BMIJ
ISSN: 2148-2586

bmij (2023) 11 (1):121-135
doi: https://doi.org/10.15295/bmij.v11i1.2179
Research Article

From a strategic management perspective, comparison of graduate/undergraduate education performances of research universities and efficiency determinants: The case of Turkey

Stratejik yönetim perspektifinden araştırma üniversitelerinin lisansüstü/lisans eğitim performanslarının karşılaştırılması ve etkinlik belirleyicileri: Türkiye örneği

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Abstract

This study determined undergraduate and graduate education efficiency scores using the 2020 data from 20 state research universities in Turkey. The study used input-oriented data envelopment analysis to compare undergraduate and graduate education efficiencies. In the study, the efficiency of the research universities in the prioritized field(s) was compared with the efficiency in the field(s) in which they operate intensively. It also includes suggestions on increasing their effectiveness in the prioritized field(s). In addition, the Tobit regression model, which is a regression model for limited dependent variables, was used to determine the determinants of efficiency scores. The findings show the undergraduate and graduate education performances of research universities comparatively. In addition, based on the results obtained from the Tobit regression model, suggestions were made to increase graduate performance. Five factors (the number of graduate students per faculty member, the number of undergraduate students per academic staff, the number of graduates/undergraduates in the number of students and graduations, and the number of faculty members per program) have a significant effect on graduate performance. Therefore, it is important in terms of strategic management that research universities should be restructured by considering these factors or that they should be considered in plans. The study offers an alternative perspective to performance management in both education and management.

Keywords: Data Envelopment Analysis, Tobit Regression, Higher Education Institutions, Strategic Management, Research Universities

Jel Codes: I23, M10

Submitted: 19/12/2022

Revised: 1/03/2023

Accepted: 22/03/2023

Online Published: 25/03/2023

Öz

Bu çalışmada, Türkiye'de yerleşik 20 devlet araştırma üniversitesinin 2020 yılı verileri kullanılarak lisans ve lisansüstü eğitim etkinlikleri skorları belirlenmiştir. Lisans ve lisansüstü eğitim etkinliklerinin karşılaştırıldığı çalışmada, girdi odaklı veri zarflama analizi kullanılmıştır. Çalışmada stratejik yönetim bağlamında karar verme birimlerinin önceledikleri alan(lar)daki etkinliklerinin, yoğun faaliyet gösterdikleri alan(lar)daki etkinlikleri ile karşılaştırmasını ve önceledikleri alan(lar)daki etkinliklerini nasıl artırabileceklerine yönelik öneriler içermektedir. Ayrıca çalışmada, etkinlik skorlarının belirleyicilerinin tespit edilmesine yönelik kısıtlı bağımlı değişkenlerde regresyon modeli olan Tobit regresyon modeli kullanılmıştır. Elde edilen bulgular araştırma üniversitelerinin lisans ve lisansüstü performanslarını karşılaştırmalı olarak sunmaktadır. Bununla birlikte Tobit regresyon modelinden elde edilen sonuçlardan yola çıkarak lisansüstü performansın artırılması için önerilerde bulunulmuştur. Beş faktör (öğretim üyesi başına düşen lisansüstü öğrenci sayısı, akademik personel başına düşen lisans öğrenci sayısı, öğrenci ve mezuniyet sayılarında lisansüstü/lisans sayısı ve program başı öğretim üyesi sayısı) lisansüstü performans üzerinde anlamlı etkiye sahiptir. Araştırma üniversitelerinin bu faktörleri göz önünde bulundurarak yeniden yapılandırılması veya bundan sonra yapılacak planlamalarda bunların dikkate alınması stratejik yönetim açısından önemlidir. Çalışma hem eğitim hem de yönetim alanında, performans yönetimine farkı bakış açısı sunmaktadır.

Anahtar Kelimeler: Veri Zarflama Analizi, Tobit Regresyon, Yükseköğretim Kurumları, Stratejik Yönetim, Araştırma Üniversiteleri

JEL Kodları: I23, M10

Citation: Pehlivanlı, E.A., From a strategic management perspective, comparison of graduate/undergraduate education performances of research universities and efficiency determinants: The case of Turkey bmij (2023) 11 (1): 121-135, doi: https://doi.org/10.15295/bmij.v11i1.2179

Introduction

Universities are the units where society professionals are trained and science produced. They train professionals with knowledge at the limits of science within the framework of different disciplines. Like many organizations, universities are independent decision-making units (DMUs) that use resources (mostly from the central budget) to train human resources and produce science. In other words, they transform resources into outputs. In this transformation, inputs (resources) and outputs (products) are multiple. As a requirement of social accountability and strategic management, the performance of universities should be evaluated, and efficiency should be increased with necessary improvements. One of the most widely used methods in comparing DMUs with multiple inputs and outputs is the Data Envelopment Analysis (DEA) technique, introduced to the literature by Charnes, Cooper and Rhodes (1978).

While the number of universities in Turkey was only three until the 1950s, it increased to 29 until the 1980s and 72 in the 2000s. As a result, in 2022, there will be 208 universities in Turkey, 136 of them established after 2000. As of the 2021-2022 academic year, there are 8.296.959 students enrolled, of which 3.250.101 are associate, 4.579.047 bachelor, 358.271 master and 109.540 doctorate students. The education of these students is provided by a total of 184.702 people, consisting of 32.185 professors, 20.144 associate professors, 41.484 assistant professors, 38.392 lecturers and 52.497 research assistants. In 2022, the share allocated for universities from the central budget was approximately 57 billion Turkish Liras (4.3 billion USD).

