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Global MalmquistIndex:The Effect of the Balanced Factor

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Abstract**:** The BalancedFactor is an element that plays an important rolefor managersin many areas of their work. This factor may have a substantial effect on the circular-type orGlobal MalmquistIndex (GMI), whichis one of themost important indices for measuring productivityand growth.Due to the properties of GMI, in addition to the circularity, such as generating a single measure of productivity, being immune to LP infeasibility etc.,it is worthwhileto improve it for measuring the effect of the balanced factor, which can be computed as the ratio of BSCDEA and DEA efficiency scores. Consequently the new decomposition would be introduced to present precise interpretations.

Key words: Data Envelopment Analysis (DEA), Balanced Scorecard (BSC), Global Malmquist Index (GMI), Balanced Factor Change (BFC)

INTRODUCTION

Data Envelopment Analysis is a mathematical programming method that measures the relativeefficiency of decisionmaking units (DMUs),first proposed by Farrell (1957). Thereafter, Charnes *et al*. (1978) proposed the basic CCR model as an evaluation tool for measuringDMUs' relative efficiency.It was developed for variable returns to scale by Banker *et al*. (1984)who introducedthe BCC model. Today, there are many DEA models for evaluating the performance of DMUs in different matching areas.

Balanced Scorecard which is a management tool was first introduced by Kaplan and Norton (1992). It was motivated because there are many other measures in addition to financialmeasures. In thismethod all the measures would be categorized into different groups denoted as 'cards' which allow managersto arrange indices aligned with theorganization's strategies and manage them. Generally there are four cards: financial, customer, internal process, learning growth and innovation. Cards can be omitted or newer cards added to cover all the perspectives.

We will use a combination of two mentioned methods,which was first presented by Golany in 2006, to consider many existing qualitative factors in addition to quantitative ones in order to measure distance functions in the MalmquistIndex. In other words, we will consider bothquantitative and qualitative measures simultaneously. The Balanced Factor can be defined as the ratio of the efficiency scores of DEA-BSC and DEA models. In the result, the new expanded Global MalmquistIndex and the new decompositions would be introduced.

The StandardMalmquistIndex was introduced as an index for measuring inputs consumption by Malmquist in 1953. Then, Caves *et al*. (1982) used this concept to measure the relative productivity change overtime periods.Later, in 1992, Fare, Grosskopf, Lindgren, and Roose (FGLR) applied DEA to measure the Malmquist Index assuming constant returns to scale. Also, they identified two components: efficiency change and technological change. Subsequently in 1994, Fare, Grosskopf, Norris, and Zhang (FGNZ) expanded the Malmquist Index with considering VRS technology and adding another important factor, 'scale efficiency change'. As mentioned above, DEA models with different technologies are used to compute the distance functions and measure the Malmquist Indexbyintroducing different decompositions.

Pastor and Lovell, proposed an alternative productivity measurement index called Global MalmquistIndex in 2005. This index is based on the Global Efficient Frontier whereallDMUs of acrossperiods would be considered.Also, different decompositions including their components can be defined for this Index,similar to the standard form. For example, consider FGLR decomposition which uses CRS technology, where itbreaks down MI into efficiency change (EC) and technological change (TC) and FGNZ, usingVRS and CRS technologies, breaks down MI into pure efficiency change (PEC), scale efficiency change (SEC) and TC. Now,using CRS technology, GMI breaks down into EC and best-practice change (BPC)and employing both VRS and CRS technologies like what happens to the standard form,just EC decomposes to PEC and SEC and in result this index will breaks down into PEC, SEC and BPC which.

