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ASSESSING THE RELATIVE PERFORMANCE OF UNIVERSITY DEPARTMENTS: TEACHING VS. RESEARCH

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Abstract

Data Envelopment Analysis (DEA) is known as a non-parametric method to evaluate the relative efficiencies of a set of homogenous decision-making units (DMUs) (i.e., banking, health, education, etc.) that use multiple inputs to produce multiple outputs. DEA models also have applications for universities or specifically, departments of a university. In practice, determining input and output measures may be based on the available data. However, lack of defining an important measure or use of invalid data may mislead the decision maker. Therefore, this study aims to assess the affect of missing values such as by discarding of outputs on DMU's efficiency values. The up-to-date data for the departments of an engineering faculty are considered and their performances are presented based on teaching and research oriented measures.

Keywords: Data Envelopment Analysis, Higher Education, University Departments, Teaching, Reserach
Jel Classification: A22, C14, C44, I23

Özet

Veri Zarflama Analizi (VZA) homojen karar verme birimler kümesinin (ör., bankacılık, sağlık, eğitim, vb.) göreli etkinliklerinin değerlendirilmesinde kullanılan parametrik olmayan bir yöntemdir. VZA modellerinin aynı zamanda üniversiteler ya da daha spesifik olarak üniversite bölümleri için de kullanılmıştır. Uygulamada, girdi ve çıktı ölçütlerinin belirlenmesi mevcut verilerden hareketle gerçekleştirilir. Fakat, önemli bir ölçütün ele alınmaması ya da güvenilir olmayan verilerin kullanılması karar vericiyi yanlış yönlendirebilir. Bu yüzden, çalışmada mevcut olmayan verilerin, örneğin çıktı ölçütlerinden çıkartılarak, karar verme birimlerinin etkinlik değerlerine etkisi değerlendirilmiştir. Bir Mühendislik Fakültesinde bulunan bölümlere ait güncel veriler incelenerek performans değerleri eğitim ve akademik araştırma yönünden değerlendirilmiştir.

Anahtar Kelimeler: Veri Zarflama Analizi, Üniversite Bölümleri, Kayıp Veriler, Etkinlik Ölçümü
Jel Sınıflaması: A22, C14, C44, I23

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1. INTRODUCTION

The DEA method, introduced by Dantzig (1951) and Farrell (1957) and improved by Charnes et al. (1978), is a technique used to measure the performance of *n* production units or, more generally, of Decision Making Units (DMUs). It identifies a non parametric piece-wise linear frontier, for each unit separately, which represents the best practice in input/output transformation.

The most common application areas of DEA measure are educational departments, health care units, and banking. Seiford (1997) proposed a DEA literature bibliography for the years 1978-1996 concerning for about 800 papers. Gattoufi et al., (2002) claim that there had been a 150% increase in since Seiford (1997), and formed a DEA paper list from 1951 to 2001. Tavares (2002) considered 3203 studies for 1978-2001. Emrouznejad et al. (2008) present survey and analysis of the first 30 years of scholarly literature in DEA.

DEA has several applications for education where the DMUs are considered as primary, secondary schools, or higher education units. The relative performances of universities, faculties, or departments are studied. Although there is no exact formula to determine the input and outputs for higher education, outputs can be generally categorized into teaching, research, and service, it is very difficult to find true measures for these dimensions (Ahn and Seiford, 1993). Usually, inputs are determined as the resources or the factors that may affect the performance of decision making units (i.e., number of employees, administrative expenses (i.e., salary and wages), miscellaneous expenses (office and school supplies, etc.), operational expenses (i.e., light and water, operating and maintenance, representations, energy, and administration services, buildings and grounds, libraries and student services). On the other hand, outputs are considered as the benefits gained from the performance of the decision making units (i.e., books, edited books, monographs, original papers, project reports, patents, presentations, other publications, number of finished, supervised PhD-theses, etc.

The studies in literature that assess the efficiency of universities considered private or public universities of a country as DMUs. The most recent study on evaluation of universities in Turkey is provided by Oruc et al. (2009).

