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APPLICATION OF STEPWISE DATA ENVELOPMENT ANALYSIS AND GREY INCIDENCE ANALYSIS TO EVALUATE THE EFFECTIVENESS OF EXPORT PROMOTION PROGRAMS

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Abstract. Export promotion programs are incentives to increase the participation of companies in international markets. On the other hand, governments try to help exporting companies with developing their goal markets. Therefore, for this purpose, many different programs have been created. To show the effectiveness of these programs, the paper refers to stepwise DEA and grey incidence analysis. Finally, the article determines a unified ranking of the applied programs that can be used by decision makers for resource allocation considering different types of programs based on their effectiveness.

Keywords: Multiple criteria decision making, stepwise DEA, grey incidence analysis, food industry, export promotion programs.

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1. Introduction

Economic scholars believed that export had a major and direct impact on economic conditions and growth of the country. At a micro level, the export of goods and services has become increasingly important for the survival of growth oriented domestic firms. At a macro level, exporting is important for dealing with trade deficit problems experienced by many countries (Julian, Ali 2009). These impacts persuade governments to design and provide some programs in order to promote the magnitude and diversity of export in their countries.

Export promotion programs (EPPs) are a class of policies that governments make to encourage and reinforce domestic exporters to expand their activities. It can be defined as an incentive program designed for attracting firms into export by offering help with product and market identification and development (Korsakienė, Tvaronavičienė 2012; Travkina, Tvaronavičienė 2011; Valuckaite, Snieska 2007; Zhou *et al.* 2010), prescription and post-shipment, financing, training, payment guaranty schemes, trade fairs, trade visits, foreign representation, etc. (Shamsuddoha *et al.* 2009; Lages *et al.* 2008) used electronic information retrieval methods (Burinskas *et al.* 2010; Azimi *et al.* 2011; Büyüközkan 2004) and systems (Kaklauskas *et al.* 2002a,b, 2003, 2010; Zavadskas *et al.* 2005).

Some studies have shown a positive direct impact of EPPs on export performance (Balassa 1978; Kumar Roy 1993; Ramaseshan, Soutar 1996; Billings *et al*. 2003; Francis, Collins-Dodd 2004; Shamsuddoha, Ali 2006; Zia 2008; Julian, Ali 2009; Larbi, Chymes 2009; Lederman *et al.* 2010; Freixanet 2011; Argent 2011). Also, Armah and Epperson (1997), Knowles and Mathur (1997), and Onunkwo and Epperson (2000) have tried to measure the global impact of specific promotion interventions. Some studies have indirectly evaluated program effects, considering them among other factors to explain export performance (Crick, Chaudhry 1997; Katsikeas *et al.* 1996; Walters 1983).

This study is done to determine the effects of EPPs on Iran food industry. A set of different EPPs are proposed to food product exporters in Iran. This diversity in programs and their requested funds forces decision makers to appraise the effects of different EPPs and assign financial resources based on a logical and structured manner. The aim of this study to determine and clarify the effectiveness of EPPs in Iran is satisfied through a hybrid application of stepwise data envelopment analysis (stepwise DEA) and grey incidence analysis (GIA) methods.

The paper is organized as follows: section 2 discusses the concept of stepwise DEA, section 3 briefly introduces the GIA method and section 4 explores the framework of data gathering. The analysis and their results are presented in section 5. Finally, section 6 consists of conclusions and future work.

2. Stepwise data envelopment analysis

Data envelopment analysis was originally proposed by Charnes *et al.* (1978) as a method to evaluate the relative efficiency of a set of units that consume a set of m inputs and transform them into a set of s outputs. For more details on DEA refer to Cooper *et al.* (2002) and Ray (2004). For reviewing applications for DEA see Emrouznejad *et al.* (2008).