In real word study or scenarios, Balanced Factor is an important factor for managers.It will influence the MalmquistIndex and its decompositions as well.To fulfill this aim DEA-BSC would be used instead of CCR model as a new technology thatresults in an expanded MalmquistIndex with the expanded components,'expanded efficiency change (EEC) and expanded technological change (ETC)'. Then using both CCR and DEA-BSC models,balanced factor change (BFC) would be introduced in a way that EEC breaks down into BFC and EC.Later, considering VRS, CCR and BSC-DEA technologies, we will have 4 components in

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which EC breaks down into PEC and SEC(for more details see Alirezaee and Rajabi (2011)).In 2011, Alirezaee and Afsharian presented new insight into the Global MalmquistIndex using trade-off, CRS, and VRS technologies and presented the four-component decomposition: Pure efficiency change, scale efficiency change, rule and regulation change, and expanded best-practice change.This paper improves the definition of GMI by employing DEA-BSC technologyin addition to CRS and VRS technologies with different components.

The remainder of this paper is organized as follows:in the next section, we will review the Classic and Global MalmquistIndex. Thereafterusing the DEA-BSC technology, the expanded Global MalmquistIndex and a new decomposition would be presented and the balanced factor change would be introduced as a new component. Lasting the final section, the proposed method would be illustrated with an example and concluding remarks willbe presented.

The Classic And Global Forms Of Mi:

Consider*n* DMUs, let $X_j = (x_{1j}, x_{2j}, \ldots, x_{mj})$ be the observed input vectorand $Y_j = (y_{1j}, y_{2j}, \ldots, y_{sj})$ the observed output vectorof DMU_j. It is assumed thatthe inputs and outputs are nonnegative and nonzero.

Considering the following CRS and VRS technologies, the Standard MalmquistIndex and two important decompositions has been defined later.

Input Orientated CRS Model Input Orientated VRS Model

$$\begin{aligned} & Max \ \sum_{r=1}^{s} u_r y_{rp} \\ & s.t \\ & \sum_{i=1}^{m} v_i x_{ip} = 1 \\ & \sum_{r=1}^{s} u_r y_{rj} - \sum_{i=1}^{m} v_i x_{ij} \le 0 \quad , \ j = 1, \ldots, n \\ & u_r \ge \varepsilon \qquad r = 1, \ldots, s \\ & v_i \ge \varepsilon \qquad i = 1, \ldots, m \end{aligned} \tag{1}$$

$$\begin{aligned} & Max \ \sum_{r=1}^{s} u_r y_{rp} + u_0 \\ & s.t \\ & \sum_{i=1}^{m} v_i x_{ip} = 1 \\ & \sum_{r=1}^{s} u_r y_{rj} - \sum_{i=1}^{m} v_i x_{ij} + u_0 \le 0 \quad , \ j = 1, \ldots, n \\ & u_r \ge \varepsilon \qquad r = 1, \ldots, s \\ & v_i \ge \varepsilon \qquad i = 1, \ldots, m \\ & u_0 \quad free\ in\ sign \end{aligned} \tag{2}$$

$$MI = \left[\frac{D^t(x^{t+1}, y^{t+1})}{D^{t+1}(x^t, y^t)} \frac{D^{t+1}(x^{t+1}, y^{t+1})}{D^t(x^t, y^t)} \right]^{1/2} \tag{3}$$

$$MI = \frac{D_{CCR}^{t+1}(x_p^{\ t+1}, y_p^{\ t+1})}{D_{CCR}^{t}(x_p^{\ t}, y_p^{\ t})} \left[\frac{D_{CCR}^{t}(x_p^{\ t+1}, y_p^{\ t+1})}{D_{CCR}^{t+1}(x_p^{\ t+1}, y_p^{\ t+1})} \frac{D_{CCR}^{t}(x_p^{\ t}, y_p^{\ t})}{D_{CCR}^{t+1}(x_p^{\ t}, y_p^{\ t})} \right]^{1/2} = EC.TC \tag{4}$$

$$MI = \frac{D_{VRS}^{t+1}(x_p^{t+1}, y_p^{t+1})}{D_{VRS}^{t}(x_p^{t}, y_p^{t})} \frac{\dfrac{D_{CCR}^{t+1}(x_p^{t+1}, y_p^{t+1})}{D_{VRS}^{t+1}(x_p^{t+1}, y_p^{t+1})}}{\dfrac{D_{CCR}^{t}(x_p^{t}, y_p^{t})}{D_{VRS}^{t}(x_p^{t}, y_p^{t})}} \left[\frac{D_{CCR}^{t}(x_p^{t+1}, y_p^{t+1})}{D_{CCR}^{t+1}(x_p^{t+1}, y_p^{t+1})} \frac{D_{CCR}^{t}(x_p^{t}, y_p^{t})}{D_{CCR}^{t+1}(x_p^{t}, y_p^{t})} \right]^{1/2}$$

