MEASURING EFFECTIVENESS USING DATA ENVELOPMENT ANALYSIS: A CASE OF UNIVERSITY

Ahmet Dogan
Department of Management Information Systems
Osmaniye Korkut Ata University

Ismet Soylemez
Department of Industrial Engineering
Abdullah Gül University

Ugur Ozcan
Department of Industrial Engineering
Gazi University

Abstract: For universities, performance measurements become more important in order to both keep up with their competitors and control their own inner dynamics. In this study, Data Envelopment Analysis (DEA) – a method used for measuring the effectiveness of systems – is applied to the academic units of a university in Turkey in order to measure the effectiveness of the faculties. At the end of the study the effectiveness value for each faculty is determined. Furthermore, comparisons are made using the performance measurements within each academic unit as well as between the units. According to these results, conclusive evaluations are made for the effective and non-effective faculties.

Keywords: Data envelopment analysis, performance measurement, effectiveness, university

Introduction

In higher education system of Turkey, a significant expansion process is arising in recent years, and many new universities and programs are being opened.   Such that, while the number of public universities was 52 before 2006, this numbers has reached to 114 with an increase of more than two times as per the data of 2015. Along with this process, discussions in different areas regarding the higher education system and universities are becoming intense in the recent period, and operations for restructuring the higher education are being carried out. And measurement of performance in higher education is consisting one of the subjects of discussion in this field. This issue is a factor that will affect managerial success as well as being a public and legal requirement (Cinar, 2013). The increase of demand for higher education especially in developing countries with a high young population rate is pushing the universities to use their resources effectively. Data Envelopment Analysis (DEA) is frequently being used in the effectiveness measurement of universities that have many inputs and outputs (Oruc et al., 2009).

The purpose of the study is to determine the effectiveness of the faculties of Gaziantep University considering the activities in the academic year of 2014-2015. For this purpose, number of academic personnel (Prof., Assoc. Prof., Ass. Prof., Instructor, Lecturer, Specialist), the budget used, capacity of educational area have been used as input variables, and number of students, number of graduate students, number of projects and number of publications have been used as output variables in the study.   In the light of the obtained input and output variables, the analysis of the current condition has been made by using DEA among performance measurement methods, and by determining the ineffective academic units, their reasons of ineffectiveness and improvements required to be performed for their effectiveness have been revealed.

Method

In this section, the selection of decision making units to be used in DEA, determining the input and output variables considered to be relevant and the choice of appropriate DEA model are given.

Selection of Decision Making Units

The basic assumption in DEA is that all DMUs (Decision Making Units) have similar strategic objectives and that they generate uniform outputs by using identical inputs (Özel, 2014). In this context Gaziantep University, which is a public university, has been addressed and the faculties of the university have been included in the assessment. Within the analysis 15 faculties of Gaziantep University were tried to be included, but due to some reasons such as being just opened, diificulties to get sufficient information from the relevant reports and the authorized units. Within this scope, 12 faculties have been included in the effectiveness analysis.

Determination of Input and Output Variables

For each DMU it is necessary to identify the same inputs and same outputs in DEA. For this purpose, the input and output variables used in the efficiency analyses of state and foundation universities have been examined in the literature and some variables in the various studies are shown in Table 1 (Özel, 2015);

