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# Measuring the Efficiency of Turkish Universities Using Measure-Specific Data Envelopment Analysis

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## Ölçüt Odaklı Veri Zarflama Analizi Kullanılarak Türk Üniversitelerinin Etkinlik Ölçümü

**Abstract**

This study measures the efficiency of Turkish universities through standard and measure-specific Data Envelopment Analysis (DEA) approaches. The purpose of this paper is three-fold. Firstly, the study shows the applicability of standard and measure-specific DEA methodologies in performance evaluation of Turkish universities. Secondly, it presents the benchmark shares which show the importance of each efficient university in measuring the inefficiencies of inefficient universities. Finally, the study analyzes efficiencies by means of the geographical regions which the universities are located.

**Key Words** : Efficiency, Data Envelopment Analysis, Measure-Specific DEA, University Performance.

**JEL Classification Codes** : C61, D24, I23.

**Özet**

Bu çalışmada standart ve ölçüt odaklı veri zarflama analizi (VZA) kullanılarak Türk üniversitelerinin etkinlik ölçümü yapılmıştır. Bu çalışmanın üç temel amacı bulunmaktadır. Öncelikle çalışmamız, standart ve ölçüt odaklı VZA yaklaşımlarının Türk üniversitelerinin etkinlik ölçümünde kullanılabileceğini göstermektedir. İkinci olarak, etkin olan üniversitelerin, diğer üniversitelerinin etkin olmamasının ölçülmesinde ne kadar pay sahibi olduğunu gösteren rol model payları sunulmuştur. Son olarak etkinlik düzeyleri üniversitelerin yer aldığı coğrafi bölgelere göre analiz edilmiştir.

**Anahtar Sözcükler** : Etkinlik, Veri Zarflama Analizi, Ölçüt Odaklı VZA, Üniversite Performansı.

## 1. Introduction

It is difficult to measure efficiency in higher education institutions due to two main characteristics. Firstly, it is not always possible to determine input and output prices in non-profit organizations such as universities. Secondly, multiple outputs and inputs should be taken into consideration. Various approaches have been developed to resolve the problem of efficiency measurement in this context. These approaches are classified as parametric and non-parametric techniques. (Johnes, 2006)

Data Envelopment Analysis (DEA) is a non-parametric approach for identifying relative efficiency of "Decision Making Units" (DMUs) with multiple inputs and outputs (Farrell, 1957; Charnes et al., 1978; Fare et al., 1985). This makes DEA a suitable tool for measuring the efficiency of universities, because of multiple input-output nature of research and teaching functions in universities. DEA models have been widely applied for the efficiency evaluation of universities. Among these studies, some recent ones can be counted as, (Abbott et al., 2003; Johnes, 2006; Flegg et al., 2007; Worthington et al., 2008; Johnes et al., 2008) and details are shown in Table: 1 and Table: 2.

DEA approach differentiates DMUs into two groups: efficient DMUs and inefficient DMUs. A DMU is efficient if it obtains the maximum score of 1; else, it is inefficient. DEA also provides targets for inefficient units by improving inputs and outputs proportionally. On the other hand, in some cases, it may be impossible for an inefficient DMU to improve all of the inputs or outputs proportionally at the same time in order to be efficient. For these types of situations, measure specific data envelopment models can be used (Ulucan *et al*. 2010; Zhu 2000, 2002; Banker *et al*. 1986; Thanassoulis *et al*. 1992). Measure-specific models take sets of specific inputs or outputs of interest and give the target values for only those factors.

This study examines DEA based efficiency evaluation approach to measure the relative efficiency of Turkish universities using the methodological order in the literature (Ulucan *et al*. 2010; Zhu 2000). First, standard input and output-oriented VRS DEA models are applied to 50 universities. Then we applied the measure-specific DEA model in order to obtain more achievable targets for universities. In this step of the analysis, measure-specific VRS DEA models are applied to data to determine the efficiency scores of the universities under one of the inputs or outputs are of interest which means that only one of the inputs or outputs can be changed. In practice, it can be more motivating for universities to set alternative targets by means of each input and output.

**Table: 1**
**Main Characteristics of the University Efficiency Evaluation Studies**

| Author | Year | Data Period | Inputs | Outputs | # of DMU | Country | Technique |
|---|---|---|---|---|---|---|---|
| Johnes | 2006 | 2000–2001 | 6 | 3 | 109 | UK | CRS, VRS |
| Flegg | 2007 | 1994–2004 | 4 | 3 | 45 | UK | Malmquist |
| Worthington | 2008 | 1998–2003 | 5 | 6 | 35 | Australia | Malmquist |
| Johnes | 2008 | 2003–2004 | 6 | 3 | 109 | China | VRS |
| Abbott | 2003 | 1995 | 4 | 1 | | Australia | VRS |