$$= PEC.SEC.TC \tag{5}$$

Which notation $D^{t+1}(x^t, y^t)$ is the distance between observations overtime periods t and t+1 and can be calculated as follows:

$$\begin{aligned} D_{CRS}^{t+1}(X_p^t, Y_p^t) = Max \ & \sum_{r=1}^{s} u_r^{t+1} y_{rp}^t \\ s.t \quad & \sum_{i=1}^{m} v_i^{t+1} x_{ip}^t = 1 \\ & \sum_{r=1}^{s} u_r^{t+1} y_{rj}^{t+1} - \sum_{i=1}^{m} v_i^{t+1} x_{ij}^{t+1} \le 0 \quad , j = 1, \ldots, n \\ & u_r^{t+1} \ge \varepsilon \qquad r = 1, \ldots, s \\ & v_i^{t+1} \ge \varepsilon \qquad i = 1, \ldots, m \end{aligned} \tag{6}$$

Now, considering the following linear programming model, we will have the Global MalmquistIndex and its decompositions as follows:

$$\begin{aligned} & Max \ \sum_{r=1}^{s} u_r y_{rp} \\ s.t \quad & \sum_{i=1}^{m} v_i x_{ip} = 1 \\ & \sum_{r=1}^{s} u_r y_{rj} - \sum_{i=1}^{m} v_i x_{ij} \le 0 \quad , j = 1, \ldots, n \times t \\ & u_r \ge \varepsilon \qquad r = 1, \ldots, s \\ & v_i \ge \varepsilon \qquad i = 1, \ldots, m \end{aligned} \tag{7}$$

Which t in model (7) indicates the number of total time periods.

$$Global\, Malmquist\, Index(GMI) = \frac{D_{CRS}^{G}(X_p^{t+1}, Y_p^{t+1})}{D_{CRS}^{G}(X_p^{t}, Y_p^{t})} \tag{8}$$

$$GMI = \frac{D_{CRS}^{t+1}(X_p^{t+1}, Y_p^{t+1})}{D_{CRS}^{t}(X_p^{t}, Y_p^{t})} \left[\frac{D_{CRS}^{G}(X_p^{t+1}, Y_p^{t+1})}{D_{CRS}^{t+1}(X_p^{t+1}, Y_p^{t+1})} \times \frac{D_{CRS}^{t}(X_p^{t}, Y_p^{t})}{D_{CRS}^{G}(X_p^{t}, Y_p^{t})} \right] = EC \times BPC \tag{9}$$

$$GMI = \frac{D_{VRS}^{t+1}(X_p^{t+1}, Y_p^{t+1})}{D_{VRS}^{t}(X_p^{t}, Y_p^{t})} \frac{\dfrac{D_{CRS}^{t+1}(X_p^{t+1}, Y_p^{t+1})}{D_{VRS}^{t+1}(X_p^{t+1}, Y_p^{t+1})}}{\dfrac{D_{CRS}^{t}(X_p^{t}, Y_p^{t})}{D_{VRS}^{t}(X_p^{t}, Y_p^{t})}} \left[\frac{D_{CRS}^{G}(X_p^{t+1}, Y_p^{t+1})}{D_{CRS}^{t+1}(X_p^{t+1}, Y_p^{t+1})} \times \frac{D_{CRS}^{t}(X_p^{t}, Y_p^{t})}{D_{CRS}^{G}(X_p^{t}, Y_p^{t})} \right] \tag{10}$$

$$= PEC \times SEC \times BPC$$

Which $D^G(x^t, y^t)$ can be calculated as follows:

$$D_{CRS}^{G}(X_p^t, Y_p^t) = Max \sum_{r=1}^{s} u_r y_{rp}^t$$

$$\begin{aligned} s.t \quad & \sum_{i=1}^{m} v_i x_{ip}^t = 1 \\ & \sum_{r=1}^{s} u_r y_{rj} - \sum_{i=1}^{m} v_i x_{ij} \le 0 \quad , j = 1, \ldots, n \times t \\ & u_r \ge \varepsilon \qquad r = 1, \ldots, s \\ & v_i \ge \varepsilon \qquad i = 1, \ldots, m \end{aligned} \tag{11}$$