The classic CCR model can be introduced as follows. Suppose there are a set of m homogenous units. Each unit, $DMU_j, j = 1, 2, \ldots, n$, use a set of m inputs $X_j = \left(x_{1j}, x_{2j}, \ldots, x_{mj}\right)$ to produce a set of s outputs $Y_j = \left(y_{1j}, y_{2j}, \ldots, y_{sj}\right)$. The input oriented CCR model to evaluate the relative efficiency of these DMUs for each $DMU_0, 0 \in \{1, 2, \ldots, n\}$ is developed as follows:

$$\begin{aligned}
&\min \theta_0 \\
&\sum_{j=1}^{n} \lambda_j x_{ij} \le \theta_0 x_{i0},\ i = 1,2,\ldots,m, \\
&\sum_{j=1}^{n} \lambda_j y_{rj} \ge y_{r0},\ r = 1,2,\ldots,s, \\
&\lambda_j \ge 0, \qquad j = 1,2,\ldots,n.
\end{aligned} \tag{1}$$

In model (1), θ_0 shows the radial efficiency of DMU_0 and $\lambda_j, j = 1,2,\ldots,n$ is a vector of intensity variables. DMU is efficient if its radial efficiency is equal to one and all of its slack variables in optimal solutions of model (1) are zero. Now, suppose that the input vector is segmented into two sub vectors: discretionary inputs $X_j^d = \left(x_{1j}^d, x_{2j}^d, \ldots, x_{kj}^d\right)$ and non discretionary inputs $X_j^{nd} = \left(x_{1j}^{nd}, x_{2j}^{nd}, \ldots, x_{lj}^{nd}\right)$. Then, according to Banker and Morey (1986), the input oriented CCR model with non discretionary variables is constructed as

$$\begin{aligned}
&\min \theta_0 \\
&\sum_{j=1}^{n} \lambda_j x_{ij} \le \theta_0 x_{i0},\ i = 1,2,\ldots,k, \\
&\sum_{j=1}^{n} \lambda_j x_{ij} \le x_{i0},\ \ i = 1,2,\ldots,l, \\
&\sum_{j=1}^{n} \lambda_j y_{rj} \ge y_{r0},\ r = 1,2,\ldots,s, \\
&\lambda_j \ge 0, \qquad j = 1,2,\ldots,n.
\end{aligned} \tag{2}$$

One of the most important aspects of applying DEA is the choice of input and output variables. Golany and Roll (1989), Norman and Stocker (1991), Kittelson (1993), Lovell and Pastor (1997), Salinas-Jimenez and Smith (1996), Jenkins and Anderson (2003), Sigala *et al.* (2004), and Wagner and Shimshak (2007) examined this problem in the area of DEA following different procedures.

Wagner and Shimshak (2007) proposed stepwise DEA as an approach to variable selection. This method is presented in two forms: backward and forward. Since this paper uses the forward one, it is explained in this section. The forward approach has proposed some simple rules on adding variables in the DEA model – one at a time.

If a "core" model of one input and one output can be determined as a starting point, then, the stepwise method can also be adapted to add variables to the DEA model instead of dropping them. In the forward stepwise approach, the goal is the identification of variables that cause the largest difference in total efficiency scores.

Suppose there are a set of m inputs and s outputs to be considered for efficiency evaluation and the user wants to choose the most effective variables. As for the forward stepwise method, work is stated considering one input and one output as the core model. In the next step, run a set of $(m-1)+(s-1)$ DEA analysis adding one input variable and one output variable at a time in each run. Then, choose the single input or output to be added by selecting the maximum average difference in efficiency scores resulting from this single variable. The process is repeated until there are not any variables to be added or all units become efficient.

3. Grey incidence analysis

Deng (1982) introduced the grey system theory (GST) as a tool for studying system uncertainty. One of the major components of GST is grey incidence analysis (GIA) dealing with the analysis of complex systems consisting of multiple factors the mutual interactions of which determine the behaviour of the system. It is often the case that among all factors, investigators want to know the ones having dominant effect, whereas the others exert less influence on the development of the system (Liu, Lin 2010). GIA is applied in different studies related to system analysis, for instance, Zhou *et al.* (2005), Yan-hui *et al.* (2007), Wang *et al.* (2008), Lin *et al.* (2009) and Yue (2009). Assume that X_i is a system factor and its observation value at ordinal position *k* is $x_i(k), k=1,2,\ldots,n$. Then, $X_i=(x_i(1),x_i(2),\ldots,x_i(n))$ is referred to as the behavioural sequence of factor X_i.