Arcelus and Coleman (1997), Beasley (1990), Bessent et al. (1983), Buzzigoli et al. (2010), Cokgezen (2009), de Miranda et al. (2010), Gimenez and Martinez (2006), Johnes and Johnes (1995), Kao and Hung (2008), Kao and Pao (2009), Koksal and Nalcaci (2006), Kontolaimou et al. (2006), Kontolaimou et al. (2005), Leitner et al. (2007), Moreno and Tadepalli (2002), Stern (1994), Tompkins and Green (1988), and Tzeremes and Halkos (2010) have assessed the efficiency of departments of universities. These papers had presented efficiency values based on teaching or research. On the other hand, this study focuses on both teaching and research efficiencies. Further, the effect of discarding output variables are evaluated.

The paper is organized as follows. Second section summarizes DEA. The DEA application is explained in the third section along with the obtained results and last section provides conclusions and future research directions.

2. DATA ENVELOPMENT ANALYSIS

Since the seminal paper by Charnes, Cooper and Rhodes (CCR) in 1978 there has been a large number of papers, which have applied and extended the methodology (Charnes et.al., 1978). The use of the CCR and Banker, Charnes, Cooper (BCC) (1984) of DEA models together helps determine the overall technical and scale efficiencies of the respondents and whether the data exhibits varying returns to scale.

DEA utilize appropriate input and output measures to assess the efficiency of units. Further, an excessive number of inputs and outputs may lead to problems, so that the evaluation does not make sense because of many efficient DMUs, and many-sided evaluations cannot be achieved owing to many zero weights. To deal with these problems, there is a restriction for selecting input and output factors. Assuming that there are m input elements, s output elements, and n DMUs, n should be satisfied with the restriction that $n \geq (m+s)$.

Determining the input and output factors are a difficult task since including or excluding a factor may affect the research results. The success of results may depend on the correct and adequate variable values, the information should not be included in another factor, the factors should exactly represent the system in concern, the improvement in the inputs should be reflected to outputs, and the factors should be related with the one or more goal of the activity. Also, one unit decrease in output factors should not increase input factors.

3. ASSESING UNIVERSITY DEPARTMENTS

The universities provide the foremost research and advanced training in every society that are generally divided into a number of academic departments, schools, or faculties. Universities may have variable policies or cultural and economic standards available. Universities can be considered as public and private universities. Public university systems are ruled over by government-run higher education boards that review financial requests and budget proposals and then allocate resources to each university. Private universities are privately funded and generally have a broader independence from government policies.

This study considers the Engineering Departments of Eskisehir Osmangazi University which is one of the public universities in Turkey founded in 1970 and renamed in 1993. The data for teaching year 2009-2010 is considered for the study. The homogenous decision making units are determined as nine engineering departments in Meselik Campus of Eskisehir Osmangazi University.

Inputs and outputs used in efficiency estimations of higher education institutions can be compiled in two broad categories for each of the following: human and physical capital, as inputs; and research and teaching activities, as outputs. In the studies where the efficiency of higher education units is assessed, researchers use subsets of these broadly defined two input/two output categories in their studies.

3.1. Efficiency scores related with teaching

Three input variables are illustrated in Figure 1 and defined as follows:

1. Number of academic staff: This input variable indicates the total number of the professors, associate professors, and assistant professors working full time at the department in concern.

2. Number of assistant staff: Research assistants and other staff (i.e., graduate students etc.) help academic staff usually during teaching.

3. Number of students: Each year, approximately 1.5 million high school graduates go through a Student Selection Exam organized by the Student Selection and Placement Center. After the evaluation of test results, candidates who have been successful may be considered for placement in a four-year undergraduate engineering program. Their percentile ranks among those candidates who took the exam is considered a success indicator for his/her future education. Some of the engineering departments of the faculty in concern have regular and second education programs. Students in public universities pay symbolic fees for regular programs. On the other hand, in a second education program, students are subject to same curriculum and receive the same diploma as regular students however, take their classes in the afternoon and pay relatively higher student fees. Being more expensive, the second shift of the same department is preferred less than the regular version; furthermore, the performance percentile rank for second education program is accordingly lower.

Computer Engineering, Geology Engineering, Chemical Engineering, and Metallurgy Engineering departments do not have second education programs. However, in order to be fair, total number of students in each department is considered.

Four output variables are defined as follows:

1. Percent of the graduates at the undergraduate level: Each year, only a percent of the students who were registered four year ago are able to graduate and receive an engineering diploma. This variable corresponds to the percent of the students that were graduated during 2009-2010 education term.

2. Average Grade Point Average (GPA) of the undergraduate students: GPA is a measure of a student's academic achievement at a college or university; calculated by dividing the total number of grade points received by the total number attempted. Average of students' GPA in each department is considered as a variable to assess the teaching efficiency.