As above, employing CRS technology,both indices break down into two components, EC and TC in standard MI and EC and BPC in GMI. Later using CRS and VRS technologies we will have 3-component decomposition in both form of MI, which EC breaks down into PEC and SEC.

The definition of the GMI in comparison to MI shows that MI is the geometric mean of times t and t+1 (expression 12) and is not circular but considering one global technology solve this serious problem.

$$MI = \left[\frac{D^t(x^{t+1}, y^{t+1})}{D^{t+1}(x^t, y^t)} \frac{D^{t+1}(x^{t+1}, y^{t+1})}{D^t(x^t, y^t)} \right]^{1/2} \tag{12}$$

Expanded Global Malmquist Index:

First we review the expanded MalmquistIndex measurement in the classic form, and then we propose our method in its global form.

To consider Balanced Factor we can use BSC method accompanying with DEA models. Theintegrated DEA-BSC model through the following balanced constraint will accomplish this goal.

Also, in this way all appropriate indices with qualitative and quantitative measures would be considered via cards in BSC method, which aligns with the strategies of the organizations. Assuming k_0 cards, the balanced constraints will be defined as follows:

$$\sum_{k=1}^{k_0} \left(\sum_{r \in C_k} u_r y_{rj} \Big/ \sum_{r=1}^{s} u_r y_{rj} \right) = 1 \quad \forall \text{ j} \tag{12}$$

Which the first summation is the proportion of the total output of DMUp devoted to card C_k which is the "importance" of card C_k related toDMUp. This term indicates the amount of depending DMUp on outputs in C_k in its efficiency score. To impose the desired balance, decision makers put suitable bounds for these components. This can be added into the model through the following constraints.

$$L_{C_k} \le \sum_{r \in C_k} u_r y_{rp} \Big/ \sum_{r=1}^{s} u_r y_{rp} \le U_{C_k} \quad \forall k \tag{13}$$

As mentioned in the previous section, we can define different decompositions based on different technologies which are used.Now, if we change the CRS technology as the basic technology with DEA-BSC technology, we will have the expanded MI as follows:

$$EMI = EEC \times ETC \;;\; EEC = \frac{D_{BD}^{t+1}(x_p^{\,t+1}, y_p^{\,t+1})}{D_{BD}^{t}(x_p^{\,t}, y_p^{\,t})} \;,$$

$$ETC = \left[\frac{D_{BD}^{t}(x_p^{\,t+1}, y_p^{\,t+1})}{D_{BD}^{t+1}(x_p^{\,t+1}, y_p^{\,t+1})} \frac{D_{BD}^{t}(x_p^{\,t}, y_p^{\,t})}{D_{BD}^{t+1}(x_p^{\,t}, y_p^{\,t})} \right]^{1/2} \qquad (14)$$

It is noticeable that we can have its decompositions the same as the standard form.Now, by considering CRS technology in addition to DEA-BSC technology, the following decomposition would be appeared:

$$EMI = EC \times BFC \times ETC \;; \qquad BFC = \left[\frac{D_{CCR}^{t}(x_p^{\,t}, y_p^{\,t})}{D_{BD}^{t}(x_p^{\,t}, y_p^{\,t})} \times \frac{D_{BD}^{t+1}(x_p^{\,t+1}, y_p^{\,t+1})}{D_{CCR}^{t+1}(x_p^{\,t+1}, y_p^{\,t+1})} \right] \qquad (15)$$