Research universities, the first example in the world being John Hopkins University, founded in 1876, are institutions that provide pure research and research-based education. In the European Union, the European Research Area (ERA), established in 2000, is a system of scientific research programs that integrates the research resources of the union. To improve Turkey's effectiveness in ERA, a conference called "Turkish Universities in ERA" was held at METU in 2015. The participants published the declaration of establishing research universities (Mammadov & Aypay, 2020). In 2017, the Council of Higher Education (CHE) assigned fifteen existing universities as research universities. In 2020, the list of research universities was revised by CHE, as in Table 1. Except for İstanbul University Cerrahpaşa, founded in 2018 by divided from İstanbul University, most of the research universities are among the country's first universities. These institutions are over half a century old, with an average year of establishment is 1970.

Table 1: Research Universities (2020)

#	Name of University	Est.	#	Name of University	Est.
1	Ankara University	1946	**11**	İzmir Higher Institute of Tech.	1992
2	Boğaziçi University	1971	**12**	Middle East Technical University	1956
3	Çukurova University	1973	**13**	Uludağ University	1975
4	Ege University	1955	**14**	Yıldız Technical University	1982
5	Erciyes University	1982	**15**	Fırat University	1975
6	Gazi University	1982	**16**	Karadeniz Technical University	1955
7	Gebze Technical University	1992	**17**	Atatürk University	1957
8	Hacettepe University	1967	**18**	Dokuz Eylül University	1982
9	İstanbul Technical University	1944	**19**	Marmara University	1982
10	İstanbul University	1933	**20**	İstanbul University Cerrahpaşa	2018

In this study, the graduate and undergraduate performances of twenty research universities in Turkey will be evaluated in comparison with DEA. This paper handles the university performances via two-phase DEA. For the first stage, the frontiers and efficient universities will be determined. The second stage is for the determination of the factors which are affecting the efficiency. The rest of the paper is as follows; the second section is about the literature review, the third is about the methodology, the fourth is about the data and variable selection, the fifth is about empirical findings, and the last is the summary and conclusion.

Literature review

They are researching the efficiency and identifying sources of efficiency of universities (HEIs) dating to the 1960s. Early studies (Bowen, 1980; Maynard, 1970; Southwick Jr, 1969; Verry & Layard, 1975) focus on a single output, such as the number of students, the number of graduates or the number of student enrolments. However, multi-output models give better efficiency scores. Tomkins and Green (1988), one of the first to use DEA for HEIs, determined the efficiency of UK HEIs with a multi-output model. Later studies are as follows; Johnes and Johnes (1993) applied the DEA model to the 36 UK universities' economy departments. They used academic staff data and research grants and publications as outputs.

Coelli (1996) and Avkiran (2001) assessed the efficiency of 36 Australian universities. While Coelli (1996) states that only one of 36 Austrian universities is fully efficient, Avkiran (2001) states that three universities are fully efficient. In the first study, the university activities were modelled as a whole, academic section and an administrative section. In the latter study, universities were modelled as general delivery of educational services and fee-paying enrolments. They used the academic and administrative staff as inputs, enrolments and research quantum as outputs.

Although these four studies are very important in bringing the need to measure the performance of HEIs to the literature, the studies conducted in the following years examine from three perspectives. These are education, research and public services, which are also the main objectives of HEIs. These objectives may conflict, such that the institution that focuses on research may not be able to allocate sufficient resources to education, or the institutions that prioritize education may not be at a sufficient level in research/public services.

Another confusion is whether to focus on single or multiple objectives. Focusing on a single objective of HEIs (teaching, research or public service) cannot adequately explain the complex structure of HEIs and limits the ability to make meaningful comparisons with their counterparts. Moreover, many outcomes, such as skill acquisition or socialization, cannot be measured clearly. Another issue remains whether some factors, such as research income or several students, are inputs or outputs (Agasisti & Bonomi, 2014; Günay & Dulupçu, 2019; Worthington, 2001). In addition, considering that DEA is examining the relative efficiency of homogeneous DMUs, it is debatable whether homogeneity will be based on the university/institution or department/program for HEIs.

In this context, the international literature on the efficiency of HEIs can be classified as follows (derived from Günay & Dulupçu, 2019);

- Institution/university level (Abbott & Doucouliagos, 2003; Avkiran, 2001; Breu & Raab, 1994; Kantabutra & Tang, 2010; Kuah & Wong, 2011; Sagarra et al., 2017),
- Department/program level (Agasisti et al., 2011; Kao & Hung, 2008; Kounetas et al., 2011; Madden et al., 1997; Mayston, 2014; Tauer et al., 2007),
- Teaching efficiency (Agasisti & Bonomi, 2014; Agasisti & Dal Bianco, 2009; Barra & Zotti, 2016a; J. Johnes, 2003; Mikušová, 2017),
- Research efficiency (Abramo & D'Angelo, 2009; Chu Ng & Li, 2000; J. Johnes & Li, 2008; Munoz, 2016; Rhaiem, 2017),
- Both teaching and research efficiency (Barra & Zotti, 2016b; Beasley, 1995; Kao, 2012; Martín, 2006; Tochkov et al., 2012),
- Effects of external factors (Cherchye & Abeele, 2005; Fandel, 2007; Kuo & Ho, 2008; Lee, 2011; Warning, 2004; Wolszczak-Derlacz, 2017),