3. Number of successful students (3.0< GPA <3.49)

4. Number of honor students (3.5<GPA<4.0)

Besides these variables, the total teaching hours for academic staff could be considered and more reliable results could be obtained. Since these data were not available, this issue is left for further studies.

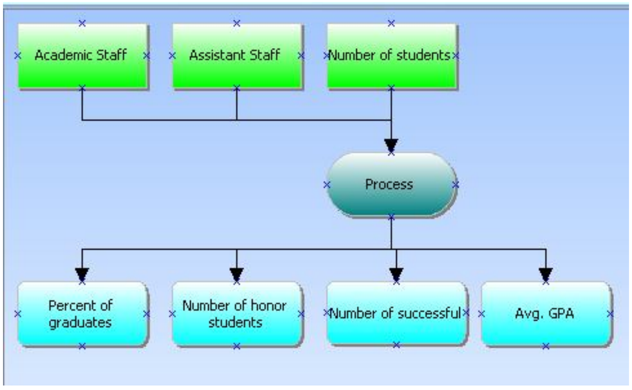

Figure 1. Input and output variables to assess teaching efficiency of departments

Data for the input and output variables are given in Figure 2.

Unit Name	Activ	Academic Staff	Assistant Staff	Number of	Percent of	Number of hono	Number of su	Avg. GPA
Chemical Eng.	☑	24.00	2.00	343.00	34.00	41.00	13.00	2.37
Civil Eng.	☑	20.00	8.00	912.00	19.00	61.00	36.00	2.14
Computer Eng.	☑	5.00	4.00	241.00	61.00	25.00	11.00	2.37
Elec. Electr. Eng.	☑	11.00	7.00	632.00	60.00	60.00	39.00	2.42
Geology Eng.	☑	9.00	8.00	198.00	60.00	18.00	3.00	2.06
Industrial Eng.	☑	17.00	6.00	620.00	49.00	69.00	34.00	2.34
Mechanical Eng.	☑	22.00	13.00	865.00	38.00	67.00	46.00	2.20
Metallurgy Eng.	☑	6.00	7.00	224.00	38.00	24.00	4.00	2.17
Mining Eng.	☑	22.00	7.00	613.00	56.00	11.00	3.00	1.75

Figure 2. Input and output variable data to assess teaching efficiency

3.2. Efficiency scores related with research

A single input variable is defined as the number of academic staff. The input and output variables to evaluate research efficiency is illustrated in Figure 3. The output variables are defined as the published journal papers and conference papers. The quality of a publication is related to the journal in which the article is published. However, there is no single measure of weighting journals. The journals that are indexed in well known databases such as Science Citation Index (SCI) are considered more prestigious than many other refereed journals in the engineering literature. Therefore, the number of publications in internationally and nationally refereed journals are considered in this study. Likewise, academic staffs attend to international or national conferences to present their research outcomes, get feedbacks, and communicate with other researchers for possible collaborative studies. Further, projects are an important indicator for a department's performance. In this study, total number of, proposed-accepted, ongoing, and completed projects are considered.

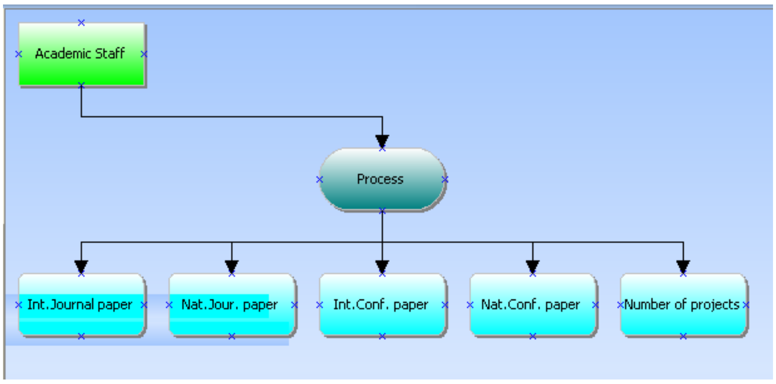

Figure 3. Input and output variables to assess research efficiency of departments

Figure 4 provides the input and output data. When the output data are examined, it is seen that some of the departments have 0 data such as, number of published papers national journals, number of national papers attended, and number of projects. In order to deal with missing values four cases are defined and their results are discussed.