Table 1. Input and output variables used for VZA in previous studies

Author	Input Variables	Output Variables
Tomkins and Green (1988)	Number of Employees Operating Expenses Other Expenses Personnel Expenses	Numbers of Graduate and Undergraduate Students Number of Publications Total Income
Beasley (1995)	Operating Expenses Research Income Personnel Expenses	Number of Graduate and Undergraduate Students Number of Indexed Publications
Abbott and Doucouliagos (2003)	Operating Expenses Number of Academic Staff Number of Administrative Staff Fixed Assets	Research Quantity Number of Graduate and Undergraduate Degree Number of Students
Flegg et al. (2004)	Number of Graduate Students Number of Graduate Students Number of Faculty Members Total Expenses	Project Revenues Number of Undergraduate Degree Number of Graduate Alumni
Kutlar and Kartal (2004)	Runners, Staff, Service Procurement and Consumption Expenditures Number of Administrative Staff Area Number of Academic Staff	Number of Graduate Students Student Fees Number of Projects Number of Students
Baysal et al. (2005)	Number of Faculty Members Investment Expenses Personnel Expenses Other Current Expenses	Number of Publications Number of Doctoral Students Number of Graduate Students Number of Graduate Students
Babacan and Kartal (2007)	Number of Professor Number of Associate Professor Number of Assistant Professor Number of Assistant Lecturer General Budget Expenditures Number of Administrative Staff Budget Expenditures	University Income Number of Indexed Publications Number of Graduate Alumni Number of Graduate Students Number of Undergraduate Degree Number of Graduate Students
Kutlar and Babacan (2008)	General Budget Expenditures Budget Expenditures Number of Professor Number of Associate Professor Number of Assistant Professor Number of Assistant Lecturer Number of Administrative Staff	Number of Indexed Publications University Income Number of Graduate Students Number of Undergraduate Degree Number of Graduate Students Number of Graduate Alumni
Özden (2008)	Number of Faculty Members Other Academic Staff Total Expenses	Number of Publications Number of Graduate Students Number of undergraduate and graduate students Other Income

		Education Revenues
Bal (2013)	Number of Faculty Members Other Number of Academic Staff	Number of Students / Faculty Number rate
		The sum of SCI, SSCI, AHCI indexed articles and citations

In the study, the principle $n \geq m + p + 1$; where *m* being the number of inputs, *p* being the number of outputs and *n* being the number of the DMUs (Behdioğlu and Özcan: 2009; Boussofiane et al.: 1991). According to this, it can be seen that 12 DMUs are suitable regarding the input-output numbers used in the study.

$$12 \geq 3 + 4 + 1$$

In the article, the activities of Gaziantep University in the academic year of 2014-2015 have been considered. The data required for DMU units to be analyzed within the scope of the article have been obtained from the activity report of 2014-2015 and administration's activity reports for the year 2015 which have been published by the university. And the data required for DMU units which were not included in such reports have been obtained by contacting the authorized units of faculties. The number of academic personnel (Prof., Assoc. Prof., Ass. Prof., Instructor, Lecturer, Specialist), the budget used, the capacity of educational area have been used as input variables, and the number of students, the number of graduate students, the number of projects and the number of publications have been used as output variables in the study.

Determination of DEA Model

Data Envelopment Analysis (DEA) is a method being used in measuring relative effectiveness based on linear programming techniques of institutions or units being defined as Decision Making Unit (DMU). The best feature of DEA is its ability to define the ineffectiveness amount and resources of DMUs. This method, while presenting the most effective DMUs, provides information on what amount of input the ineffective DMUs should increase/decrease in order to become effective, and what amount of output they should increase/decrease. DEA is especially more suitable for measuring the effectiveness of non-profit organizations such as universities. Because criteria such as the incomes and profitability of such institutions are not satisfactory in measuring their effectiveness. And the main two reasons of this is that they are non-profit organization and that they are not gaining their income by selling a product or service. DEA is being used in measuring the effectiveness of institutions that generate the same outputs by using the same inputs. Effectiveness measurement methods other than DEA are assessing the producer as per an average producer by the central tendency approach. But DEA is assessing each DMU only as per the most effective DMU (Celik, 2014; Charnes et al., 1997).

DEA is a non-parametric method among performance measurement methods (Vassiloglou and Giokas, 1990). Following more extensive recognition of data envelopment analysis, the basic concepts and principles of the method have brought along model diversity. Various models such as CCR (Charnes, Cooper, Rhodes) ratio model, BCC (Banker, Charnes, Cooper) income model as per scale, additive model and multiplicative model have been developed (Baysal et al., 2005). CCR and BCC models are forming the basis of DEA. In the study, BCC-O model with output-oriented variable yield has been used.

Results and Findings

In this study, output-oriented BCC-O model has been used in order to determine the effectiveness of the faculties of Gaziantep University and an effectiveness result was generated among these units. MaxDEA.6.9 package software has been used in the analysis. The data regarding 12 faculties included in the effectiveness analysis are shown in Table 2.