**Table: 2**
**Input-Outputs of the University Efficiency Evaluation Studies**

| Author | Year | Inputs | Outputs |
|---|---|---|---|
| Johnes | 2006 | Nr. of undergraduate students, Nr. of postgraduate students, Number of academic staff, Expenditure on administration, Expenditure on library, Total depreciation and interest | Nr.of first degree graduates, Nr.of higher degree graduates, The grant for research |
| Flegg | 2007 | Nr. of undergraduate students, Nr. of graduate students, Academic staff expenditures, Other expenditures | Nr.of undergraduate degrees, Nr.of postgraduate degrees, Income from research grants, |
| Worthington | 2008 | Number of academic staff, Number of non-academic staff, Non-labour expenditure, Nr. of undergraduate students, Nr. of postgraduate students, | Undergraduate completions, postgraduate completions, Ph.D. Completions, National grants, Industry grants, Publications |
| Johnes | 2008 | Staff to student ratio, Nr.of professor to academic staff ratio, Nr.of postgraduate students, Research expenditure, Index of library books, Index of building areas | Impact of research, Total nr.of research, Index of publication per academic staff |
| Abbott | 2003 | Number of academic staff, Number of non academic staff, Non-labour expenditure, The value of non-current assets | Research allocation index |

We also determine the importance of each efficient university in measuring the inefficiencies of inefficient universities. In order to do this, we calculate the percentage share of efficient universities, acting as benchmarks or referents for the inefficient DMUs. Moreover, efficiencies are analyzed by means of the geographical regions which the universities are located. After universities are grouped into their regions, the measure-specific VRS efficiency of each region is calculated. Rather than, getting the average of efficiencies of universities in each region, a weighted factor-specific formula is used to compute region efficiencies.

The rest of the paper is arranged as follows. Second section of the study explains input and output oriented VRS DEA approach. Measure-specific DEA model is also discussed in this section. An application of both the standard and the measure-specific

DEA methodologies in Turkish universities is performed in the third part. We also present the data and the dimensions of the application in this section.

## 2. Data Envelopment Analysis (DEA)

Data envelopment analysis (DEA), introduced by Charnes, Cooper and Rhodes (CCR), is a mathematical programming method for measuring the relative efficiency of decision making units (DMUs) with multiple outputs and multiple inputs (Seiford *et al.* 2003). A main advantage of DEA is that it does not require any prior assumptions on the underlying functional relationships between inputs and outputs.

DEA models can be input and output oriented. The models can be specified as constant returns to scale (CRS) or variable returns to scale (VRS). Output-oriented DEA models maximize output for a given quantity of input factors. Conversely, input-oriented models minimize input factors required for a given level of output.

### 2.1. Input and Output Oriented VRS Models

The linear programming models in 2.1 and 2.2 are input and output oriented VRS models where $DMU_o$ represents one of the n DMUs under evaluation and $x_{io}$ and $y_{ro}$ are the ith input and rth output for $DMU_o$, respectively (Zhu 2002).

$$\begin{aligned} & Min\ \theta \\ & Subject\ to: \\ & \sum_{j=1}^{n} \lambda_j x_{ij} \le \theta x_{io} \quad i = 1,2,\dots,m \\ & \sum_{j=1}^{n} \lambda_j y_{rj} \ge y_{ro} \quad r = 1,2,\dots,s \\ & \sum_{j=1}^{n} \lambda_j = 1 \\ & \lambda_j \ge 0 \qquad j = 1,2,\dots,n \end{aligned} \tag{2.1}$$

$$\begin{aligned} & Max\ \phi \\ & Subject\ to: \\ & \sum_{j=1}^{n} \lambda_j x_{ij} \le x_{io} \quad i = 1,2,\dots,m \\ & \sum_{j=1}^{n} \lambda_j y_{rj} \ge \phi y_{ro} \quad r = 1,2,\dots,s \\ & \sum_{j=1}^{n} \lambda_j = 1 \\ & \lambda_j \ge 0 \qquad j = 1,2,\dots,n \end{aligned} \tag{2.2}$$

### 2.2. Measure-Specific Models

Input or output oriented Data Envelopment Analysis models assume proportional improvements of inputs or outputs. In other words, to become efficient, a DMU must realize all the target values obtained for inputs in an input oriented model or outputs in output oriented model. In some cases, it may be impossible for a DMU to improve all of the inputs or outputs at the same time. For these types of situations, Measure-specific data envelopment models can be used. Measure-specific models take sets of specific inputs or outputs of interest and give the target values for only those factors. The use of these models can be appropriate for the situations where only one or some of the inputs or outputs can be intervened.

Let $I \subseteq \{1,2,...,m\}$ and $O \subseteq \{1,2,...,s\}$ represent the sets of specific inputs or outputs of interest, respectively. Input oriented VRS envelopment model is converted to input oriented measure-specific VRS model with the inclusion of equation 2.3 into the 2.1. (Zhu 2002):

$$\sum_{j=1}^{n} \lambda_j x_{ij} \leq x_{io} \quad i \notin I \tag{2.3}$$

Output oriented VRS envelopment model is converted to output oriented measure-specific VRS model with the inclusion of equation 2.4 into the 2.2.

$$\sum_{j=1}^{n} \lambda_j y_{rj} \geq y_{ro} \quad r \notin O \tag{2.4}$$

## 3. An Efficiency Evaluation Application in Turkish Universities

### 3.1. Datasets on Turkish Universities

University education is the responsibility of the Higher Education Council of Turkey, and funding is provided by the state for public institutions that make up the bulk of the tertiary education system. Currently, there are 103 public universities in Turkey.