Methodology approaches on the efficiency of HEIs other than DEA (derived from Günay & Dulupçu, 2019);

- Malmquist index (Agasisti & Pérez-Esparrells, 2010; Edvardsen et al., 2017; Flegg et al., 2004; Thanassoulis et al., 2011; Worthington & Lee, 2008),
- Robust frontiers (Bonaccorsi et al., 2006; Fernández-Santos & Martínez-Campillo, 2015),
- Metafrontier (Lu & Chen, 2013),
- Stochastic frontier analysis (SFA) (Abbott & Doucouliagos, 2009; G. Johnes & Johnes, 2009; McMillan & Chan, 2006),
- Bootstrapping (Lee, 2011; Villano & Tran, 2018).

In addition to the international literature, many studies have been conducted to measure the efficiency of HEIs in Turkey since the 2000s. Kurtar and Kartal (2004), Çokgezen (2009), and Köksal and Nalçacı (2006) evaluated the efficiency of HEIs based on departments and programs. Ustasüleyman (2007), Kutlar and Babacan (2008), Özden (2008), Ulucan (2011), Selim and Bursalıoğlu (2013) and Günay, Dulupçu and Oruç (2017) evaluated the efficiency of HEIs as a whole.

Some studies examined only the research efficiency of HEIs (Günay & Haliloğlu, 2018). In addition, some studies examined only educational efficiency (Baysal et al., 2005; Yeşilyurt, 2009). However, there are also studies examining both research and educational efficiency together (Çınar, 2013; Haktanırlar-Ulutaş, 2011).

Although there is a sufficient number of studies investigating the efficiency of HEIs, studies investigating the efficiency of research universities are limited. In addition, in the literature review, no research has been found examining universities' undergraduate and graduate efficiencies. Therefore, this study aims to present the undergraduate and graduate education performances of research universities in Turkey in the literature.

Methodology

Starting from Farrell's (1957) concept of technical efficiency, Charnes, Cooper and Rhodes (1978) proposed Data Envelopment Analysis to compare the decision-making activities of Decision Making Units (DMUs) with similar input/output factors. This approach, which uses the constant return to scale (CRS - CCR model) approach, was developed by Banker, Charnes and Cooper (1984) and presented the variable return to scale (VRS - BCC model) approach. With these models, targets for reducing input factors and increasing output factors can be presented to DMUs. In this way, it is aimed to ensure the efficiency of DMUs, and the factors that cause efficiency loss can be determined.

The method ranks the DMUs (research universities for this study) included in the analysis, starting with the most efficient. At this point, the method is limited to the efficiency of the most efficient DMU included in the analysis. In other words, the most efficient DMU sets the highest bar (as fully efficient). Studies on university performance (e.g. Avkiran 2001) indicate that the university's scale is not an important issue for efficiency so small universities could perform as large ones. From this point of view, the constant return to scale efficiency model (CCR) is preferred for this study.

The DEA model can be designed as output or input oriented. The output-oriented model presents targets to achieve full efficiency by enhancing outputs, while the input-oriented model is the opposite. The current study uses the output-oriented model to obtain targets to enhance outputs more suitable for HEIs.

Output-oriented CCR-DEA model is used to measure the relative efficiency of DMUs, let x_{ij} $(i = 1,\dots,m)$ and y_{rj} $(r = 1,\dots,s)$ represent the input and output amounts of j^{th} university. The model is as follows for the evaluation of DMU_k:

$$\begin{aligned} &\theta_k = min\ \textstyle\sum_{i=1}^{m} v_i x_{i0} \\ &\textstyle\sum_{r=1}^{s} u_r y_{r0} = 1 \\ &\textstyle\sum_{r=1}^{s} u_r y_{rj} \le \sum_{i=1}^{m} v_i x_{ij}\ ,\ j = 1,2,\dots,n \\ &u_r \ge \varepsilon\ ;\ v_i \ge \varepsilon; r = 1,\dots,s;\ i = 1,\dots,m \end{aligned} \qquad (1)$$

where m is the number of inputs, s is the number of outputs of evaluated n universities. Moreover, for k^{th} university, $1/\theta_k$ is efficiency score, ε is a small positive number, u_r is weight of output r and v_i is weight of input i. If $\theta_k = 1$, is considered a fully efficient university; otherwise, considered inefficient (Charnes et al., 1994).

Efficiency scores obtained from DEA are between 0 and 1 as seen in equation (1). The dependent variable (efficiency score) is limited to a certain range (0-1). The Tobit Regression Model proposed by Tobin (1958) estimates the limited dependent variables. For the i^{th} observation (university) Tobit model can be expressed as (McDonald & Moffitt, 1980);

$$\begin{aligned} &y_i^* = x_i'\beta + u_i\ (\mathrm{i} = 1,2,3,\dots.\mathrm{n}) \\ &if\ y_i^* < 1\ ;\ y_i = y_i^* \\ &if\ y_i^* \ge 1\ ;\ y_i = 1 \end{aligned} \qquad (2)$$

where x_i' is the independent variable, β is the unknown parameter, u_i is the normally distributed residuals, $y_i^*$is the latent variable and y_i is the DEA score obtained from equation (1).