Table 2. Data regarding the faculties of Gaziantep University

DMU	Acedemic	Acedemic Unit	Input Variables			Output Variables			
			Number of academic staff (Input 1)	Budget expenditures (TL) (Input 2)	Capacity of educational area (Input 3)	Number of students (Output 1)	Number of graduate students (Output 2)	Number of projects (Output 3)	Number of publications (Output 4)
1	Faculties	ENGINEERING	138	1637964452	3156	6607	675	39	310
2		MEDICINE	518	3380067764	2623	1476	114	63	172

3		ARCHITECTURE	8	71502931	500	249	18	8	15
4		ARTS AND SCIENCES	102	947693766	665	2806	548	35	276
5		ECONOMIC AND ADMINISTRATIVE SCIENCES	42	372229353	1320	2214	241	1	33
6		EDUCATION IN GAZIANTEP	55	414707546	2000	1504	371	4	37
7		DENTISTRY	44	384778827	483	323	20	14	41
8		HEALTH SCIENCES	31	200944688	1325	1079	147	1	13
9		FINE ARTS	20	121745709	225	524	74	2	14
10		LAW	20	114934526	475	495	80	0	5
11		THEOLOGY	15	267185831	380	1023	0	0	37
12		COMMUNICATIONS	16	113027935	200	286	42	1	21

The outputs obtained as the result of effectiveness analysis realized by the MaxDea.6.9 package software after constituting the data set are being shown in Table 3.

Table 3. Effectiveness results obtained

DMU	Academic Units	Effectiveness Scores	Benchmark	Times as a benchmark for another DMU	Effectiveness Results
1		1	01(1,000000)	0	**Effective**
2		1	02(1,000000)	0	**Ineffective**
3		1	03(1,000000)	1	**Effective**
4		1	04(1,000000)	1	**Effective**
5		1	05(1,000000)	0	**Effective**
6	Faculties	1	06(1,000000)	0	**Effective**
7		0,895305	03(0,390624); 04(0,342224); 09(0,267152)	0	**Ineffective**
8		1	08(1,000000)	0	**Effective**
9		1	09(1,000000)	1	**Effective**
10		1	10(1,000000)	0	**Effective**
11		1	11(1,000000)	0	**Effective**
12		1	12(1,000000)	0	**Effective**

When Table 3 is examined, the listing of academic units which are being defined in Table 2 and which were determined as DMUs for analysis are being shown in the first column. These numbers assigned to academic units have no numeric and priority value. In the second column, the information on faculties that each decision making unit is affiliated is being shown. In the third column, effectiveness scores of each DMU are being shown. It is being observed that these scores have a value in the range of 0 and 1. While the DMUs with an effectiveness score of 1 are being named as "effective" DMUs, the ones with an effectiveness score under 1 are being named as "ineffective" DMUs. According to this, as per the outputs obtained by using the BCC-O model with the data set constituted considering the activities of academic units of Gaziantep University in the academic year of 2014-2015, it can be seen that 11 out of 12 faculties are effective. In the fourth column, information on reference set have been provided. According to this, the reference set formed as per ineffective and effective DMUs are being shown. For instance, the Architecture Faculty (3), Arts and Sciences Faculty (4) and Fine Arts Faculty (9) can be seen to refer the Dentistry Faculty (no. 7) - being the unique ineffective DMU –to be effective. In the fifth column, the number of being reference of an effective DMU to an ineffective is being shown. For instance, it is being observed that Architecture Faculty –which is an effective DMU with no 3 - becomes reference for an ineffective DMU once. Interpretations similar to above examples are able to be made for the other DMUs. Finally, in the sixth column, the effectiveness results of analyzed DMUs are provided. When the final column is considered, it can be seen that the faculties no 1, 2, 3, 4, 5, 6, 8, 9, 10, 11, 12 are effective, and faculty no 7 is ineffective. If we examine the faculty no 7 – which is the unique ineffective academic unit - considering he benchmark (reference group) in Table 2, it can be seen that the Architecture Faculty (3), the Art and Sciences Faculty (4) and the Fine Arts Faculty (9) are included in the reference group of Dentistry Faculty (7). It can be told that faculty no 7 may become effective; in other words may reach to targeted values; by taking the academic units with no 3, 4 and 9 as reference. For instance, the calculation of target value of number of students, number of graduate students, number of projects and number of publications – which are the outputs of the faculty no 7 - is as follows;

Number of Students   :1198 $\cong [(0{,}390624 *249) + (0{,}342224 *2806) + (0{,}267152 *524)]$

Number of Graduates   :214 $\cong [(0{,}390624 *18) + (0{,}342224 *548) + (0{,}267152 *74)]$

Number of Projects   :16 $\cong [(0{,}390624 *8) + (0{,}342224 *35) + (0{,}267152 * 2)]$

Number of Publications   :104 $\cong [(0{,}390624 *15) + (0{,}342224 *276) + (0{,}267152 *14)]$

The equations above show that the faculty no. 7 should aim the values 1198, 214, 16 and 104 to become effective. Here the value 0,390624 specifies the weight of the effective academic unit no 3 and the value 249 specifies the output value of it.

