper and lower limits of interval efficiency for DMU_o under variable RTS technology be defined as follows:

$$\Theta_{o^*}^E = \max_{u,v} \frac{\frac{u^t y_o + u_o}{u^t x_o}}{\max_j \frac{u^t y_j + u_o}{u^t x_j}} \quad (13)$$

s.t. $u \geq 0, v \geq 0$.

$$\Theta_{o^*}^E = \min_{u,v} \frac{\frac{v^t x_o}{u^t y_o + u_o}}{\max_j \frac{u^t y_j + u_o}{v^t x_j}} \quad (14)$$

s.t. $u \geq 0, v \geq 0$.

We can obtain the lower limit of efficiency directly by

$$\Theta_{o^*}^E = \min_{p,r} \frac{\frac{y_{op} + u_o}{x_{or}}}{\max_j \frac{y_{jp} + u_o}{x_{jr}}} \quad (15)$$

Which is proven in what follows

The optimal value in (15) can be said that the optimal weight vectors U and V in (14) have the entry 1, respectively, and all other entries are 0. This fact is proven by theorem 3. First, we assume to have following inequality:

$$(A_1): \frac{x_{j2_1}}{x_{o_1}} \leq \frac{x_{j2_2}}{x_{o_2}}$$

$$(B_1): \frac{y_{j2_1} + u_o}{y_{j2_1} + u_o} \leq \frac{y_{j2_2} + u_o}{y_{j2_2} + u_o}$$

According to lemma 1, we must have following condition:

$$x_{j2_1}, y_{j2_1} + u_o, x_{o_1}, y_{o_1} + u_o > 0$$

$$x_{j2_2}, y_{j2_2} + u_o, x_{o_2}, y_{o_2} + u_o > 0$$

So. We must have $u_o > -\min_{r,j} \{y_{rj}\}$ or $u_o > \max_{r,j} \{-y_{rj}\}$

If $u_o > \max_{r,j} \{-y_{rj}\}$ Then we will have:

Therefore according to lemma1, we will have

$$\frac{(x_{j2_1})(y_{o_1} + u_o)}{(y_{j2_1} + u_o)(x_{o_1})} \leq \frac{(t_1 x_{j2_1} + t'_1 x_{j2_2})(t_2 (y_{o_1} + u_o) + t'_2 (y_{o_2} + u_o))}{(t_2 (y_{j2_1} + u_o) + t'_2 (y_{j2_2} + u_o))(t_1 x_{o_1} + t'_1 x_{o_2})}$$

$$\frac{\frac{y_{o_1} + u_o}{x_{o_1}}}{\frac{y_{j2_1} + u_o}{x_{j2_1}}} \leq \frac{t_2 (y_{o_1} + u_o) + t'_2 (y_{o_2} + u_o) / t_1 x_{o_1} + t'_1 x_{o_2}}{t_2 (y_{j2_1} + u_o) + t'_2 (y_{j2_2} + u_o) / t_1 x_{j2_1} + t'_1 x_{j2_2}}$$

Theorem 3: If $u_o = \frac{u_o^*}{u_1^* + u_2^*}$ and $u_o > \max_{r,j} \{-y_{rj}\}$ then

the optimal value of (14) and (15) are equal (where u_o^*, u_1^*, u_2^* are optimal answer of model 14).

Proof. In order to simplify the notation, we consider the case of two-dimensional input and two-dimensional output data.

$$(14): \Theta_{o^*}^E = \min_{u,v} \min_j \frac{(u^t y_o + u_o) / v^t x_o}{(u^t y_j + u_o) / v^t x_j} = \frac{(u^{*t} y_o + u_o^*) / v^{*t} x_o}{(u^{*t} y_{j2} + u_o^*) / v^{*t} x_{j2}}$$

$$(15): \Theta_0^E = \min_{p,r} \min_j \frac{(y_{0p} + u_0)/x_{0r}}{(y_{jp} + u_0)/x_{jr}} = \frac{(y_{0p_1} + u_0)/x_{0r_1}}{(y_{j_1p_1} + u_0)/x_{j_1r_1}} = \min_{p,r} \frac{(y_{0p} + u_0)/x_{0r}}{(y_{j_2p} + u_0)/x_{j_2r}} \geq \min_{p,r} \min_j \frac{(y_{0p} + u_0)/x_{0r}}{(y_{jp} + u_0)/x_{jr}} = \frac{(y_{0p_1} + u_0)/x_{0r_1}}{(y_{j_1p_1} + u_0)/x_{j_1r_1}} = (15)$$

From (16), (17), the following equation holds:

$$\frac{(u^{*t} y_0 + u_0^*)/v^{*t} x_0}{(u^{*t} y_{j_2} + u_0^*)/v^{*t} x_{j_2}} = \frac{(y_{0p_1} + u_0)/x_{0r_1}}{(y_{j_1p_1} + u_0)/x_{j_1r_1}} = (15)$$

Where j_2 and j_1 denote the optimal values of j , respectively. (15) is the special case of (14) where v^* has r_1 th entry is 1, u^* has p_1 th entry is 1 and all other entries are 0. Thus the following holds.