Finally, considering VRS technology in addition to CRS and DEA-BSC technologies, results in decomposing EC into PEC and SEC like what happens in FGNZ decomposition.

$$EMI = PEC \times SEC \times BFC \times ETC \qquad (16)$$

$D_{BD}^{t+1}(X_p^{\,t}, Y_p^{t})$ Can be calculated via the following model:

$$\begin{aligned} D_{BD}^{t+1}(X_p^{\,t}, Y_p^{t}) = Max \; & \sum_{r=1}^{s} u_r^t y_{rp}^t \\ s.t. \quad & \sum_{i=1}^{m} v_i^t x_{ip}^t = 1 \\ & -\sum_{i=1}^{m} v_i^{t+1} x_{ij}^{t+1} + \sum_{r=1}^{s} u_r^{t+1} y_{rj}^{t+1} \le 0 \qquad \forall j \\ & L_{C_k} \le \sum_{r \in C_k} u_r^t y_{rp}^t \Big/ \sum_{r=1}^{s} u_r^t y_{rp}^t \le U_{C_k} \quad \forall k \\ & u_r^{t+1}, v_i^{t+1} \ge \varepsilon \qquad \forall i, r \end{aligned} \qquad (17)$$

Consider global linear programming model instead of basic models of DEA. Now, we can apply all mentioned concepts and define the expanded GMI and its new decompositions as follows:

$$Expanded\;\; Global\;\; Malmquist\;\; Index\,(EGMI) = \frac{D_{BD}^{G}(X_p^{\,t+1}, Y_p^{t+1})}{D_{BD}^{G}(X_p^{\,t}, Y_p^{t})} \qquad (18)$$

$$EGMI = EEC \times EBPC \qquad (19)$$

$$Expanded\;\; Best\;\; Practice\;\; Change\,(EBPC) = \left[\frac{D_{BD}^{G}(X_p^{\,t+1}, Y_p^{t+1})}{D_{BD}^{t+1}(X_p^{\,t+1}, Y_p^{t+1})} \times \frac{D_{BD}^{t}(X_p^{\,t}, Y_p^{t})}{D_{BD}^{G}(X_p^{\,t}, Y_p^{t})} \right] \qquad (20)$$

Where $D_{BD}^{G}(X_p^t, Y_p^t)$ can be computed through the following model:

$$
\begin{aligned}
D_{BD}^{G}(X_p^t, Y_p^t) = Max \sum_{r=1}^{s} u_r y_{rp}^t \\
s.t. \quad \sum_{i=1}^{m} v_i x_{ip}^t = 1 \\
-\sum_{i=1}^{m} v_i x_{ij} + \sum_{r=1}^{s} u_r y_{rj} \le 0 \qquad , \qquad j = 1, \ldots, n \times t \\
L_{C_k} \le \sum_{r \in C_k} u_r y_{rp}^t / \sum_{r=1}^{s} u_r y_{rp}^t \le U_{C_k} \quad \forall k \\
u_r, v_i \ge \varepsilon \qquad \forall i, r
\end{aligned}
\tag{21}
$$

Using CRS technology in addition to DEA-BSC model, we will have the following decomposition:

$$EGMI = EC \times BFC \times EBPC$$

Employing VRS, CRS and DEA-BSC technologies, 4-component decomposition will be defined:

$$EGMI = PEC \times SEC \times BFC \times EBPC$$

Illustrative Example:

The following example will illustrate the proposed method for calculating the expanded GMI and its decompositions. Considering table1, we have 15 DMUs with 2 inputs and 3 outputs at two periods. Suppose that we have 4 cards relating to BSC method,3 card related to outputs and one related to 2 inputs, and the importance of all 3 cards related to each output are bounded between 0.2 and 0.6.

The results of the GMI and expanded GMI and their componentsare shown in tables 2 and 3, respectively.