As it is seen in the example above, it can be said that one of the most significant results of effectiveness scores generated as the results of the implementations of data envelopment analysis is obtaining outputs such as what kinds of improvements should the ineffective DMUs make over the current inputs and outputs in order to become effective. Thus, DMUs can observe their current conditions, by which kinds of improvements they can make to become effective and their potential improvements by comparing their current values with their target values. In Table 3, the real output values of DMUs and their targeted output values are shown.

Table 4. Real output values and targeted output values for the academic units

D M U	Acad emic Units	Effective ness Scores	Number of students	Number of graduate students	Number of projects	Number of publicati ons	Number of students	Number of graduate students	Numbe r of project s	Number of publicati ons	Effec tiven ess Scor es
			Real Output Variables				**Targeted Output Variables**				
1	Faculties	1	6607	675	39	310	6607	675	39	310	1
2		1	1476	114	63	172	1476	114	63	172	1
3		1	249	18	8	15	249	18	8	15	1
4		1	2806	548	35	276	2806	548	35	276	1
5		1	2214	241	1	33	2214	241	1	33	1
6		1	1504	371	4	37	1504	371	4	37	1
7		0,895305	323	20	14	41	1197	214	16	104	1
8		1	1079	147	1	13	1079	147	1	13	1
9		1	524	74	2	14	524	74	2	14	1
10		1	495	80	0	5	495	80	0	5	1
11		1	1023	0	0	37	1023	0	0	37	1
12		1	286	42	1	21	286	42	1	21	1

When Table 4 is examined, the columns one and two, are as defined in Table 3. The third column shows the effectiveness result obtained by real outputs. Columns four, five, six and seven specify the current (real) values of output variables of academic units and columns eight, nine, ten and eleven specify the target values of output variables. The twelve column shows the effectiveness result obtained by targeted outputs According to this, the faculty no 7, the number of students which is 323 should be increased to 1197, the number of graduates which is 20 should be increased to 214, the number of projects which is 14 should be increased to 16, and the number of publications which is 41 should be increased to 104.

Conclusion and Recommendations

Today's universities need certain requirements in order to hold an effective place in the system both nationally and internationally. For this reason, they are required to meet their requirements in the most efficient manner with the existing scarce resources. In this article, DEA has been applied to academic units of Gaziantep University –which is a public university in Turkey- that provides education at faculty level. Output oriented BCC-O model has been used on DEA that is used in the implementation. Number of academic personnel (Prof., Assoc. Prof., Ass. Prof., Instructor, Lecturer, Specialist), the budget used, the capacity of educational area have been used as input variables; and the number of students, the number of graduates students, the number of projects and the number of publications have been used as output variables within the study. As the result of this analysis, it has been observed that 11 out of 12 faculties were effective. The success rate of academic units included in the assessment has been obtained as % 91.67 in faculties. Regarding the rate, the university can be said to be considerably successful within faculty level. Special target values have been determined for each unit in order to increase this success rate and in order to make the ineffective units effective. By comparing the real values and targeted values, the current conditions of the units and what kinds of potential improvements could be made for ineffective ones have been revealed. Future studies can focus on analyses oriented to input and/or

output performed with different DEA models. In this way an effectiveness map of the universities in Turkey can be obtained by examining the performances of all universities in Turkey.

References

Abbott, M., & Doucouliagos, C. (2003). The efficiency of Australian universities: a data envelopment analysis. *Economics of Education Review,* 22(1), 89-97.

Babacan, A., Kartal, M., & Bircan, H. (2007). Cumhuriyet üniversitesi'nin etkinliğinin kamu üniversiteleri ile karşılaştırılması: Bir VZA tekniği uygulaması. *C.Ü. İktisadi Ve İdari Bilimler Dergisi,* 8(2), 97-114.