In our empirical work, we use input and output data for a set of 50 Turkish Universities with available data in order to determine the relative efficiency levels in producing research and educational outputs. Furthermore, for inefficient universities we determine the targets in order to be efficient. Data on four input variables and eight output variables were obtained from the The National Scientific and Technological Research Council (www.tubitak.gov.tr), The Council of Higher Education (www.yok.gov.tr) and Student Selection and Placement Center (www.osym.gov.tr) for 2008.

These 8 output criteria including student numbers, publications, projects and entry scores are explained below.

The numbers of undergraduate and postgraduate students are an obvious measure of output for any university. To measure the efficiency of universities in education, we employ three student related inputs. "*Number of undergraduate students* (UGRAD_STU)", "*Number of masters students* (MSTR_STU)" and "*Number of Ph.D. students* (PHD_STU)".

On the other hand, to measure the efficiency of specific university in research, "*Number of publications* (PBLCTN)" in SCI, SSCI and AHCI indexed journals is taken as another output.

Similarly, research is also an important output, signified by ongoing government research funding. The Scientific and Technical Research Council (TÜBİTAK) of Turkey supports research projects after evaluating proposals submitted by faculty members. "*Number of projects* (PROJ_NR)" and "*Total Distributed Budget of Projects* (PROJ_BDGT)" supported by The National Scientific and Technological Research Council are also taken as outputs.

The highest university entrance score in equally weighted score group "*University entrance score - Equally weighted* (ENTRY_SC1)" and the highest university entrance score in quantitative score group "*University entrance score - Quantitative* (ENTRY_SC2)" for each university is taken as two other outputs.

On the other hand, four inputs are identified and used in our study. These are "*Number of Professors* (PROF1)", "*Number of Associate Professors* (PROF2)", "*Number of Assistant Professors* (PROF3)" and "*Total Budget distributed by the government* (BDGT)".

The resulting input output combination is summarized in Figure 1. As mentioned above, data is composed of input and output values of 50 Universities. Descriptive statistics of data is given below in Table: 3.

**Figure: 1**
**Inputs and Outputs of the DEA Model for Universities**

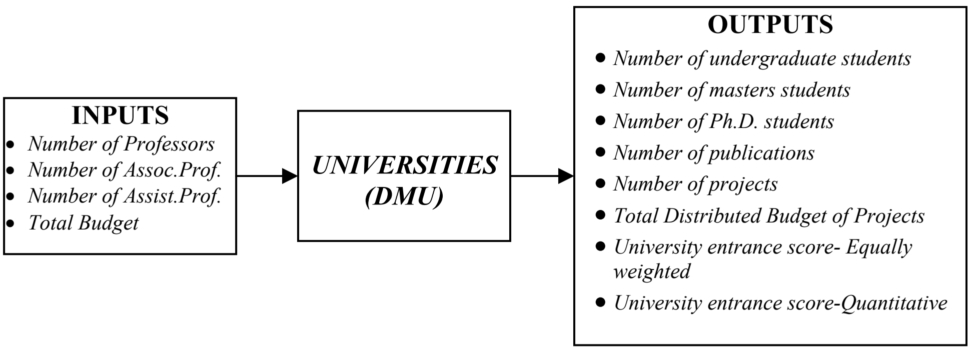

**Table: 3**
**Descriptive Statistics for Data**

| | | Average | Standard Deviation | Median | Maximum | Minimum |
|---|---|---|---|---|---|---|
| Inputs | *PROF1* | 231 | 292 | 107 | 1460 | 23 |
| | *PROF2* | 117 | 93 | 88 | 446 | 15 |
| | *PROF3* | 288 | 140 | 252 | 719 | 61 |
| | *BUDGET* | 128257243 | 84118946 | 99721250 | 449888000 | 33239000 |
| Outputs | *UGRAD_STU* | 23006 | 13370 | 20094 | 68235 | 850 |
| | *MSTR_STU* | 1731 | 1720 | 975 | 7228 | 192 |
| | *PHD_STU* | 641 | 808 | 242 | 3275 | 26 |
| | *PBLCTN* | 380 | 300 | 279 | 1270 | 2 |
| | *PROJ_NR* | 20 | 19 | 13 | 80 | 0 |
| | *PROJ_BDGT* | 2709572 | 3121592 | 1779050 | 17806000 | 50700 |
| | *ENTRY_SC1* | 342770 | 17488 | 342393 | 377671 | 276708 |
| | *ENTRY_SC2* | 360771 | 17199 | 362322 | 391567 | 277814 |