Dataset and variable selection

This study focuses on the efficiency of 20 research universities in Turkey. The data covers the 2020 data of the 20 research universities. Data was obtained from CHE's statistics website (istatistik.yok.gov.tr: accessed date 12.05.2022). The literature selects inputs and outputs in this study in which undergraduate and graduate efficiencies are compared. Mojahedian et al. (2020) reviewed the DEA literature for HEIs. The frequencies of the inputs and outputs obtained from the study are given in Table 2.

Table 2: Input/Output Frequencies for HEIs

#	Name of the variable	Frequency	Input/output
1	Number of academic staff	113	Input
2	Budget and costs	107	Input
3	Number of students	50	Input
4	Number of administrative staff	42	Input
5	Space	23	Input
6	Students score before the university	14	Input
7	Number of graduates	75	Output
8	Publications	69	Output
9	Income	55	Output
10	Number of students	50	Output
11	Students' score	11	Output

Source: Mojahedian et al., 2020

In parallel with the studies of HEI efficiency literature, the number of academic staff, the number of students taken as inputs, and the number of graduates taken as output. This study differs from previous studies in two points. First, the number of programs not included in most previous studies was added to the inputs. Secondly, undergraduate and graduate education efficiencies were evaluated comparatively. Since the publication and cost efficiency is not mentioned in the study, articles/citations and costs/incomes are not included.

This study examines education in research universities and undergraduate and graduate education. Although, for undergraduate education, the inputs are several academic staff (professors, associate professors, assistant professors, lecturers, and research assistants), some students and several undergraduate programs (associate and bachelor's degrees), the only output is some graduates from undergraduate programs for 2020. The model is visualized in Figure 1.

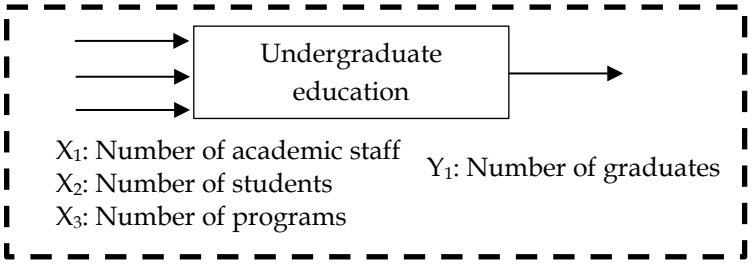

Figure 1: DEA Model for Undergraduate Education Efficiency

Graduate education differs slightly from undergraduate education. For graduate education, the inputs are the number of faculty members (professors, associate professors and assistant professors), students and graduate programs (master's and doctorate). The only output is number of graduates from graduate programs for 2020. The model is visualized in Figure 2.

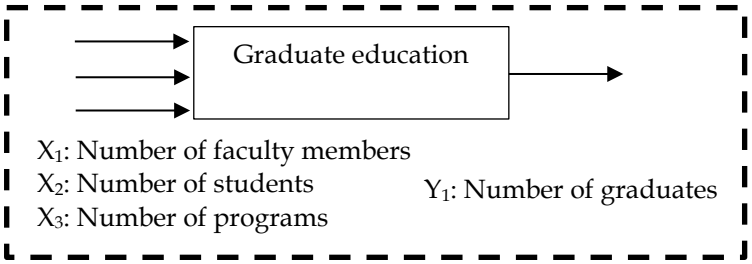

Figure 2: DEA Model for Graduate Education Efficiency

The descriptive statistics of the factors for 20 research universities are seen in Table 3. As can be seen from the table, the average number of graduates at research universities in Turkey is around 10000 for undergraduate education and around 1000 for graduate education. Similarly, the approximate number of students is 72000 in undergraduate and 7200 in graduate education, corresponding to approximately one-tenth of undergraduate education.

Table 3: Descriptive Statistics of Inputs and Outputs

	Factor Name	Index	Input/ Output	Minimum	Maximum	Mean	Standard Deviation
Undergraduate Education	*Number of academic staff*	X_1	Input	596	4011	2433.25	959.42
	Number of students	X_2	Input	4214	426868	72657.15	115167.11
	Number of programs	X_3	Input	19	263	126.6	69.69
	Number of graduates	Y_1	Output	309	78570	10752.35	16913.97
Graduate Education	*Number of faculty staff*	X_1	Input	208	1927	1186.6	501.45
	Number of students	X_2	Input	1232	14054	7215.4	3638.71
	Number of programs	X_3	Input	37	749	298.85	182.01
	Number of graduates	Y_1	Output	202	2706	1063.65	637.22

Empirical results

The input-oriented CCR model is applied to measure the efficiency of research universities. The results obtained for undergraduate and graduate education are given below.

Undergraduate education efficiency scores

The efficiency score results and the ranks of the research universities for undergraduate education are presented in Table 4.