Different grey incidence degrees are defined between two behavioural sequences X_i and $X_0=(x_0(1),x_0(2),\ldots,x_0(n))$ as follows (Liu, Lin 2010).

Definition 1. Let X_i and X_j be two sequences of the same length. Then,

$$\varepsilon_{ij}=\frac{1+|s_i|+|s_j|}{1+|s_i|+|s_j|+|s_i-s_j|}, \tag{3}$$

where

$$s_i=\sum_{k=2}^{n-1}x_i^0(k)+\frac{1}{2}x_i^0(n). \tag{4}$$

In Eq. (4), $x_i^0(k)$ is defined as $x_i^0(k)=x_i(k)-x_i(1),\ k=1,2,\ldots,n$ and X_i^0 is called the zero image of sequence X_i. s_j and s_i-s_j are defined similarly. Then, ε_{ij} is called the absolute degree of grey incidence between X_i and X_j.

Definition 2. Let X_i and X_j be two sequences of the same length with non-zero initial values. Then, X_i' and X_j' are the initial image of X_i and X_j obtained by dividing all elements of each sequence to its initial value, i.e.

$$x_i'(k)=\frac{x_i(k)}{x_i(1)},\ k=1,2,\ldots,n. \tag{5}$$

Then, the absolute degree of grey incidence of X_i' and X_j' is referred to as the relative degree of (grey) incidence of X_i and X_j, denoted r_{ij}, i.e.

$$r_{ij} = \frac{1+\left|s'_i\right|+\left|s'_j\right|}{1+\left|s'_i\right|+\left|s'_j\right|+\left|s'_i - s'_j\right|}, \tag{6}$$

where
$$s'_i = \sum_{k=2}^{n-1} x_i'^0(k) + \frac{1}{2} x_i'^0(n). \tag{7}$$

Definition 3. Assume that X_i and X_j are the sequences of the same length with non-zero initial entries. ε_{ij} and r_{ij} are the absolute degree and relative degree of grey incidence of X_i and X_j, and $\theta \in [0,1]$. Then,

$$\rho_{ij} = \theta\varepsilon_{ij} + (1-\theta) r_{ij} \tag{8}$$

is called the synthetic degree of (grey) incidence between X_i and X_j.

Note that the absolute degree looks at relationships from the angle of absolute magnitude, the relative degree – from the angle of the rates of changes in each observation with respect to their initial point and the synthetic degree – from the combined angle of both.

Now, suppose that $Y_1, Y_2, \ldots, Y_s$ are the sequences of the characteristic behaviour of the system (output variables), and $X_1, X_2, \ldots, X_m$ are the behavioural sequence of relevant factors (input variables). Then, the absolute matrix of grey incidences is the $s \times m$ matrix $A = \left[\varepsilon_{ij}\right]$, the ijth element of which is the absolute degree of grey incidence between Y_i and X_j. The relative matrix of grey incidences $B = \left[r_{ij}\right]$ is the $s \times m$ matrix the ijth element of which is the relative degree of grey incidence between Y_i and X_j. The synthetic matrix of grey incidences $C = \left[\rho_{ij}\right]$ is the $s \times m$ matrix the ijth element of which is the synthetic degree of grey incidence between Y_i and X_j.

Considering, for example, matrix *C*, the favourability characteristics of the factors can be defined as follows:

Definition4. If *l* and *j* $\in \{1, 2, \ldots, m\}$ satisfy

$$\rho_{il} \geq \rho_{ij} \tag{9}$$

for $i = 1, 2, \ldots, s$, then factor X_l is supposed to be more favourable than factor X_j denoted as $X_l \succ X_j$; if for $j = 1, 2, \ldots, m, j \neq l$ we always have $X_l \succ X_j$, and then X_l is called the most favourable factor (Liu, Lin 2010).