**Table: 4**
**Efficiency Scores for Turkish Universities in Output-oriented VRS Models**

| | Output oriented VRS Score | | Output oriented VRS Score |
|---|---|---|---|
| Abant İzzet Baysal | 1.00 | İnönü | 1.00 |
| Adnan Menderes | 0.96 | İstanbul | 1.00 |
| Afyon Kocatepe | 1.00 | İstanbul Teknik | 1.00 |
| Akdeniz | 0.96 | Kafkas | 1.00 |
| Ankara | 1.00 | K.M.Sütçü İmam | 1.00 |
| Atatürk | 0.98 | Karadeniz Teknik | 1.00 |
| Balıkesir | 1.00 | Kırıkkale | 1.00 |
| Boğaziçi | 1.00 | Kocaeli | 1.00 |
| Celal Bayar | 0.99 | Marmara | 1.00 |
| Cumhuriyet | 0.97 | Mersin | 1.00 |
| Çanakkale 18 Mart | 1.00 | Mimar Sinan | 0.96 |
| Çukurova | 0.96 | Muğla | 0.99 |
| Dicle | 0.97 | Mustafa Kemal | 1.00 |
| Dokuz Eylül | 0.98 | Niğde | 1.00 |
| Dumlupınar | 1.00 | Ondokuz Mayıs | 1.00 |
| Ege | 1.00 | Orta Doğu Teknik | 1.00 |
| Erciyes | 1.00 | Pamukkale | 1.00 |
| Fırat | 0.92 | Sakarya | 1.00 |
| Galatasaray | 1.00 | Selçuk | 1.00 |
| Gazi | 1.00 | Süleyman Demirel | 1.00 |
| Gaziantep | 1.00 | Trakya | 0.98 |
| Gaziosmanpaşa | 1.00 | Uludağ | 1.00 |
| Gebze Y.T.E. | 1.00 | Yıldız Teknik | 0.95 |
| Hacettepe | 1.00 | Yüzüncü Yıl | 0.99 |
| Harran | 0.99 | Z.Karaelmas | 1.00 |

### 3.2. Input and Output-oriented VRS DEA Models

In this part, standard output-oriented VRS DEA models are applied to 50 DMUs using the I/O combination shown in Figure: 1. Average efficiency score is determined as 0.99. In addition to this high average efficiency scores, only 15 universities (DMUs) are found as inefficient. Efficiency scores are given in Table: 4.

Table: 5 shows target improvements for input oriented and output oriented models respectively. For example, Adnan Menderes Universitiy should decrease its input 1 (*Number of Professors*) by 42%, input 2 (*Number of Associate Professors*) by 66%, input 3 (*Number of Assistant Professors*) by 27% and input 4 (*Total Budget*) by 27% according to input oriented model. On the other hand, when the output orient model is taken into consideration, the same university should increase output 1 (*Number of undergraduate students*) by 4%, output 2 (*Number of masters student*) by 106%, output 3 (*Number of Ph.D. students*) by 102%, output 4 (*Number of publications*) by 4%, output 5 (*Number of projects*) by 51%, output 6 (*Total Distributed Budget of Projects*) by 69%, output 7 (*University entrance score - Equally weighted*) by 4% and output 8 (*University entrance score – Quantitative*) by 4%.

**Table: 5**
**Input and Output Oriented VRS Targets (%) for Inefficient Turkish Universities**

| | Input Oriented VRS Targets (%) | | | | Output Oriented VRS Targets (%) | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | PROF1 | PROF2 | PROF3 | BUDGET | UGRAD_STU | MSTR_STU | PHD_STU | PBLCTN | PROJ_NR | PROJ_BDGT | ENTRY_SC1 | ENTRY_SC2 |
| Adnan Menderes | -42 | -66 | -27 | -27 | 4 | 106 | 102 | 4 | 51 | 69 | 4 | 4 |
| Akdeniz | -41 | -44 | -25 | -25 | 4 | 58 | 100 | 10 | 39 | 4 | 6 | 4 |
| Atatürk | -4 | -45 | -40 | -15 | 2 | 41 | 19 | 2 | 35 | 128 | 4 | 2 |
| Celal Bayar | -9 | -40 | -9 | -9 | 1 | 17 | 89 | 1 | 81 | 60 | 1 | 2 |
| Çukurova | -8 | -9 | -8 | -16 | 4 | 4 | 54 | 10 | 67 | 96 | 4 | 4 |
| Cumhuriyet | -20 | -39 | -20 | -20 | 3 | 59 | 177 | 3 | 104 | 183 | 3 | 3 |
| Dicle | -20 | -20 | -36 | -20 | 3 | 107 | 384 | 3 | 740 | 742 | 3 | 3 |
| Dokuz Eylül | -31 | -33 | -23 | -15 | 2 | 14 | 6 | 2 | 30 | 23 | 2 | 4 |
| Fırat | -20 | -40 | -41 | -17 | 20 | 69 | 38 | 9 | 27 | 169 | 9 | 33 |
| Harran | -4 | -5 | -4 | -17 | 55 | 263 | 318 | 1 | 1 | 1 | 1 | 1 |
| Mimar Sinan | -52 | -15 | -33 | -15 | 4 | 102 | 4 | 2930 | - | 1332 | 12 | 4 |
| Muğla | -8 | -2 | -2 | -2 | 1 | 65 | 221 | 25 | 1 | 35 | 1 | 4 |
| Trakya | -25 | -17 | -18 | -17 | 2 | 45 | 127 | 2 | 470 | 576 | 2 | 2 |
| Yıldız Teknik | -39 | -15 | -25 | -11 | 5 | 5 | 5 | 5 | 77 | 130 | 5 | 5 |
| Yüzüncü Yıl | -19 | -37 | -28 | -27 | 43 | 1 | 134 | 1 | 74 | 145 | 2 | 1 |