Table 4: The Undergraduate Education Efficiency Scores and the Ranks

The name of the HEI	Abbreviation	Value	Rank
Gazi University	Gazi	1	1
Karadeniz Technical University	KATU	1	1
Atatürk University	AtaUni	1	1
Fırat University	Fırat	0.889	4
Erciyes University	Erciyes	0.839	5
Marmara University	Marmara	0.815	6
Ege University	Ege	0.805	7
Çukurova University	Çukurova	0.770	8
Dokuz Eylül University	DokuzEylül	0.758	9
Ankara University	Ankara	0.705	10
Hacettepe University	Hacettepe	0.693	11
Uludağ University	Uludağ U.	0.625	12
Boğaziçi University	Boğaziçi	0.603	13
Middle East Technical University	METU	0.577	14
İstanbul University	İstanbul	0.566	15
Yıldız Technical University	YTU	0.552	16
İstanbul Technical University	ITU	0.538	17
İzmir Higher Technology of Institute	İzmir H. T. I.	0.429	18
Cerrahpaşa İstanbul University	Cerrahpaşa	0.282	19
Gebze Technical University	GTU	0.270	20

According to Table 4, Karadeniz Technical University, Atatürk University and Gazi University are the efficient HEIs for undergraduate education and share the first rank. The result is compatible with the study of Çınar (2013) for Gazi University. Marmara University, Fırat University, Erciyes University and Ege University have more than 0.80 efficiencies, even if they are not fully efficient. The rest of them have lower than 0.80 efficiencies.

The results show that the leading HEIs of the country, such as Boğaziçi University, Middle East Technical University, and İstanbul Technical University, are not fully efficient at undergraduate education. These HEIs do not prioritize undergraduate education. For example, METU's mission is clarified as "*METU's mission is to attain excellence in research, education and public service for society, humanity and nature by nurturing creative and critical thinking, innovation and leadership within a framework of universal values*"(Mission & Vision | METU - Middle East Technical University, Date accessed: 17/12/2022).

Gebze Technical University and Cerrahpaşa İstanbul University have lower than 0.30 efficiency for undergraduate education. This inefficiency can be explained as follows: Gezbe Technical University started undergrad education at the undergraduate level with the transformation of Gebze Institute of Technology, established in 1992, and only engaged in graduate education and research activities in 2014. Therefore, it is acceptable that it is ranked lower among other research universities that started their undergraduate education half a century ago. İstanbul Cerrahpaşa University was founded in 2018 by separating from İstanbul University. It is among the research universities with the legacy it received from İstanbul University, which is based on a long history. The fact that it was established recently and cannot provide regular undergraduate graduates explains its low efficiency.

The previous sections explained the aims of research universities and the reasons for their separate evaluation from other higher education institutions. Research universities prioritize graduate education and research. For this reason, the results of the graduate education efficiency of HEIs are discussed in the next section.

Graduate education efficiency scores

The efficiency score results and the ranks of the research universities for graduate education are presented in Table 5.

Table 5: The Graduate Education Efficiency Scores and the Ranks

The name of the HEI	Abbreviation	Value	Rank
Middle East Technical University	METU	1	1
Yıldız Technical University	YTU	1	1
Marmara University	Marmara	1	1
İstanbul Technical University	ITU	0.997	4
Boğaziçi University	Boğaziçi	0.936	5
Gebze Technical University	GTU	0.89	6
Çukurova University	Çukurova	0.84	7
Gazi University	Gazi	0.831	8
İzmir Higher Technology of Institute	İzmir H. T. I.	0.804	9
Ankara University	Ankara	0.800	10
Fırat University	Fırat	0.784	11
Dokuz Eylül University	DokuzEylül	0.777	12
Hacettepe University	Hacettepe	0.737	13
Karadeniz Technical University	KATU	0.716	14
Atatürk University	AtaUni	0.653	15
Ege University	Ege	0.614	16
İstanbul University	İstanbul	0.549	17
Uludağ University	Uludağ U.	0.501	18
Erciyes University	Erciyes	0.425	19
Cerrahpaşa İstanbul University	Cerrahpaşa	0.341	20

Marmara University, Yıldız Technical University and Middle East Technical University are fully efficient HEIs for graduate education (Table 5). It is seen that İstanbul Technical University (0.997) and Boğaziçi University (0.936), among the other leading universities of the country, have efficiency scores above 0.90. These five HEIs have the first five ranks.

CHE published the rankings of research universities on 13/12/2021 (https://www.yok.gov.tr/Sayfalar/Haberler/2021/arastirma-universiteleri-ile-toplanti.aspx). Four of these five universities are in the top five in CHE's ranking, consistent with the research findings. However, despite the relatively low efficiency in undergraduate education (0.27), Gebze Technical University ranks 9th in graduate education efficiency with an efficiency score of 0.804. Cerrahpaşa University, on the other hand, is in the last place with the lowest efficiency score (0.341) in graduate education due to the effect of the new establishment explained above.

Since this study aims to compare the research universities' undergraduate and graduate efficiency scores, ranking and efficiency comparisons are examined in the following section.

Comparison of the undergraduate and graduate efficiency scores and rankings

The distribution of the efficiency scores of the universities in the undergraduate and graduate education processes is shown in Figure 3. The horizontal axis gives the undergraduate education efficiency scores, and the vertical axis gives the graduate education efficiency scores. The 45-degree orange line (y=x) reflects the situation where both efficiencies are equal. Universities above this line have graduate education efficiency scores greater than undergraduate education efficiency scores, while those below are the opposite.

