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Detection Efficient Enterprises via Data Envelopment Analysis

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***Abstract*—**In this paper, the Turkey's Top 500 Industrial Enterprises data in 2014 were analyzed by data envelopment analysis. Data envelopment analysis is used to detect efficient decision-making units such as universities, hospitals, schools etc. by using inputs and outputs. The decision-making units in this study are enterprises. To detect efficient enterprises, some financial ratios are determined as inputs and outputs. For this reason, financial indicators related to productivity of enterprises are considered. The efficient foreign weighted owned capital enterprises are detected via super efficiency model. According to the results, it is said that Mercedes-Benz is the most efficient foreign weighted owned capital enterprise in Turkey.

***Keywords*—**Data envelopment analysis, super efficiency, financial ratios, BCC model.

I. Introduction

DETERMINATION of efficient enterprises is important in economy because the big enterprises have a significant role. The Istanbul Chamber of Industry (ICI) has published the Top 500 list of the biggest companies in Turkey according to the results of the ICI 500, a survey of Turkey's Top 500 Industrial Enterprises for every year [13]. The enterprises in the survey are mainly ranked by their production-based sales. In addition to being ranked by size based on their sales revenues (net), the companies listed in the ICI 500 survey are also ranked by their gross value added at producer prices, their equity capital, their total assets, their pre-tax profit and loss for the period, their exports and their average number of wage workers for the year. For the purposes of the survey, industrial operations include the mining and quarrying, manufacturing, and energy sectors. The survey includes private, public, foreign and foreign weighted owned capital enterprises that are established in Turkey and engaged in industrial production.

Financial ratios are used to understand an enterprise's financial position and performance. These ratios are classified regarding financial structure, profitability ratios, economic profit, asset turnover rates, functional distribution of net value added as factor incomes, non-operating revenues, employment and distribution of gross value added, as well as labor productivity [1]. Financial ratios are obtained by using gross value added at producer prices, equity capital, total assets, pre-tax profit and loss for the period, exports and average number of wage workers.

The literature on the performance of the enterprises has been also limited. Ozdemir and Duzgun [2] examined the automotive firms in top 500 according to ICI by taking care of the differences in their capital structure. Tezcan [3] investigates the factors affecting productivity of enterprises by using non- parametric regression. Erdoğan [1] applied factor analysis on the financial ratios of the top 500 industrial enterprises in Turkey for 2010. Düzgün and Taşcı [4] investigated the factors affecting the export performance of the enterprises in ICI-500 by using panel data model.

In this study, the results of ICI 500 survey for 2014 is examined. As a result of ICI survey, Turkey's largest enterprises mostly consist of petrochemical, automotive and iron-steel companies in 2014. Some statistics related to enterprises is mentioned in the report of ICI 500 as follow: Total employment is 580 thousand, meaning that a 5.3% increase from the year before. Enterprises' fixed assets to total assets ratio decreased from 50% to 46%. Total debt to equity ratio showing healthy financial base of an enterprise preserved the high level of the previous year at 132% [13].

The ICI top 500 increased their net sales by 3.9% reaching TL 473 billion accounting for 40% of Turkey's industrial export [13].

The primary aim of this study is to examine the technical efficiency performance of enterprises in ICI top 500 for 2014 by using Data envelopment analysis (DEA) models and finding the most efficient ones. This paper is organized as follows: The following part consists the introduction of the DEA models. Then, the data, financial ratios and empirical results have been explained. In last part, the conclusion has been given.

II. Statistical Models

A. DEA Models and Super Efficiency Approach

Farrell [5] defined that technical efficiency (TE) multiplied by allocative efficiency is overall one. Then Charnes, Cooper and Farrell [6] proposed DEA model used multiple inputs and outputs. DEA is a nonparametric linear programming method which measures the relative efficiency of a set of similar units. These similar units are called as decision making units (DMUs) in DEA [7], [8].

The mostly used two approaches in DEA are constant returns to scale and variable returns to scale. The CCR model proposed by Charnes, Cooper, Rhodes [6] is based on constant returns to scale assumption while the BCC model proposed by Banker, Charnes, Cooper [9] is based on variable return to scale assumption. In this study, we have used input-oriented BCC models.

Banker, Charnes and Cooper [9] presented the BCC model which applies to the cases of variable returns to scale. In