### 3.3. Measure-Specific DEA Model

In this step of the analysis, Measure-specific VRS DEA models are applied to data to determine the efficiency scores of the universities under one of the inputs or outputs are of interest which means that only one of the inputs or outputs can be changed. In practice, it can be more motivating for DMUs to set alternative targets by means of each input and output. Table 6 shows the efficiency scores obtained through measure-specific VRS DEA model for inefficient universities. Every column of the table shows the efficiency scores for universities obtained through models that take the input or output in that column of interest. The universities that we found efficient in input and output-oriented VRS DEA models previously, are also efficient in the measure-specific VRS DEA models.

**Table: 6**
**Measure-Specific VRS-DEA Scores for Universities**

| | PROF1 | PROF2 | PROF3 | BUDGET | UGRAD_STU | MSTR_STU | PHD_STU | PBLCTN | PROJ_NR | PROJ_BDGT | ENTRY_SC1 | ENTRY_SC2 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Adnan Menderes | 0.44 | 0.31 | 0.62 | 0.68 | 0.63 | 0.24 | 0.29 | 0.52 | 0.43 | 0.27 | 0.93 | 0.96 |
| Akdeniz | 0.52 | 0.42 | 0.52 | 0.75 | 0.54 | 0.27 | 0.23 | 0.62 | 0.44 | 0.35 | 0.92 | 0.96 |
| Atatürk | 0.96 | 0.48 | 0.49 | 0.84 | 0.88 | 0.68 | 0.82 | 0.97 | 0.65 | 0.38 | 0.93 | 0.97 |
| Celal Bayar | 0.87 | 0.56 | 0.89 | 0.91 | 0.89 | 0.56 | 0.41 | 0.84 | 0.45 | 0.40 | 0.99 | 0.98 |
| Cumhuriyet | 0.59 | 0.44 | 0.74 | 0.72 | 0.76 | 0.33 | 0.22 | 0.63 | 0.38 | 0.19 | 0.93 | 0.97 |
| Çukurova | 0.56 | 0.71 | 0.91 | 0.73 | 0.87 | 0.84 | 0.50 | 0.78 | 0.48 | 0.37 | 0.95 | 0.96 |
| Dicle | 0.73 | 0.56 | 0.42 | 0.77 | 0.36 | 0.29 | 0.14 | 0.75 | 0.08 | 0.07 | 0.95 | 0.97 |
| Dokuz Eylül | 0.66 | 0.61 | 0.70 | 0.85 | 0.70 | 0.67 | 0.64 | 0.81 | 0.50 | 0.44 | 0.98 | 0.95 |
| Fırat | 0.62 | 0.44 | 0.45 | 0.83 | 0.52 | 0.32 | 0.38 | 0.81 | 0.50 | 0.19 | 0.90 | 0.73 |
| Harran | 0.92 | 0.83 | 0.90 | 0.74 | 0.48 | 0.20 | 0.11 | 0.95 | 0.67 | 0.62 | 0.97 | 0.99 |
| Mimar Sinan | 0.45 | 0.74 | 0.55 | 0.85 | 0.48 | 0.43 | 0.70 | 0.01 | 0.00 | 0.01 | 0.88 | 0.95 |
| Muğla | 0.86 | 0.86 | 0.98 | 0.94 | 0.98 | 0.50 | 0.28 | 0.73 | 0.92 | 0.62 | 0.99 | 0.96 |
| Trakya | 0.71 | 0.51 | 0.55 | 0.81 | 0.54 | 0.44 | 0.27 | 0.78 | 0.10 | 0.07 | 0.96 | 0.97 |
| Yıldız Teknik | 0.60 | 0.58 | 0.54 | 0.89 | 0.67 | 0.59 | 0.74 | 0.72 | 0.46 | 0.35 | 0.92 | 0.94 |
| Yüzüncü Yıl | 0.81 | 0.46 | 0.48 | 0.68 | 0.40 | 0.72 | 0.31 | 0.76 | 0.40 | 0.22 | 0.96 | 0.99 |

After measure-specific VRS efficiency scores are calculated, we examined the target values to attain for an inefficient DMU to become efficient. Table: 7 summarizes the required percentage change in inputs or outputs of a DMU which would make this DMU become efficient.