Bal, V. (2013). Vakıf üniversitelerinde veri zarflama analizi ile etkinlik belirlenmesi. *Manas Sosyal Araştırmalar Dergisi,* 2(5), 1-20.

Baysal, M. E., Alçılar, B., Çerçioğlu, H., & Toklu, B. (2005). Türkiye'deki devlet üniversitelerinin 2004 yılı performanslarının, veri zarflama analizi yöntemiyle belirlenip buna göre 2005 yılı bütçe tahsislerinin yapılması. *Sakarya Üniversitesi Fen Bilimleri Enstitüsü Dergisi,* 9(1), 67-73.

Beasley, J. E. (1995). Determining teaching and research efficiencies. *Journal Of The Operational Research Society,* 46(4), 441-452.

Behdioğlu, S., Özcan, G. (2009). Veri zarflama analizi ve bankacılık sektöründe bir uygulama, *Süleyman Demirel Üniversitesi İktisadi ve İdari Bilimler Fakültesi Dergisi,* 14(3), 304 (2009).

Boussofiane, A., Dyson, R. & Rhodes, E. (1991). Applied DEA, *European Journal of Operational Research,* 2, 6, 1-15.

Çelik, K. (2014). Avrupa birliği ülkelerinin bilişim teknolojilerini kullanma etkinliklerinin araştırılması: Bir veri zarflama analizi uygulaması. Yüksek lisans tezi, *Gazi Üniversitesi Bilişim Enstitüsü,* Ankara.

Charnes, A.et al.. Data envelopment analyses theory, methodology and aplications. *United States Of America,* 3-4 (1997).

Charnes, W., Cooper, E., & Rhodoes, E. (1978). Measuring the efficiency of decision making units. *European Journal Of Operations Research,* 2, 429-444.

Çınar, Y. (2013). Türkiye'de kamu üniversitelerinin eğitim-araştırma etkinlikleri ve etkinlik artışında stratejik önceliklerin rolü: Çok-aktiviteli VZA uygulaması. *Ankara Üniversitesi Sbf Dergisi,* 68(2), 27-62.

Flegg, T., Allen, D. O., Field, K., & Thurlow, T. W. (2004). Measuring the efficiency of British universities: A multi-period data envelopment analysis. *Economics of Education Review,* 12(3), 231-249.

Kutlar, A., & Babacan, A. (2008). Türkiye'deki kamu üniversitelerinde CCR etkinliği-ölçek etkinliği analizi: DEA tekniği uygulaması. *Kocaeli Üniversitesi Sosyal Bilimler Enstitüsü Dergisi,* 15(1) , 148-172.

Kutlar, A., & Kartal, M. (2004). Cumhuriyet üniversitesinin verimlilik analizi: fakülteler düzeyinde veri zarflama yöntemiyle bir uygulama. *Kocaeli Üniversitesi Sosyal Bilimler Enstitüsü Dergisi,* 8(2), 49-79.

Oruç, K. O., Güngör, İ., & Demiral, M. F. (2009). Üniversitelerin etkinlik ölçümünde bulanık veri zarflama analizi uygulaması. *Selçuk Üniversitesi Sosyal Bilimler Enstitüsü Dergisi,* (22), 279-294.

Özden, Ü. H. (2008). Veri zarflama analizi (VZA) ile Türkiye'deki vakıf üniversitelerinin etkinliğinin ölçülmesi. *İstanbul Üniversitesi İşletme Fakültesi Dergisi*, 37(2), 167-185.

Özel Kadılar, G. (2015). Türkiye'deki vakıf üniversitelerinin etkinlik çözümlemesi, *Eğitim Ve Bilim,* 40(177), 31-41.

Özel, G. (2014). Devlet üniversitelerinin etkinlik analizi: Türkiye örneği. *Hacettepe Üniversitesi Eğitim Fakültesi Dergisi (H. U. Journal Of Education).* 29(3), 124-136.

Tomkins, C., & Green, R. (1988). An experiment in the use of the data envelopment analysis of evaluating the efficiency of Uk university departments of accounting. *Financial Accountability,* 4 (2), 147-164.

Vassiloglou, M., & Giokas, D. (1990). A study of the relative efficiency of bank branches: An application of data envelopment analysis. *Journal Of The Operational Research Society,* 41(7), 591-597.