Table 1: Data of 15 DMUs with 2 Inputs and 3 Outputs at 2 Periods

Unit	*Period 1*					*Period 2*				
	Input1	Input2	Output1	Output2	Output3	Input1	Input2	Output1	Output2	Output3
DMU 1	8	10	20	5	5	8	10	30	5	10
DMU 2	7	9	14	4	6.5	7	9	10	10	6.5
DMU 3	10	8	10	6	7	10	8	10	6	7
DMU 4	12	14	18	5	3	12	14	30	5	8
DMU 5	14	3	4	7.5	8	14	3	10	7.5	5
DMU 6	8	8	11	6	5.5	8	8	20	6	5.5
DMU 7	15	10	16	2.5	3	15	10	10	2.5	7
DMU 8	10	10	13	5.5	9	10	10	13	5.5	20
DMU 9	6	12	16	4.5	7.5	6	12	16	4.5	10.5
DMU 10	20	8	13	2.5	6	20	8	20	2.5	6
DMU 11	10	15	22	3	8.5	10	15	15	8	8.5
DMU 12	8	4	5	4.5	5	8	4	5	4.5	5
DMU 13	9	16	20	8	7	9	16	15	8	7
DMU 14	17	9	14	6	4	17	9	14	10	4
DMU 15	6	8	12	3.5	8	6	8	12	3.5	8

Table 2: The Results of the Global Malmquist Index and its Decompositions

Unit	PEC	SEC	EC	BPC	GMI(TFPG)
DMU1	1.00	1.00	1.00	1.28	1.28
DMU2	1.07	1.01	1.08	1.31	1.41
DMU3	0.81	0.99	0.80	1.25	1.00
DMU4	1.14	0.94	1.08	1.29	1.39
DMU5	1.00	1.00	1.00	1.00	1.00
DMU6	1.00	0.98	0.98	1.31	1.29
DMU7	0.59	0.95	0.56	1.53	0.85
DMU8	1.00	1.12	1.12	1.27	1.42
DMU9	1.00	1.00	1.00	1.10	1.10
DMU10	0.90	1.02	0.92	1.59	1.46
DMU11	0.97	0.82	0.79	1.43	1.14
DMU12	1.00	0.90	0.90	1.11	1.00
DMU13	0.94	0.81	0.76	1.16	0.88
DMU14	1.07	0.89	0.95	1.45	1.38
DMU15	1.00	0.83	0.83	1.20	1.00

Table 3: The Results of the Expanded Global Malmquist Index and its Decompositions

Unit	BFC	PEC	SEC	EEC	EBPC	EGMI(TFPG)
DMU1	1.04	1.00	1.00	1.04	1.34	1.40
DMU2	0.95	1.07	1.01	1.02	1.31	1.34
DMU3	1.01	0.81	0.99	0.80	1.24	1.00
DMU4	1.21	1.14	0.94	1.31	1.30	1.71
DMU5	1.00	1.00	1.00	1.00	1.08	1.08
DMU6	0.93	1.00	0.98	0.91	1.31	1.20
DMU7	1.53	0.59	0.95	0.85	1.23	1.05
DMU8	1.00	1.00	1.12	1.12	1.27	1.42
DMU9	1.00	1.00	1.00	1.00	1.10	1.10
DMU10	1.04	0.90	1.02	0.96	1.24	1.19
DMU11	1.19	0.97	0.82	0.95	1.29	1.22
DMU12	0.93	1.00	0.90	0.83	1.20	1.00
DMU13	1.01	0.94	0.81	0.77	1.21	0.93
DMU14	0.98	1.07	0.89	0.93	1.24	1.16
DMU15	1.00	1.00	0.83	0.83	1.20	1.00

According to the results of tables 2 and 3, we will find the effects of the balanced factor on the GlobalMalmquist Index and its components.

About DMU4, there is no significant difference in BPC and EBPC (+0.01), but considering the balanced factor leads to an increase in the EC (+0.23) because of the effect of a balanced factor increase (+0.21) and consequently we will have an increase in the MalmquistIndex (+0.32).It means that this DMU has a substantial adaption with bank strategies,which have been imposed through balanced constraints in the model.