**Table: 7**
**Efficiency Improvements (%) for DMUs to be Efficient in Measure-Specific VRS Model**

| | PROF1 | PROF2 | PROF3 | BUDGET | UGRAD_STU | MSTR_STU | PHD_STU | PBLCTN | PROJ_NR | PROJ_BDGT | ENTRY_SC1 | ENTRY_SC2 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Adnan Menderes | -56 | -69 | -38 | -32 | 58 | 317 | 245 | 94 | 134 | 276 | 8 | 4 |
| Akdeniz | -48 | -58 | -48 | -25 | 84 | 274 | 336 | 62 | 127 | 183 | 9 | 4 |
| Atatürk | -4 | -52 | -51 | -16 | 13 | 47 | 22 | 3 | 54 | 164 | 7 | 4 |
| Celal Bayar | -13 | -44 | -11 | -9 | 12 | 77 | 146 | 19 | 122 | 149 | 1 | 2 |
| Çukurova | -44 | -29 | -9 | -27 | 15 | 19 | 99 | 29 | 110 | 167 | 5 | 5 |
| Cumhuriyet | -41 | -56 | -26 | -28 | 31 | 200 | 346 | 59 | 166 | 423 | 7 | 3 |
| Dicle | -27 | -44 | -58 | -23 | 180 | 245 | 607 | 33 | 1143 | 1395 | 5 | 3 |
| Dokuz Eylül | -34 | -39 | -30 | -15 | 42 | 49 | 56 | 24 | 99 | 127 | 2 | 6 |
| Fırat | -38 | -56 | -55 | -17 | 91 | 209 | 161 | 23 | 100 | 424 | 11 | 36 |
| Harran | -8 | -17 | -10 | -26 | 107 | 410 | 807 | 6 | 49 | 62 | 3 | 1 |
| Mimar Sinan | -55 | -26 | -45 | -15 | 110 | 132 | 42 | 8491 | | 6806 | 14 | 5 |
| Muğla | -14 | -14 | -2 | -6 | 2 | 101 | 251 | 37 | 9 | 62 | 1 | 4 |
| Trakya | -29 | -49 | -45 | -19 | 84 | 126 | 264 | 28 | 866 | 1313 | 4 | 3 |
| Yıldız Teknik | -40 | -42 | -46 | -11 | 50 | 70 | 36 | 39 | 119 | 185 | 8 | 6 |
| Yüzüncü Yıl | -19 | -54 | -52 | -32 | 147 | 38 | 223 | 31 | 149 | 359 | 4 | 1 |

Percentages in Table: 7 represent the amount of change in the input or output for a DMU to become efficient. As an example, to make Adnan Menderes University efficient, we have twelve alternatives. If the number of professors is reduced by 56%, then this DMU will become an efficient DMU in our professor-specific VRS DEA model. In a similar manner, if the number of publications increases by 94%, then this DMU will become an efficient DMU in the publication-specific VRS-DEA model.

Table: 6 provides us an insight about what must a DMU do to become an efficient DMU in any of the models. It is clearly seen that many of the targets seem to be very difficult to attain for example for Adnan Menderes University to be efficient by means of PhD Students-specific VRS DEA model, it should increase its PhD Students by 245%. This kind of an increase seems impossible. So we can say that for Adnan Menderes University, it is nearly impossible to become efficient in PhD Students -specific VRS DEA model; but if the same DMU decreases the number of assistant professors by 38%, then it will be considered as an efficient DMU in the assistant professor-specific VRS DEA model.Table: 8 is a combined representation of targets of Akdeniz University for input-oriented VRS DEA model, output-oriented VRS DEA model and measure-specific VRS DEA models.

**Table: 8**
**Alternative Targets of Akdeniz University for Input-oriented, Output-oriented and Measure-specific VRS DEA Models**

| Models | Alternative Targets for Akdeniz University | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | PROF1 | PROF2 | PROF3 | BUDGET | UGRAD_STU | MSTR_STU | PHD_STU | PBLCTN | PROJ_NR | PROJ_BDGT | ENTRY_SC1 | ENTRY_SC2 |
| Input Oriented VRS DEA | -41 | -44 | -25 | -25 | | | | | | | | |
| Output Oriented VRS DEA | | | | | 4 | 58 | 100 | 10 | 39 | 4 | 6 | 4 |
| PROF1-specific VRS DEA | -48 | | | | | | | | | | | |
| PROF2-specific VRS DEA | | -58 | | | | | | | | | | |
| PROF3-specific VRS DEA | | | -48 | | | | | | | | | |
| BUDGET-specific VRS DEA | | | | -25 | | | | | | | | |
| UGRAD_STU-specific VRS DEA | | | | | 84 | | | | | | | |
| MSTR_STU-specific VRS DEA | | | | | | 274 | | | | | | |
| PHD_STU-specific VRS DEA | | | | | | | 336 | | | | | |
| PBLCTN-specific VRS DEA | | | | | | | | 62 | | | | |
| PROJ_NR-specific VRS DEA | | | | | | | | | 127 | | | |
| PROJ_BDGT-specific VRS DEA | | | | | | | | | | 183 | | |
| ENTRY_SC1-specific VRS DEA | | | | | | | | | | | 9 | |
| ENTRY_SC2-specific VRS DEA | | | | | | | | | | | | 4 |

Akdeniz University should decrease its inputs by 41%, 44%, 25%, and 25% simultaneously according to input oriented model. Similarly, when the output orient model is taken into consideration, the same university should increase its outputs by 4%, 58%, 100%, 10%, 39%, 4%, 6% and 4% simultaneously. On the other hand, to make Akdeniz University efficient, we have twelve alternatives within the context of measure-specific models. For instance, if the number of professors is reduced by 48% or the numbers of publications are increased by 62%, then this university again will become efficient. In practice, it can be more motivating for universities to set alternative targets by means of each input and output.