4. Data gathering framework

This study was done within the period from January 2000 to December 2009. The obtained data are gathered from the existing documents and reports on export performance of food industry in Iran. The study, according to the actual reports, admits six types of EPPs along with an additional factor in the money equivalent considered as an uncontrollable factor. According to the present data, six types of EPPs can be identified: (1) export rewards (ER), (2) international exhibitions (IE), (3) protection of transfer to export (PTE), (4) currency support (CS), (5) training and announcement (TA) and (6) insurance support (IS). Table 1 shows data obtained considering a time period, export magnitude and money equivalent (ME).

Table 1. EPPs and export data covering the period from January 2000 to December 2009

Year	Export	ER	IE	PTE	CS	TA	IS	ME
2000	207253	10880	3				0.2	1750
2001	195634	46658	3				0	7950
2002	325761	81309	4	620			0.3	8320
2003	248755	65223	1	527			0.09	8740
2004	4139033	115302	2	1115	68	73	0.2	8500
2005	6488543	176641	3	1864	72	277	0.2	9000
2006	8391825	217663	4	4285		1221	0.9	9500
2007	9008304	235806	3	2603	42135	1859	0.09	8900
2008	11666950	223130	3	14955	4933	1597	1.4	9500
2009	14085273	267381	3	22019		817	3.4	9850

5. Data analysis

This section displays the results of analyses conducted with reference to the above data.

5.1. Stepwise DEA

This section points to the method based on the stepwise DEA model where a classic CCR (Charnes *et al.* 1978) model is applied every year as a DMU. The above introduced models are performed considering ME as non-discretionary input (Banker, Moray 1986).

In a forward stepwise DEA manner, the initial efficiency of DMUs without any input is equal to zero. Now, each EPP is considered as discretionary input and that with ME as non discretionary input. The results of adding new inputs to the model are shown in Table 2.

Table 2. The results of adding one input to DEA with ME as non discretionary input

Efficiency Added EPP	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	Average
ER	1	0.23	0.16	0.18	0.72	0.72	0.74	0.73	0.99	1	0.647
IE	1	0.41	0.28	1	0.86	0.65	0.54	0.80	0.90	1	0.744
PTE	1	1	0.05	0.02	1	0.98	0.56	1	0.85	1	0.746
CS	1	1	1	1	0.01	0.01	1	0.0002	0.0002	1	0.602
TA	1	1	1	1	1	0.9	0.32	0.24	0.40	1	0.786
IS	1	1	0.3	0.1	0.24	0.35	0.1	1	1	1	0.609

Since the TA variable has the highest impact on average efficiency improvement, it can be chosen in this phase as the most important EPP. In phase 2, the DEA model is run considering non discretionary variable ME and TA as two discretionary variables. Table 3 shows the received results. In this phase, PTE causes the highest increase in average efficiency and therefore this variable is chosen as the second effective EPP.

Phase 3 begins by considering non discretionary variable ME and two discretionary variables TA and EPP. The obtained efficiency is shown in Table 4 indicating that in this phase the highest increase in average efficiency is obtained by adding the ER variable.

Phase 5 runs considering ME with TA, PTE and ER. Efficiency obtained by adding the remaining EPPS is shown in Table 5 according to which the highest increase in average efficiency is achieved adding the CS variable chosen in this phase. While all DMUs reach full efficiency in this phase, adding more variables do not have any effect on efficiency.

Table 3. The results of adding one input to DEA with ME as non discretionary and TA as discretionary input

Efficiency Added EPP	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	Average
ER	1	1	1	1	1	0.89	0.74	0.73	0.99	1	0.935
IE	1	1	1	1	1	0.89	0.54	0.80	0.89	1	0.912
PTE	1	1	1	1	1	1	0.91	1	0.85	1	0.976
CS	1	1	1	1	1	0.89	1	0.24	0.39	1	0.852
IS	1	1	1	1	1	1	0.68	1	1	1	0.968

Table 4. The results of adding one input to DEA with ME as non discretionary and TA and PTE as discretionary inputs

Efficiency Added EPP	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	Average
ER	1	1	1	1	1	1	0.967	1	1	1	0.9967
IE	1	1	1	1	1	1	0.91	1	0.96	1	0.987
CS	1	1	1	1	1	1	1	1	0.966	1	0.9966
IS	1	1	1	1	1	1	0.91	1	1	1	0.991