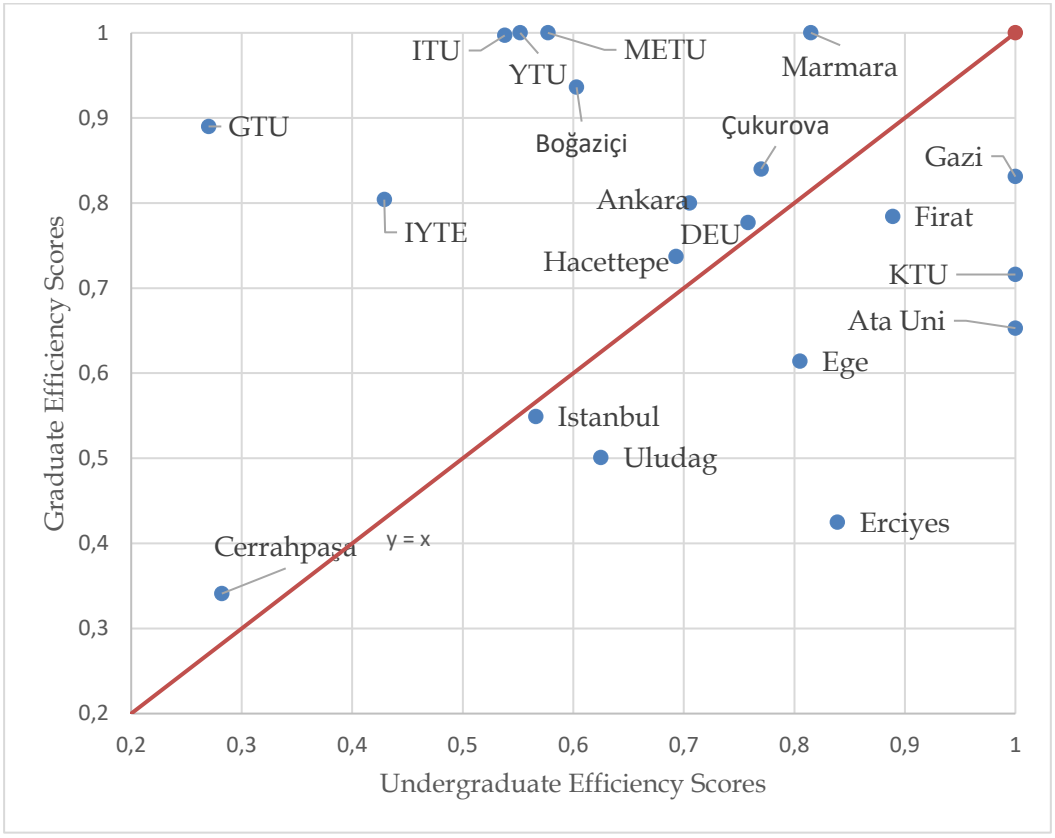

Figure 3: Efficiency Score Comparison for Each HEI

Of the 20 HEIs included in the data envelopment analysis, 8 had a graduate effectiveness score below the undergraduate effectiveness score. When these HEIs are examined, it is seen that three of them (Gazi University, Karadeniz Technical University and Atatürk University) are fully active in undergraduate education. By using their resources more efficiently, these three universities will be more successful in prioritizing graduate education, which is expected from research universities. The remaining five HEIs (Fırat University, Erciyes University, İstanbul University, Uludağ University and Ege University) must improve their undergraduate and graduate education efficiencies.