### 3.4. Benchmark Shares

In this part of the study, we aim to determine the importance of each efficient DMU in measuring the inefficiencies of inefficient DMUs. In other words, we aim to calculate the percentage share of efficient DMUs, acting as benchmarks or referents for the inefficient DMUs. Measure-specific VRS DEA model is taken into consideration when calculating benchmark-shares. The target values obtained in the previous part are important in determining the benchmark-shares of efficient DMUs.

**Table: 9**
**Benchmark Shares (%) for Efficient DMUs**

| | PROF1 | PROF2 | PROF3 | BUDGET | UGRAD_STU | MSTR_STU | PHD_STU | PBLCTN | PROJ_NR | PROJ_BDGT | ENTRY_SC1 | ENTRY_SC2 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Abant İzzet Baysal University | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Afyon Kocatepe University | 15 | 0 | 0 | 16 | 7 | 4 | 2 | 16 | 0 | 0 | 1 | 6 |
| Ankara University | 0 | 0 | 3 | 0 | 2 | 1 | 2 | 0 | 0 | 0 | 1 | 0 |
| Balıkesir University | 5 | 2 | 1 | 9 | 19 | 1 | 9 | 1 | 8 | 7 | 1 | 14 |
| Boğaziçi University | 6 | 5 | 0 | 9 | 0 | 6 | 0 | 3 | 1 | 0 | 10 | 27 |
| Çanakkale 18 Mart University | 0 | 0 | 0 | 3 | 0 | 0 | 0 | 0 | 13 | 0 | 0 | 0 |
| Dumlupınar University | 14 | 42 | 13 | 6 | 12 | 27 | 18 | 6 | 2 | 14 | 1 | 1 |
| Ege University | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 3 | 0 | 0 | 0 |
| Erciyes University | 6 | 0 | 10 | 17 | 9 | 0 | 0 | 21 | 0 | 0 | 10 | 0 |
| Galatasaray University | 2 | 3 | 10 | 6 | 1 | 9 | 5 | 3 | 2 | 5 | 37 | 7 |
| Gazi University | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 |
| Gaziantep University | 3 | 0 | 4 | 1 | 0 | 1 | 0 | 1 | 0 | 0 | 1 | 3 |
| Gaziosmanpaşa University | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 2 | 0 |
| Gebze Y.T.E. University | 6 | 1 | 3 | 6 | 2 | 12 | 15 | 9 | 9 | 15 | 1 | 0 |
| Hacettepe University | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 |
| İnönü University | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| İstanbul University | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| İstanbul Teknik University | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| K.M.Sütçü İmam University | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Kafkas University | 0 | 0 | 21 | 1 | 3 | 0 | 1 | 0 | 0 | 0 | 0 | 1 |
| Karadeniz Teknik University | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Kırıkkale University | 0 | 0 | 0 | 5 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 |
| Kocaeli University | 4 | 11 | 4 | 1 | 19 | 1 | 1 | 2 | 3 | 6 | 9 | 1 |
| Marmara University | 0 | 0 | 0 | 0 | 0 | 6 | 7 | 0 | 0 | 0 | 1 | 0 |
| Mersin University | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Mustafa Kemal University | 6 | 0 | 0 | 0 | 0 | 0 | 0 | 8 | 18 | 0 | 0 | 0 |
| Niğde University | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 1 | 0 | 0 |
| Ondokuz Mayıs University | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 5 | 0 | 0 | 0 | 0 |
| Middle East Technical University | 21 | 31 | 18 | 12 | 6 | 17 | 29 | 16 | 29 | 39 | 12 | 19 |
| Pamukkale University | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 5 | 0 |
| Sakarya University | 2 | 0 | 0 | 2 | 3 | 0 | 6 | 0 | 0 | 6 | 2 | 0 |
| Selçuk University | 7 | 3 | 4 | 6 | 7 | 15 | 4 | 2 | 4 | 4 | 4 | 3 |
| Süleyman Demirel University | 3 | 0 | 0 | 0 | 4 | 0 | 0 | 0 | 5 | 0 | 0 | 11 |
| Uludağ University | 0 | 0 | 8 | 0 | 6 | 0 | 0 | 2 | 2 | 2 | 1 | 6 |
| Z.Karaelmas University | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 |

Benchmark shares represent the importance of each efficient DMU in measuring the inefficiencies of inefficient DMUs. The bigger the benchmark share, the more important an efficient DMU is in benchmarking (Zhu 2000).