Table 5. The results of adding one input to DEA with ME as non discretionary and TA, PTE and ER as discretionary inputs

Efficiency Added EPP	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	Average
IE	1	1	1	1	1	1	0.96	1	1	1	0.996
CS	1	1	1	1	1	1	1	1	1	1	1
IS	1	1	1	1	1	1	0.96	1	1	1	0.996

The forward stepwise DEA shows that EPPs can be ordered as follows:

$$TA \succ PTE \succ ER \succ CS \succ IE = IS\,.$$

5.2. Grey incidence analysis

In this section, data on Table 1 are analyzed employing the GIA method as described in section 3. According to Equations (3) – (8), absolute incidence matrix A, relative incidence matrix B and synthetic incidence matrix C are calculated as follows.

The results in Table 6 show that with reference to Eq. (9), the favourability of EPPs, according to their grey synthetic incidence and matrix C, is as follows:

$$ER \succ CS \succ PTE \succ TA \succ IS \succ IE .$$

Table 6. Grey incidence matrixes

	ER	IE	PTE	CS	TA	IS
A	0.5131	0.500000005	0.50039	0.50053	0.5005	0.50000004
B	0.500001	0.500000005	0.500002	0.50012	0.50001	0.50000018
C	0.5065	0.500000005	0.50019	0.50032	0.500036	0.50000011

5.3. Aggregating the results

Sections 5.1 and 5.2 present two distinct rankings obtained for EPPs shown in Table 7.

Table 7. EPPs ranking obtained by stepwise DEA and GIA

EPP	Ranking obtained by	
	Stepwise DEA	GIA
ER	3	1
IE	5.5*	6
PTE	2	3
CS	4	2
TA	1	4
IS	5.5*	5

*Since IE and IS achieved the same rank in the DEA method, this rank is obtained as the average of 5 and 6.

This section dis plays analysis carried out on the basis of the obtained results. While the achieved ranks of different EPPs are ordinal numbers, their aggregation with averaging is not appropriate. To aggregate the results of two methods, DEA and GIA, the Copeland pair-wise rank aggregation method is used (Copeland 1951; Pomerol, Barba-Romero 2000). The Copeland score is measured for element *i* as the difference between the number of alternatives dominated by alternative *i* based on different methods (here, DEA and GIA), minus the number of alternatives that dominate this alternative. Table 8 shows the results of the Copeland method where *M* means that the element in the row of the table is preferred to the element in the column and *X* shows that the element in the row is lost to or is incomparable with the element in the column. For example, the element in row 1 and column 2 of table is *M*, because ER is preferred to IE in both methods. Also, the numbers presented in the last column and row is the sum of elements

M in associated rows or columns. The final score for each element is the difference between the numbers in the row and column of this element.

Table 8. The final ranking of EPPs introducing Copeland measure

	ER	IE	PTE	TA	IS	ER	No. wins
ER	–	M	X	M	X	M	3
IE	X	–	X	X	X	X	0
PTE	X	M	–	X	X	M	2
CS	X	M	X	–	X	M	2
TA	X	M	X	X	–	M	2
IS	X	M	X	X	X	–	1
No. lost	0	5	0	1	0	4	
difference	3	–5	2	1	2	–3	

Therefore, the most effective EPP is export rewards annually received by exporters. Also, the “protection of transfer to export” and “training and announcement” are in the second position. Next, currency support, insurance support and international exhibitions are in the following ranks respectfully.

6. Conclusion

The paper presents a hybrid application of the stepwise DEA method and grey incidence analysis to determine the effectiveness of different export promotion programs in food product industry in Iran. The conducted analysis has determined the order of different programs and specified aggregated ranking. The results shown that while some scholars believed the ineffectiveness of export rewards this condition does not hold in the considered case. To achieve a better result, these findings can help policy makers with a better assignment of limited resources of different programs. Exporters strongly prefer receiving EPPs having a great effect on their performance. It seems that direct EPPs include a direct payment to exporters in a form of export rewards have more effects and then, indirect EPPs like training and transfer have such effects. Therefore, some revisions of the value and process of export rewards might be necessary. A similar approach can be also applied to evaluating the effectiveness of any set of programs in different industries.

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