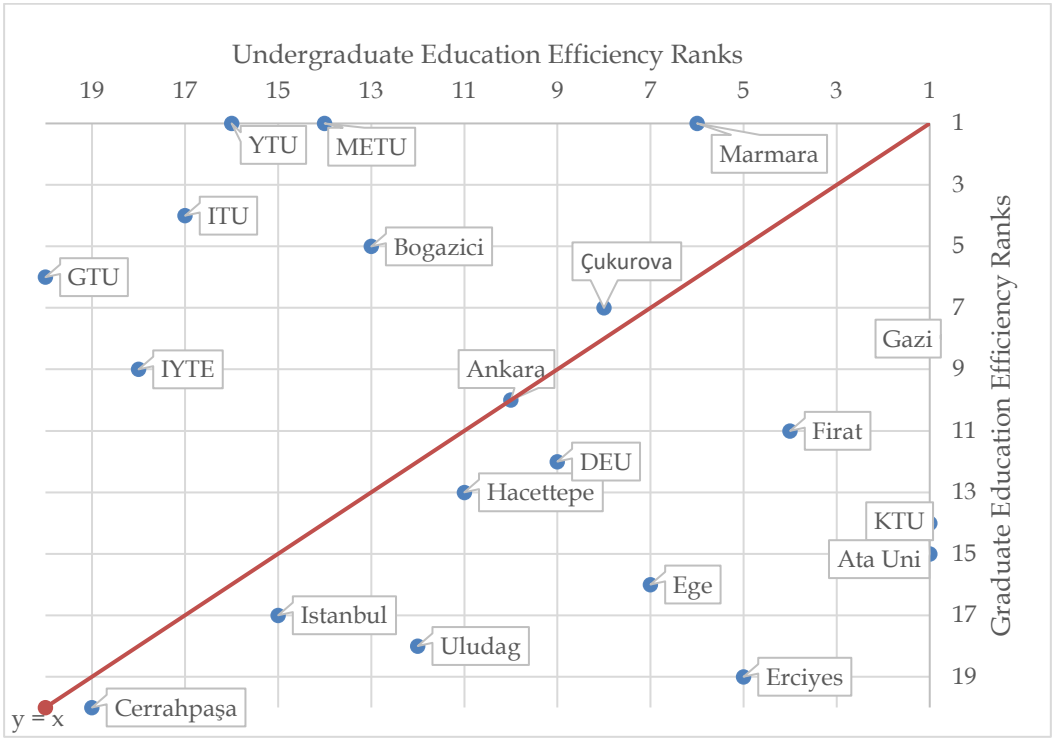

Figure 4: Efficiency Rank Comparison for Each HEI

Figure 4 shows the distribution of efficiency rankings of the 20 HEIs included in the data envelopment analysis as graduate and undergraduate, similar to Figure 3. Data Envelopment Analysis allows for the computation of efficiency scores and comparative efficiency rankings of DMUs (for this study HEIs). In this context, the distribution obtained in Figure 4 allows a wider interpretation than that obtained in Figure 3. Unlike Figure 3, İstanbul Cerrahpaşa University, Dokuz Eylül University and Hacettepe University need improved graduate education rankings.

Efficiency factors

Tobit Regression was applied to the results to understand the efficiency factors of the HEIs, as dependent variables are restricted. The factors, dependent and independent variables, and descriptive statistics are explained in Table 6. For example, the graduate efficiency score is denoted by "g" and the undergraduate efficiency score by "ug". These are dependent variables. The factors affecting these dependent variables are listed from a1 to a8 as in Table 6.

Table 6: Tobit Regression Factors' Descriptive Statistics

Factor Name	Index	Minimum	Maximum	Mean	Standard Deviation
Graduate student/faculty staff	a1	3.406	10.038	6.271	2.017
Undergrad student/academic staff	a2	6.825	154.55	26.259	36.919
Number of articles – WoS	a3	428	3377	1565.2	700.179
Number of citations – WoS	a4	1833	17942	6646.25	3398.508
Graduate students/undergrad students	a5	0.017	0.64	0.211	0.142
Graduate graduations/undergraduate graduations	a6	0.012	1.32	0.247	0.283
Academic staff/number of undergrad programs	a7	10.502	37.424	22.854	8.205
Faculty staff/number of undergrad programs	a8	2.242	6.637	4.510	1.18
Graduate efficiency score	g	0.27	1	0.685	0.215
Undergraduate efficiency score	ug	0.341	1	0.759	0.195

Correlations between variables are shown in Figure 5. "Graduate student/faculty staff" (a1) is correlated with "graduate students/undergraduate students" (a5; 0.757***), "graduate graduations/undergraduate graduations" (a6; 0.650**), "academic staff/number of undergrad programs" (a7; 0.510*), "undergraduate efficiency score" (ug; -0.471*) and "graduate efficiency score" (g; 0.541*). As noted in the previous sections, the promotion of graduate education was among the objectives of research universities. These results show that the number of graduate students per faculty member correlates directly with the graduate efficiency score.

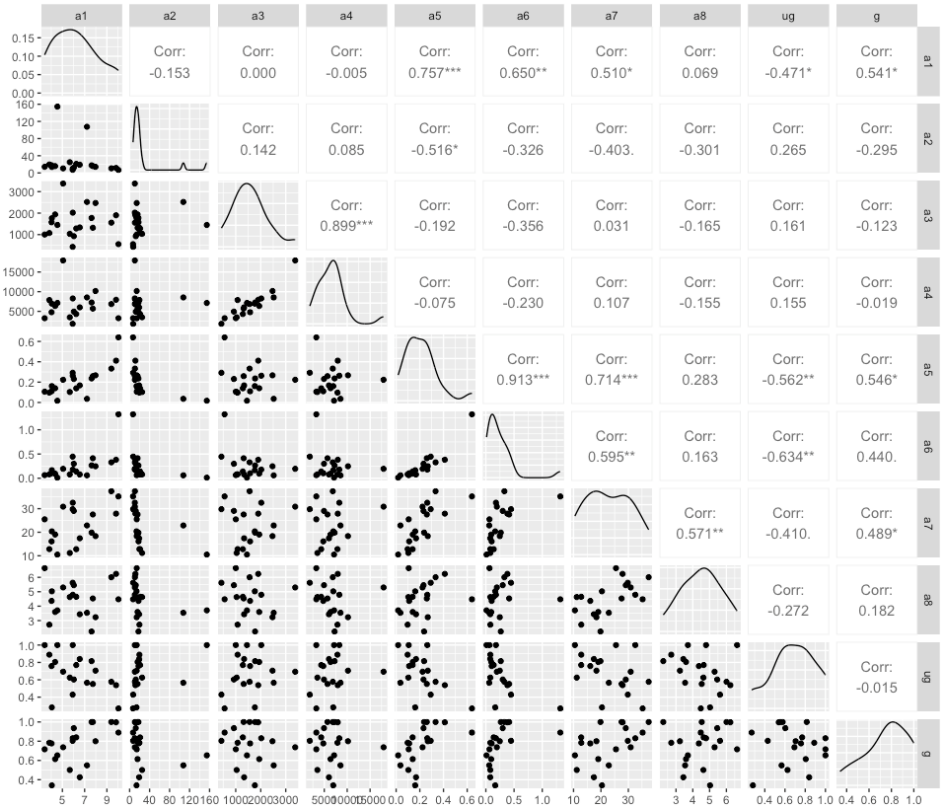

Figure 5: Correlations Between Variables

As shown in Table 7, none of the factors affects the graduate efficiency score. There might be other factors that could affect graduate efficiency. For the undergraduate efficiency score, "graduate student/faculty staff" (a1; $\beta_1 = 0.0995$; p<0.1), "undergrad student/academic staff" (a2; $\beta_2 = 0.09664$; p<0.1), "graduate students/undergrad students" (a5; $\beta_5 = 0.0498$; p<0.05), "graduate graduations/undergraduate graduations" (a6; $\beta_6 = 0.00192$; p<0.01), "faculty staff/number of undergrad programs" (a8; $\beta_8 = 0.05126$; p<0.1).