Unit Name	Activ	Academic Staff	Int.Journal p.	Nat.Jour. p	Int.Conf. p	Nat.Conf. p.	Number of projects
Chemical Eng.	☑	24	17	1E-5	16	16	8
Civil Eng.	☑	20	13	4	12	2	6
Computer Eng.	☑	5	3	1	9	3	1E-5
Elect.Electronics Eng.	☑	11	3	1E-5	14	5	4
Geology Eng.	☑	9	11	1	20	14	12
Industrial Eng.	☑	17	11	2	20	3	1
Mechanical Eng.	☑	22	2	1E-5	3	1E-5	6
Metallurgy Eng.	☑	6	4	1E-5	13	1E-5	4
Mining Eng.	☑	22	12	1	20	3	11

Figure 4. Input and output variable data to assess research efficiency

3.3. Results

The efficiency values for each department were assessed and the results are discussed in this section. First, the efficiencies for teaching performances are evaluated based on the input and output variables that were explained in Section 3.1. Then, efficiency values related with research are given.

3.3.1. Efficiency values for teaching

Based on the defined input and output variables, teaching efficiency for the departments are calculated by use of DEA software. The results are summarized in Figure 5. Six of the nine departments (Chemical Engineering, Computer Engineering, Electrics and Electronics Engineering, Geology Engineering, Industrial Engineering, and Metallurgy and Materials Engineering) are determined as efficient units. The most inefficient unit is identified as Mining Engineering with an efficiency score of 0.51.

Units	Comparison 1		
Unit name	Score	Efficient	Condition
Chemical Eng.	100.0%	✓	🟢
Civil Eng.	79.6%		🔴
Computer Eng.	100.0%	✓	🟢
Elec. Electr. Eng.	100.0%	✓	🟢
Geology Eng.	100.0%	✓	🟢
Industrial Eng.	100.0%	✓	🟢
Mechanical Eng.	86.2%		🔴
Metallurgy Eng.	100.0%	✓	🟢
Mining Eng.	51.4%		🔴

Figure 5. Teaching efficiency values of departments

3.3.2. Efficiency values for research

When the research efficiency is considered, a few DMUs suffer from missing data. However, it is known that discarding DMUs may influence the efficiency ranking of the remaining DMUs and the effect is unpredictable. Also, considering that the sample size being relatively small, these DMUs are not discarded from the analysis. Instead, several alternative ways of reconstructing a balanced output matrix missing outputs are tried. First, the missing outputs are assigned as very small number. Then, the zero values that are related with published papers in national journals and national conferences attended are restructured as output variables such as papers and conferences (the total number of international and national studies). Finally, the output variables that have zero values are discarded from output variables.

Figure 6 provides the efficiency results that are obtained from assigning a relatively small value for the zero data (i.e., output variables with zero are replaced by 0.0001). While considering all output variables (number of papers published in international papers, number of papers in national papers, number of international conferences attended, number of national conferences attended, and number of projects involved in), Civil Engineering, Computer Engineering, and Geology Engineering are determined to be the most efficient decision making units. On the other hand, Mechanical Engineering having an efficiency score of 0.20 was the most inefficient unit and needs to improve the number of academic research.

Units	Comparison 1		
Unit name	Score	Efficient	Condition
Chemical Eng.	58.0%		
Civil Eng.	100.0%	✓	
Computer Eng.	100.0%	✓	
Elect.Electronics Eng.	57.3%		
Geology Eng.	100.0%	✓	
Industrial Eng.	68.9%		
Mechanical Eng.	20.5%		
Metallurgy Eng.	97.5%		
Mining Eng.	44.6%		

Figure 6. Research efficiency results_1

In the second assessment, research efficiency values were calculated by considering the international and national data for the variables related with journal papers and conferences, in a single output variable. Therefore, the output variables turned out to be as total number of papers published in international and national journals, total number of international and national conferences attended, and number of projects involved. Figure 7 presents the scores of the department, whether it is efficient or not, along with a traffic sign scale. The only green sign that corresponds to the efficient unit is Geology Engineering. Mechanical Engineering with a 0.20 efficiency score is again identified as the most inefficient unit.