The variable space of (14) \supset that of (15). Then, we have the following relation:

$$\begin{aligned} \text{The optimal of (14)} &= \frac{(y_{0p_1} + u_0)/x_{0r_1}}{(y_{j_1p_1} + u_0)/x_{j_1r_1}} \leq \text{the optimal of} \\ (15) &= \frac{(u^{*t} y_0 + u_0^*)/v^{*t} x_0}{(u^{*t} y_{j_2} + u_0^*)/v^{*t} x_{j_2}} \end{aligned} \quad (16)$$

Here we have the following two cases with respect to inputs and outputs:

$$(A_1): \frac{x_{j_21}}{x_{01}} \leq \frac{x_{j_22}}{x_{02}}$$

$$(A_2): \frac{x_{j_22}}{x_{02}} \leq \frac{x_{j_21}}{x_{01}}$$

$$(B_1): \frac{y_{01} + u_0}{y_{j_21} + u_0} \leq \frac{y_{02} + u_0}{y_{j_22} + u_0}$$

$$(B_2): \frac{y_{02} + u_0}{y_{j_22} + u_0} \leq \frac{y_{01} + u_0}{y_{j_21} + u_0}$$

Thus, we consider the following four cases:

(A1, B1), (A1, B2), (A2, B1), (A2, B2)

We have $u_0 = \frac{u_0^*}{u_1^* + u_2^*}$ and $u_0 > \max_{r,j} \{-y_{rj}\}$ so, one of them holds by lemma 1,

$$(14) = \frac{(u^{*t} y_0 + u_0^*)/v^{*t} x_0}{(u^{*t} y_{j_2} + u_0^*)/v^{*t} x_{j_2}} \quad (17)$$

$$(14) = \frac{(u_1^* y_{01} + u_0^* y_{02} + u_0^*)/v_1^* x_{01} + v_2^* x_{02}}{(u_1^* y_{j_21} + u_2^* y_{j_22} + u_0^*)/v_1^* x_{j_21} + v_2^* x_{j_22}} \geq \begin{cases} \frac{(y_{01} + u_0)/x_{01}}{(y_{j_21} + u_0)/x_{j_21}} & \text{for } (A_1, B_1) \\ \frac{(y_{02} + u_0)/x_{02}}{(y_{j_22} + u_0)/x_{j_22}} & \text{for } (A_1, B_2) \\ \frac{(y_{01} + u_0)/x_{01}}{(y_{j_21} + u_0)/x_{j_21}} & \text{for } (A_2, B_1) \\ \frac{(y_{02} + u_0)/x_{02}}{(y_{j_22} + u_0)/x_{j_22}} & \text{for } (A_2, B_2) \end{cases}$$

Employing inductive inference, Theorem 3 for general case can be proven.

Therefore, by assumption $u_0 = u_0^* / \sum_{r=1}^s u_r^*, u_0 > \max_{r,j} \{-y_{r,j}\}$,

DMUs are improved in variable RTS technology so that their lower bounds become so large as to attain the maximum value one. The i th input element and the r th output element of the ideal point for DMU₀ by variable RTS technology are denoted as follows:

$$\bar{x}_{io} = \min_r \left\{ \frac{y_{ro} + u_0}{\max_j \frac{y_{rj} + u_0}{x_{ij}}} \right\} \quad i = 1, \dots, m. \quad (18)$$

$$\bar{y}_{ro} = \max_i \left\{ \max_j \frac{y_{rj} + u_0}{x_{ij}} x_{io} \right\} \quad r = 1, \dots, s. \quad (19)$$

Therefore, for obtaining ideal DMUs in PPS with variable RTS technology, we should do following process:

- 1) First, we calculate efficiency DMUs by adjusting Russell measure in the PPS with variable RTS technology, then we obtain strong efficiency DMUs (E).
- 2) If DMU₀ is strong efficient then we calculate following LP:

$$\begin{aligned} \min \quad & u_0 \\ \text{s.t.} \quad & \sum_{r=1}^s u_r y_{rj} - \sum_i v_i x_{ij} + u_0 \leq 0, \quad j = 1, \dots, n, \\ & \sum_{r=1}^s u_r y_{ro} - \sum_i v_i x_{io} + u_0 = 0, \\ & v_i \geq \varepsilon, \quad i = 1, \dots, m, \\ & u_r \geq \varepsilon, \quad r = 1, \dots, s. \end{aligned} \quad (20)$$

- 3) We calculate $u_0 = u_0^* / \sum_{r=1}^s u_r^*$ that (u_0^*, U^*, V^*) is optimal answer of model (20). If $u_0 > \max_{r,j} \{-y_{rj}\}$ then we can obtain ideal DMU₀ by (18), (19).

Note: In the PPS with non-decreasing RTS (BCC – CCR) we can obtain ideal DMU₀ by (18), and (19), because u_0 is always non-negative.

IV. CONCLUSION

Our aim in this paper was to obtain a method for ranking DMUs. For ranking efficiency DMUs, We calculate the ideal points of efficiency DMUs and ideal PPS by Ideal of efficiency DMUs, and already DMUs. The Performance of a DMU will be better if it's ideal point has a smaller θ^* in model (12). Because, if DMU_o have better performance then it's ideal point is closer to own DMU, as a result DMU_o is far from frontier Ideal PPS. For DMUs that $\theta^*=1$ we calculate the distance of ideal point from frontier Ideal PPS, According to the method, if DMU has a shorter distance, then it has better rank.

REFERENCES

- [1] A. Charnes, W.W. Cooper, E. Rhodes, Measuring the efficiency of decision making units, *European Journal of Operational Research* 2 (1978) 429-444.
- [2] A. Charnes, W.W. Cooper, E. Rhodes, Evaluating program and managerial efficiency: An application of data envelopment analysis to program follows through, *Management Science* 27 (6) (1981) 668-734.
- [3] F. Nagano, T. Yamaguchi, T. Fukukawa, DEA with fuzzy output data, *Communications of the Operational Research Society of Japan* 40(8)(1995), 425-429 (in Japanese).
- [4] G.R. Jahanshahloo, F. Hosseinzadeh Lotfi, N. Shoja, G. Tohidi, S. Razavyan, Ranking using 11-norm in data envelopment analysis, *Applied Mathematics and Computation* 153(2004) 215-224.
- [5] K. Tone, A slacks based measure of efficiency in data envelopment analysis. *European Journal of Operational Research* 130(2001) 498-509.
- [6] R.Fare ,C.A.K. Lovel, Measuring the technical efficiency of production. *Journal of Economic Theory* 19(1978) 150-162.
- [7] R.R. Russell, Measure of technical efficiency. *Journal of Economic Theory* 35(1985) 109-126.
- [8] P. Andersen, N.C. Petersen, A procedure for ranking efficient units in data envelopment analysis, *Management Science* 39(1993) 1261-1264.
- [9] S. Mehrabian, M.R. Alirezaee, G.R. Jahanshahloo, A complete efficiency ranking of decision making units in data envelopment analysis, *Computational Optimization and Applications* 14(1999)261-266.
- [10] T. Entani, Y. Maeda, H. Tanaka, Dual models of interval DEA and its extension to interval data, *European Journal of Operational Research* 136(2002) 32-45.
- [11] T. Entani, H. Tanaka, Improvement of efficiency intervals based on DEA by adjusting inputs and outputs, *European Journal of Operational Research* 172 (2006) 1004-1017.
- [12] T. Sueyoshi, K. Sekitani, Computational strategy for Russell measure in DEA. *European Journal of Operational Research* 180(2007) 459-471.
- [13] W.W. Cooper, K.S. Park, J.T. Pastor, A range adjusted measure of inefficiency for use with additive models and relations to other models and measures in DEA. *Journal of Productivity Analysis* 11(1999) 5-42.
- [14] W.W. Cooper, J.T. Pastor, Efficiency aggregation with enhanced Russel measure in DEA Working Paper. University of Texas at Austin, TX 78712-1174, USA (2003).
- [15] Y.-M.Wang, R. Greatbanks, J.-B. Yang, Interval efficiency assessment using data envelopment analysis. *Fuzzy Sets and Systems* 153(2005) 347-370.