Now, consider DMU2. There is no difference in BPC and EBPC, but here a decrease in EC (-0.06) leads to a decrease in the MalmquistIndex (-0.07)because of the influence of a decrease in the balanced factor (-0.05). In the other words, DMU2 has a weak adaption with the strategies of bank.The same interpretation can be presented for DMU6.

Focusing on the results of DMU14 shows that there areno significant changes in balanced factor and also in EC (-0.02), but the effect of this factor leads to a decrease in BPC (-0.21) which will cause a decrease in the MalmquistIndex (-0.22).

Finally, consider DMU7, theMalmquistIndex has increased by 20% and this DMU has changed from a negative growth to a positive growth. However we have a substantial decrease in BPC (-0.30), but balanced factor has a great increase (+0.53)and at the end it will result in changing its position from negative growth to positive one.

Conclusion:

In this paper an expanded GMI was proposed to consider the effect of the balanced factor. We used DEA-BSC technology instead of CCR technology introducing the including EEC and EBPC as components of the new expanded decomposition. Then applying both of the technologies EGMI break down into EC, BFC and EBPC. Finally, by considering VRS technology in addition to previous technologies, 4-component decomposition introduced with breaking down EC into PEC and SEC.To investigate the effect of this factor on results, the proposed method was illustrated by an example.

REFERNCES

Alirezaee, M.R., M. Afsharian, 2011. Measuring the Effect of theRules and Regulations onGlobalMalmquist Index. International Journal of Operations Research and Information Systems, 2(3): 64-78.

Alirezaee, M.R., M. Afsharian, 2010. Improving the discrimination of data envelopment analysis models in multiple time periods. International Transportations in Operational Research, 17: 667-679.

Banker, R.D., A. Charnes, W.W. Cooper, 1984. Some models for estimating technical and scale inefficiency in data envelopment analysis. *Management Science*, 31: 1078-1092.

Caves, D.C., L.R. Christensen, W.E. Dievert, 1982. The economic theory of index number and the measurement of input, output, and productivity.*Econometrica* 50: 1393-1414.

Charnes, A., W.W. Cooper, E. Rhodes, 1978. Measuring the efficiency of the decision making units.*European Journal of Operational Research*, 2: 429–444.

Cooper, W.W., L.M. Seiford, K. Tone, 2000. *Data envelopment analysis: A comprehensive text with models, applications, references, and DEA-solver software*. Kluwer Academic Publisher, Dordrecht.

Eilat, H., B. Golany, A. Shtub, 2006.Constructing and evaluating balanced portfolios of R&D projects with interactions: A DEA based methodology. *European Journal of Operational Research*, 172: 1018-1039.

Eilat, H., B. Golany, A. Shtub, 2008. R&D project evaluation: An integrated DEA and balanced scorecard approach. *Omega.*, 36: 895-912.

Farrell, M.J., 1957.The measurement of productive efficiency.*Journal of the Royal Statistical Society*, 120: 253-282.

Fare, R., S. Grosskopf, B. Lindgren, P. Roose, 1992. Productivity change in Swedish analysis pharmacies 1980–1989: A nonparametric Malmquist approach. *Journal of Productivity*, 3: 85-102.

Fare, R., S. Grosskopf, M. Norris, A. Zhang, 1994.Productivity growth, technical progress, and efficiency changes in industrial country.*American Economic Review*, 84: 66-83.

Kaplan and Norton, The balanced scorecard: Translating strategy in to action. Harvard Business School Press, Cambridge.

Kaplan, R.S., D.P. Norton, 1996a. Using the balanced scorecard as a strategic measurement system. *Harvard Business Review* (January–February).

Kaplan, R.S., D.P. Norton, 1996b. *Translating strategy into action: The balanced scorecard*. Harvard Business School Press, Boston.

Malmquist, S., 1953. Index numbers and indifferent surfaces.*Trabajos de Estadistica* 4(1): 209-242.

Pastor, J.T., & C.A. Lovell, 2005. A global Malmquist productivity index.*Economics Letters*, 88: 266-271.

Shephard, R.W., 1970. *Theory of cost and production function*.Princeton NJ: Princeton University Press.