Units	Comparison 1		
Unit name	**Score**	**Efficient**	**Condition**
Chemical Eng.	53.1%		
Civil Eng.	63.8%		
Computer Eng.	75.0%		
Elect.Electronics Eng.	45.7%		
Geology Eng.	100.0%	✓	
Industrial Eng.	57.4%		
Mechanical Eng.	20.5%		
Metallurgy Eng.	57.4%		
Mining Eng.	44.3%		

Figure 7. Research efficiency results_2

The third assessment includes the output variables as total number of papers published in international and national journals, total number of international and national conferences attended. The number of projects that the department staff included was discarded from the study. Figure 8 illustrates the efficiency scores for the departments. Geology Engineering is the most efficient unit. It is surprising that the efficiency value of Mining Engineering remained same when the output variable related with projects was not considered. On the other hand, the efficiency value of Mechanical Engineering was dramatically lower (=6.8%) comparing to the previous research efficiency cases (=20.5%).

Units	Comparison 1		
Unit name	**Score**	**Efficient**	**Condition**
Chemical Eng.	53.1%		
Civil Eng.	52.5%		
Computer Eng.	63.5%		
Elect.Electronics Eng.	45.7%		
Geology Eng.	100.0%	✓	
Industrial Eng.	57.4%		
Mechanical Eng.	6.8%		
Metallurgy Eng.	57.4%		
Mining Eng.	44.3%		

Figure 8. Research efficiency results_3

Some researchers such as, Kao and Liu (2000), Simirlis et al. (2006), and Kuosmanen (2009) focus on dealing missing data during DEA. They suggest that the input/output data that are missing might be removed from the evaluation. Based on the ideas in these papers, the output variables such as number of papers in national journals, number of national conferences attended, and number projects are discarded. Therefore, the problem turned out to be a single input (number of academic staff) and two output problem (number of papers in international published journals, number of international conferences attended). Figure 9 states the efficiency results of this case. Department of Geology Engineering was determined as the most efficient unit followed by Metallurgy Engineering (=97.5%). However, Mechanical Engineering is still far behind the efficient units.

Units	Comparison 1		
Unit name	Score	Efficient	Condition
Chemical Eng.	58.0%		
Civil Eng.	53.2%		
Computer Eng.	81.0%		
Elect.Electronics Eng.	57.3%		
Geology Eng.	100.0%	✓	
Industrial Eng.	52.9%		
Mechanical Eng.	7.4%		
Metallurgy Eng.	97.5%		
Mining Eng.	44.6%		

Figure 9. Research efficiency results_4

Missing data can be handled in various ways such as discarding the related DMUs, input/output variables. Assigning a very high value (input variable) or a very small value (output variable) to the data might also be considered. The output variables considered in this study were appropriate for grouping two variables into one, such as considering the total number of international and national journals. However, the results state that eliminating the variables with zero values or grouping the variables does not provide consistent results. On the other hand, many other applications should not have output variables that could be combined. Finally, it can be concluded that missing values may have a remarkable effect on the efficiency values of the DMUs. Replacing the zero values with a very small number might be a good starting point. Also, considering fuzzy numbers can be studied and results might be discussed in future studies.

4. CONCLUSIONS AND FUTURE RESEARCH DIRECTIONS

Universities are very important for the development of a country. Therefore, each faculty and individual department might be assessed based on various variables to identify the efficient units, and take action for inefficient ones. This study aims to assess the relative performances of departments in an engineering faculty. The studies in literature have considered the efficiency values either depending on the data related with teaching or research. This study aims to evaluate the research and teaching efficiencies. It is known that, the performance values of decision making units rely on the input and output variables. In addition, the use of accurate and reliable data is crucial. Another important issue, data values with zero, was also considered in this study. For this purpose, several cases to deal with these values were provided. In the four cases studied, it was observed that most of the efficiency results vary one to another.

During assessing the teaching efficiency, this study might provide more realistic results when the excessive total teaching hours of academics staff are included. Also, quantitative results derived from questionnaires applied to academics and assistant staff related with work satisfaction can be considered in future studies.

One of the most important problems in public universities in Turkey is the budget allocation. The laboratories related with the department, computer laboratories, and library facilities usually cannot get the required budget. Also, access to journal databases might be limited. Academics staff (especially who have recently received their Ph.D.) working at Turkish Universities (i.e., developing or recently founded), usually suffer from teaching loads and lack of time for research. Therefore, several variables including these issues should be addressed to improve the quality of the DEA studies while assessing teaching and research efficiencies.

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