Tobit Models for graduate and undergraduate efficiency scores can be explained as (respectively);

$$g_i^* = \beta_0 + a_1\beta_1 + a_2\beta_2 + a_3\beta_3 + a_4\beta_4 + a_5\beta_5 + a_6\beta_6 + a_7\beta_7 + a_8\beta_8 + u_i$$

$$if\ g_i^* < 1\ ;\ g_i = g_i^*$$
$$if\ g_i^* \geq 1\ ;\ g_i = 1$$

$$ug_i^* = \beta_0 + a_1\beta_1 + a_2\beta_2 + a_3\beta_3 + a_4\beta_4 + a_5\beta_5 + a_6\beta_6 + a_7\beta_7 + a_8\beta_8 + u_i$$

$$if\ ug_i^* < 1\ ;\ ug_i = ug_i^*$$
$$if\ ug_i^* \geq 1\ ;\ ug_i = 1$$

Table 7: Tobit Regression Estimates

Dependent Variable	Graduate Efficiency Score (g)		Undergraduate Efficiency Score (ug)	
Independent Variable	**Estimate (β)**	**p-value**	**Standard Estimate**	**p-value**
Constant	4.94E+02	0.0207**	1.17E+03	9.48e-09****
a1	4.49E+01	0.1887	-5.40E+01	0.09950*
a2	-5.04E-01	0.7297	2.32E+00	0.09664*
a3	-1.65E-01	0.1833	-1.07E-01	0.36761
a4	2.36E-02	0.3452	4.33E-03	0.85656
a5	2.42E+02	0.8384	2.23E+03	0.04978**
a6	-2.38E+02	0.5789	-1.28E+03	0.00192***
a7	7.61E+00	0.3134	5.28E+00	0.46563
a8	-1.48E+01	0.7212	-7.72E+01	0.05126*
Log(scale)	-1.94E+03	<2e-16****	-1.98E+03	<2e-16****
Log-Likelihood	10.35		11.2	
Scale	0.1442		0.1382	
Wald Statistic (8-df)	14.97	0.0597*	26.2	0.00096****
The number of obs.	20		20	

Significancy codes: 0 '****' 0.001 '***' 0.01 '**' 0.05 '*' 0.1

The results indicate that undergraduate (a1) and graduate student (a2) per academic staff positively affect undergraduate efficiency. In addition, unexpectedly, the graduate student per undergraduate student ratio (a5) and graduate graduation per undergraduate graduation ratio (a6) positively affect undergraduate efficiency. As expected, faculty staff per undergraduate programs (a8) also positively affect undergraduate efficiency.

Summary and conclusion

Although there are several studies on the efficiencies of HEIs, studies examining the efficiencies of research universities are very limited. Research universities have a structure that prioritizes graduate education over undergraduate education. For this reason, this study examined the graduate education efficiency of research universities and the undergraduate education efficiency comparatively.

The sample of the research is 20 state research universities located in Turkey. In the first stage of the study, input-oriented CCR Data Envelopment Analysis was performed to select inputs and outputs from the literature. Although the efficiency scores obtained are similar to those in the literature, the comparative presentation of research universities' undergraduate and graduate education efficiencies offers a new perspective.

In the second stage of the study, the Tobit Regression Model was used to determine the determinants of the obtained efficiency scores. Finally, each HEI's undergraduate and graduate education activities were compared, and recommendations were made to those with relatively low graduate efficiency.

In determining the determinants of efficiency scores, five different determinants (graduate student/faculty staff, undergrad student/academic staff, graduate students/undergrad students, graduate graduations/undergraduate graduations, and faculty staff/number of undergrad programs) of undergraduate education efficiency obtained, although no significant variable found for graduate education efficiency. Two of these five variables are related to graduate education. This reveals the necessity of universities to bring graduate education to the fore to increase their general efficiency.

Although the literature using the same factors has not been found, the factors (the number of research projects/sections, citations/publications, and PhD graduates/doctoral program) determined for research efficiency in the study of Mamadov and Aypay (2020) are consistent with the findings obtained from this study.

In the context of strategic management, the research is important for decision-making units (such as universities) to see the advantages and weaknesses of the activities of the areas they prioritize (such as graduate education) to the areas in which they operate intensively (undergraduate education). In addition, to this study, a case study was carried out to identify the factors that can increase the efficiency of the decision-making units in the area they prioritize.

Since this study is based on educational efficiency, financial efficiency variables (income and expense) are not considered, which is the limitation of this study. However, it is recommended to carry out studies covering the cost-efficiency of research universities in future studies. Moreover, the number of publications, citations, and other ratios considered efficiency predictors in this study may be among the inputs and outputs in the efficiency calculation. The study can be expanded in light of these recommendations.

Peer-review:

Externally peer-reviewed.

Conflict of interests:

The author has no conflict of interest to declare.

Grant Support:

The author declared that this study had received no financial support.

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