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input-oriented BCC model, the original fractional programming is as in (1) and the linear programming is as in (2) [7], [10]:

$$\begin{aligned}
&\max z_k = \sum_{r=1}^{s} u_r y_{rk} - u_0 \Big/ \sum_{i=1}^{m} v_i x_{ik} \\
&\text{subject to } \sum_{r=1}^{s} u_r y_{rj} - u_0 \Big/ \sum_{i=1}^{m} v_i x_{ij} \le 1,\ j = 1,\cdots,n \\
&u_r \ge 0;\ r = 1,\cdots,s \\
&v_i \ge 0;\ i = 1,\cdots,m \\
&u_0 \in (-\infty, +\infty)
\end{aligned} \tag{1}$$

$$\begin{aligned}
&\text{Max } z_k = \sum_{r=1}^{s} u_r y_{rk} - u_0 \\
&\text{subject to } \sum_{i=1}^{m} v_i x_{ik} = 1, \\
&\sum_{r=1}^{s} u_r y_{rj} - \sum_{i=1}^{m} v_i x_{ij} - u_0 \le 0,\ j = 1,\cdots,n \\
&u_r \ge 0;\ r = 1,\cdots,s \\
&v_i \ge 0;\ i = 1,\cdots,m
\end{aligned} \tag{2}$$

Since finding solutions using the fractional programming is difficult, the fractional programming is converted to the linear programming and duality which reduces the number of constraints is used to find the solutions. The duality in linear programming is as [7], [10]:

$$\begin{aligned}
&\min w_k = q_k \\
&\text{subject to } \sum_{j=1}^{n} y_{rj}\lambda_j \ge y_{rk},\ r = 1,\cdots,s \\
&\sum_{j=1}^{n} x_{ij}\lambda_j \le q_k x_{ik},\ i = 1,\cdots,m \\
&\sum_{j=1}^{n} \lambda_j = 1 \\
&\lambda_j \text{ is the weight } \lambda_j \ge 0; \quad j = 1,\cdots,n \\
&-\infty \le q_k \le +\infty
\end{aligned} \tag{3}$$

The super-efficiency model gives efficiency scores which change the DMUs' status as "super efficient". These values are then used to rank the DMUs [11]

If the DMU is inefficient, then the reference set is the same in this model. Moreover, the frontier will be different if the DMU is efficient and the score of efficiency is larger than 1. This says that the model does not change an inefficient DMU's score, but an efficient DMU's score in this model is larger than 1 [12]. Super-BCC Model:

$$\begin{aligned}
&\min_{E_j,\lambda_1,\lambda_2,\cdots,\lambda_n} \quad E_j \\
&\text{subject to} \quad E_j X_j - \sum_{\substack{k=1 \\ k\ne j}}^{n} z_k X_k \ge 0 \\
&\qquad -Y_j + \sum_{\substack{k=1 \\ k\ne j}}^{n} z_k Y_k \ge 0 \\
&\qquad \sum_{\substack{k=1 \\ k\ne j}}^{n} z_k = 1 \\
&\qquad z_k \ge 0, k = 1,\cdots,n \\
&\qquad E_j \text{ is free}
\end{aligned} \tag{4}$$

In (4), E_j is the super-efficiency score of DMU_j estimated by the Andersen and Petersen (AP) model; X_j is the input vector of DMU_j; Y_j is the output vector of DMU_j; z_k is the intensity of DMU_k.

III. Application and Results of Analysis

TABLE I
FOREIGN WEIGHTED OWNED CAPITAL ENTERPRISES, INPUTS AND OUTPUTS

Enterprises	Input 1	Input 2	Input 3	Output 1	Output 2
	Total Equity	Total Assets	No of wage employee	Production based sales	Export
Mercedes-Benz	2143071281	3189015330	6455	4771526299	652677
Türk Pirelli	296811290	718356114	1766	1163320730	340544
Tüprag	1587932740	1664975968	1425	1149928635	221951
Delphi	592266581	812682862	4355	990085671	379392
JTI	377425341	1287694112	443	952695686	106741
Goodyear	340188976	575527117	1311	909171236	315847
Alstom Grid	445227899	899319170	939	741129011	257792
Sofra	275736039	432961857	11783	723126722	937
Componenta	103898171	654588345	2070	705484870	262510
Yazaki	134961324	349542560	4080	570861384	167028
MAN	378523108	558253954	1599	561491186	226252
Kent	411595278	641739323	1290	556111518	82099
Maxion	217844433	293407294	965	525014068	177102
Honda	184664997	457564383	759	487932084	35522
Çayeli	1270301707	1371892952	528	461539415	219091
Mutlu	237138504	305258623	807	453929908	64297
Nexans	111428355	222321746	439	449647074	73530
Standard	31747953	577851290	2275	419399315	130229
Deva	464125599	944549419	1792	405204015	12180
Cargill	444650431	634214379	298	373541017	8042
Hugo Boss	145357149	216689010	3497	370687795	139339
Baymak	237004991	272672518	581	350611181	13536
Ege Profil	145539136	351580009	287	335564960	24021
Jotun Boya	108991141	252575854	406	325609913	53468
Göknur	130315446	301892253	294	315069468	125829
Viko	263609164	359002118	760	299116212	46477
Nitto Bento	148356927	218741598	431	292986475	48547
Maxion Jantaş	108638586	157636760	425	287179730	84928
Toyota Boshoku	97432561	138028791	910	287074757	14566
Legrand	136570865	179758550	513	275672930	95572
Özmaya	81884591	252171872	324	235964446	62046
Bekaert	132502534	175609803	405	215037671	31757

In this study, the performances of foreign weighted owned capital enterprises according to 2014 Turkey ICI 500 survey have been examined using DEA. The input-oriented BCC model is obtained for each enterprise. In addition, super efficiency model is estimated to find the degree of efficiency of enterprises.