Table: 9 summarizes the benchmark-shares for our efficient DMUs. Each of the columns in Table 9 comes from a different model which takes the input or output at that column of interest. When ENTRY_SC2 output is the specific output in our VRS model, we can see from the table that Bogazici University is a referent for inefficient DMUs with the share of 27%. With respect to the same model, Middle East Technical University is the second benchmarked DMU with a share of 19%. The total of each column equals to 100%.

### 3.5. Region Efficiencies

In this part of analysis, efficiencies are analyzed by means of the regions which the universities are located using the approach developed in Zhu's study (Zhu 2000) for calculating the subgroup efficiencies. Turkey has seven geographic regions; Mediterranean, East Anatolia, Aegean, South East Anatolia, Central Anatolia, Black Sea and Marmara. The regions in this application are thought as subgroups in Zhu's approach. The number of universities in each region is shown in the third column of Table: 10.

After universities are grouped into their regions, the measure-specific VRS efficiency of each region is calculated. Rather than, getting the average of efficiencies of universities in each region, a weighted factor-specific formula is used to compute region efficiencies.

**Table: 10**
**Efficiency Scores for the Regions of Turkey in Measure-Specific VRS Model**

| Regions | Nr. of Universities | PROF1 | PROF2 | PROF3 | BUDGET | UGRAD_STU | MSTR_STU | PHD_STU | PBLCTN | PROJ_NR | PROJ_BDGT | ENTRY_SC1 | ENTRY_SC2 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Mediterranean | 6 | 0.70 | 0.81 | 0.90 | 0.88 | 0.87 | 0.67 | 0.52 | 0.84 | 0.70 | 0.54 | 0.98 | 0.99 |
| East Anatolia | 5 | 0.85 | 0.59 | 0.58 | 0.85 | 0.70 | 0.61 | 0.61 | 0.90 | 0.59 | 0.32 | 0.96 | 0.94 |
| Aegean | 8 | 0.86 | 0.77 | 0.89 | 0.93 | 0.88 | 0.69 | 0.70 | 0.88 | 0.77 | 0.64 | 0.99 | 0.98 |
| South East Anatolia | 3 | 0.84 | 0.76 | 0.70 | 0.83 | 0.50 | 0.32 | 0.19 | 0.87 | 0.34 | 0.21 | 0.97 | 0.99 |
| Central Anatolia | 9 | 0.99 | 0.97 | 0.98 | 0.98 | 0.97 | 0.95 | 0.96 | 0.98 | 0.95 | 0.92 | 0.99 | 1.00 |
| Black Sea | 4 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |
| Marmara | 15 | 0.96 | 0.95 | 0.92 | 0.98 | 0.92 | 0.91 | 0.93 | 0.93 | 0.80 | 0.74 | 0.98 | 0.99 |

Every column in Table: 10 shows the efficiency score of regions where the model is built and solved by the input or output at that column is taken of interest. The PROF1-specific VRS efficiency score of the Mediterranean region is 0.70. If the PHD_STU is our specific output, the efficiency score for Mediterranean region is 0.52 For ENTRY_SC1 is being our interest, then the efficiency of Mediterranean region is 0.98. Black Sea region is the most efficient region as it has the highest efficiency score at every input or output-specific VRS model.

This table also shows the most important factor creating the inefficiency of specific region. For example, efficiency score of South East Anatolia by means of number of professors is 0.84, whereas the efficiency score by means of number Ph.D. students is 0.19 which is the least efficiency score of this region. From this point of view, we can say that number Ph.D. students of South East Anatolia universities are the most important factor creating the inefficiency of this region.

## 4. Conclusions

There are several DEA based empirical studies of efficiency in higher education institutions. But, none of them is based on measure-specific DEA. Our study therefore attempts to fill this gap and to highlight areas which should be investigated further in future empirical studies. This study applies measure-specific DEA models to a sample of 50 Turkish universities. Application is performed using 2008 data consisting of 50 DMUs representing the universities of Turkey. 4 inputs and 8 outputs are determined according to research and education functions of universities.

The analysis conducted in three dimensions. As a first dimension, a standard output-oriented Constant Returns to Scale (CRS) and Variable Returns to Scale (VRS) DEA methodologies are applied to university data.

In some cases, it may be impossible for an inefficient DMU to improve all of the inputs or outputs proportionally at the same time in order to be efficient. It can be only possible to make progress in one output or input. In order to obtain targets by means of each output and input, the second dimension of the study is designed. In this dimension, measure-specific DEA methodology is applied to data.

As a third dimension, some additional concepts of measure-specific DEA such as benchmark shares and region efficiencies proposed by Zhu (Zhu 2000) are also evaluated.

A common result in DEA studies of university efficiency performed at the institution level, regardless of country of study, is that efficiency levels are high (Johnes 2006). Our analysis also showed a similar pattern that mean university efficiency in Turkey varies between 82% and 99% depending on the model type.

The current research may be extended towards various directions. First of all, additional university applications in different countries are recommended to be analyzed. Furthermore, the examination of efficiency over time would be interesting future study. Finally, similar analysis can be performed by various input/output combinations in order to test the sensitivity of the models.

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