The first step in DEA is determination of the DMUs. In this study, DMUs are foreign weighted owned capital enterprises. However, some foreign weighted owned capital enterprises are not included due to missing data. The data were collected from annual report of ICI 500 survey for 2014. The second step of DEA is determination of inputs and outputs. In this study, equity capital, total assets and average number of wage workers are considered as input variables and exports and production-based sales as output variables. Determination of inputs and outputs is based on the conclusion of review previous studies on top 500 enterprises. The data set used in this study is presented as in Table I.

Technical efficiency scores related to enterprises in Table I are obtained from input-oriented BCC model. The results of BCC model are illustrated in Table II.

TABLE II
RESULTS OF BCC MODEL

DMU	Efficiency	Reference sets
Mercedes-Benz	**1**	**0**
Türk Pirelli	**1**	**8**
Tüprag	0.31	2 (0.98) 17 (0.02)
Delphi	**1**	**0**
JTI	0.54	2 (0.70) 17 (0.30)
Goodyear	0.95	2 (0.68) 9 (0.32)
Alstom Grid	0.49	2 (0.12) 9 (0.73) 10 (0.15)
Sofra	0.81	2 (0.38) 17 (0.62)
Componenta	**1**	**5**
Yazaki	**1**	**2**
MAN	0.62	9 (0.71) 21 (0.29)
Kent	0.40	2 (0.15) 17 (0.85)
Maxion	0.93	9 (0.21) 10 (0.41) 21 (0.37)
Honda	0.60	2 (0.05) 17 (0.95)
Çayeli	0.23	9 (0.65) 21 (0.35)
Mutlu	0.61	2 (0.01) 17 (0.99)
Nexans	**1**	**13**
Standard	**1**	**0**
Deva	0.22	17 (0.73) 29 (0.27)
Cargill	0.26	17 (0.53) 29 (0.47)
Hugo Boss	**1**	**5**
Baymak	0.53	17 (0.39) 29 (0.61)
Ege Profil	0.58	17 (0.30) 29 (0.70)
Jotun Boya	0.81	17 (0.24) 28 (0.35) 29 (0.41)
Göknur	0.86	21 (0.75) 28 (0.25)
Viko	0.41	17 (0.07) 28 (0.39) 29 (0.53)
Nitto Bento	0.69	17 (0.04) 28 (0.45) 29 (0.51)
Maxion Jantaş	**1**	**7**
Toyota Boshoku	**1**	**9**
Legrand	0.89	21 (0.20) 28 (0.80)
Özmaya	0.97	28 (0.99) 29 (0.01)
Bekaert	0.78	28 (0.24) 29 (0.76)

As seen from Table II, the enterprises of with efficiency score 1 are considered as efficient according to results of BCC input-oriented model. The efficiency score less than 1 shows that enterprise is inefficient. According to BCC model, ten of the enterprises are efficient and the mean of efficiency is 0.73 that means the inputs should be reduced at level 27%.

The efficiency levels of insurance companies are found utilizing the super efficiency model in EMS program. The results of super efficiency model are obtained as in Table III. As seen from Table III, the most efficient foreign weighted owned capital enterprise is Mercedes-Benz, the second efficient enterprise is Standard and the third efficient enterprise is Componenta according to BCC.

TABLE III
RESULTS OF SUPER EFFICIENCY MODEL

DMU	Efficiency
Mercedes-Benz	**big**
Türk Pirelli	**1.3151**
Tüprag	0.3053
Delphi	**1.0757**
JTI	0.5428
Goodyear	0.9531
Alstom Grid	0.4912
Sofra	0.8071
Componenta	**1.464**
Yazaki	**1.0188**
MAN	0.6242
Kent	0.3998
Maxion	0.9257
Honda	0.6006
Çayeli	0.229
Mutlu	0.6063
Nexans	**1.1166**
Standard	**1.7793**
Deva	0.2214
Cargill	0.2621
Hugo Boss	**1.0838**
Baymak	0.5306
Ege Profil	0.5811
Jotun Boya	0.8069
Göknur	0.8573
Viko	0.4067
Nitto Bento	0.6899
Maxion Jantaş	**1.1513**
Toyota Boshoku	**1.1285**
Legrand	0.8946
Özmaya	0.9749
Bekaert	0.7846

IV. CONCLUSION

In this study, the technical efficiencies of 32 foreign weighted owned capital enterprises which are active in Turkey are examined. For this purpose, it is benefited from DEA which facilitates to examine different input-output components and which is a non-parametric method. Empirical results show that according to BCC model Mercedes-Benz is the most efficient enterprise in the foreign weighted owned capital enterprises in Turkey in 2014.

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