*Full research paper*

# MEASURING THE EFFICIENCY OF TURKISH RESEARCH UNIVERSITIES VIA TWO-STAGE NETWORK DEA WITH SHARED INPUTS MODEL

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## ABSTRACT

The efficiency of universities, which have a network structure of production process, is an essential component of performance measurement in education. However, most previous studies use traditional Data Envelopment Analysis (DEA), which disregards the network structure of the production process in universities. This study adopts a two-stage Network Data Envelopment Analysis (NDEA) with shared inputs model to assess the overall, teaching and research efficiencies of Turkish research universities. The findings show that only 6 out of 23 research universities are efficient, and some universities with lower world rankings are more efficient than those with higher rankings. On the other hand, no significant difference was found between the efficiency levels of regions with a high level of socio-economic development and regions with a relatively low level of socio-economic development. The study also evaluates the effects of different priority scenarios on efficiency and the optimal allocation of shared inputs between sub-processes. This study provides guidance for universities seeking to improve their performance and for the Council of Higher Education (CHE) in determining incentives for research universities. It also promotes the use of multi-stage NDEA with shared inputs model over traditional DEA for accurate efficiency assessment in the field of education.

## KEYWORDS

**Network DEA, research efficiency, regional development, shared inputs, Turkish research universities, teaching efficiency**

## HOW TO CITE

Doğan H. (2023) 'Measuring the Efficiency of Turkish Research Universities via Two-Stage Network DEA with Shared Inputs Model', *Journal on Efficiency and Responsibility in Education and Science*, vol. 16, no. 4, pp. 329-342. http://dx.doi.org/10.7160/eriesj.2023.160406

**Article history**
**Received**
September 7, 2023
**Received in revised form**
October 9, 2023
**Accepted**
November 23, 2023
**Available on-line**
December 31, 2023

***Highlights***

- *The study applies a two-stage NDEA with shared inputs model to measure the efficiency of Turkish research universities in teaching and research activities.*
- *The study reveals that 6 out of 23 research universities are efficient in both teaching and research processes.*
- *The study finds that some universities ranked lower in the world rankings are more efficient than those ranked higher.*
- *The level of regional socio-economic development does not affect the efficiency of research universities.*

## INTRODUCTION

Universities are multifaceted organizations that fulfill numerous functions and tasks in society. Teaching and research are the foremost and vital pursuits, as they enhance the development of a highly skilled workforce, generate knowledge, and provide social benefits (Erdem, 2013). It is essential to note, however, that universities vary in their objectives, aims, and capacity to undertake these activities. Some universities prioritize teaching and learning, while others prioritize scholarly research and innovation. Additionally, certain universities aim to excel in both areas and are commonly known as research universities. These institutions distinguish themselves through their pursuit of cutting-edge research, research-focused culture, and significant contributions to science and technology fields (Altbach, 2011). Research universities play a crucial role in advancing the knowledge economy and society through training researchers who push the frontiers of knowledge, generate innovative ideas and solutions for global challenges, and collaborate with diverse stakeholders to transfer knowledge and innovations. Research universities offer top-notch education to both undergraduate and graduate students, who gain invaluable experience through access to pioneering research and opportunities to participate in research projects. In addition, research universities are pioneering community service and outreach programs aimed at addressing regional and local issues and needs (Altbach and Salmi, 2011; TAÜG, 2016).

The Turkish government and higher education authorities have initiated a program to support and promote research activities and establish a culture of scientific inquiry in the country by recognizing the significance of research universities. In 2017, 10 universities were designated as research universities based on their research potential and performance indicators, and the number of research universities has since increased to 23 as of 2021. These universities are incentivized by the state to improve their research infrastructure, human resources, and overall quality. The Council of Higher Education (CHE) conducts regular monitoring and evaluation to assess their performance based on 33 indicators related to publications, citations, patents, and projects, etc. (CHE, 2020, 2021).

However, becoming a research university requires more than just achieving high levels of research output and impact. Using available resources efficiently to achieve desired outcomes in research and teaching is crucial. Efficiency refers to an organization's ability to utilize its inputs, including human capital and physical infrastructure, to produce outputs such as graduates or publications (Daft, 2015; Lindsay, 1982). Effectiveness is a crucial aspect of organizational performance, indicating the degree to which an entity meets its goals and achieves its purpose (Lindsay, 1982). Both efficiency and effectiveness are crucial for evaluating the performance of research universities.

Several techniques can be utilized to measure the efficiency of higher education institutions. One of the most prevalent approaches is using Data Envelopment Analysis (DEA), which is a non-parametric technique for comparing the relative efficiency of decision-making units (DMUs) with multiple inputs and outputs (Cooper et al., 2007). It helps in determining the efficiency of the DMUs in producing multiple outputs with multiple resources. DEA calculates the efficiency score of each DMU based on its proximity to an efficient frontier that represents the best practice among the DMUs. Additionally, DEA identifies the sources of inefficiency for each DMU and proposes potential enhancements (Charnes et al., 1978).

Nonetheless, the standard DEA has some restrictions when utilized for complex establishments such as universities that contain several activities or stages within their system. For instance, universities engage in teaching and research, which involve varying inputs and outputs, intermediate products, and interrelationships. Standard DEA models often treat the system as a black box, disregarding these aspects when transforming inputs into outputs, which can lead to imprecise or deceptive efficiency measurements (Färe and Grosskopf, 1996, 2000). To overcome this issue, researchers have developed network DEA (NDEA) models that consider the system's internal structure and processes. NDEA models disaggregate the system into multiple stages or subprocesses, each with its inputs and outputs. The transfer of products or services between the stages is indicated by intermediate flows. NDEA models can measure the system efficiency and the efficiency of individual stages and subprocesses (Färe et al., 2007; Yang et al., 2018).

NDEA models are superior to standard DEA models in evaluating research universities' efficiency as they can consider the complex and varied operations. Research universities have a two-stage system dedicated to teaching and research, with each stage having its own inputs and outputs. Staff who teach and engage in research are referred to as shared inputs. NDEA models can assess the comprehensive efficiency of research universities, as well as their individual teaching and research efficiencies. Additionally, the NDEA with shared inputs model can analyze how various strategies or scenarios impact research university efficiency (Chen et al., 2010). For instance, what would occur if research universities prioritized teaching over research or vice versa? How should a research university allocate its faculty members between teaching and research activities to achieve optimal efficiency?

Universities not only generate general economic impacts through local expenditures (such as salaries and services), but also create local knowledge spillovers through university research, which in turn lead to regional innovation processes. That is, universities generate knowledge; and this knowledge is used or developed by local firms, entrepreneurs, public institutions, and other stakeholders. This improves the economic performance, competitiveness, and welfare of the region (Arbo and Benneworth 2007; Geuna and Musico, 2009; Goldstein and Renault 2004). Numerous studies have suggested that research universities have a beneficial impact on their regions, as validated by the positive socio-economic outcomes (Chankseliani et al., 2021; Cui and Li, 2022; Findler et al., 2019; Parilla and Haskins, 2023; Smith and Bagchi-Sen, 2012). When examined in the context of Türkiye, there are also studies that show that universities in Türkiye have a high demographic, economic, spatial, social, and cultural influence on their regions (Erdoğan and Karagöl, 2018; Işık and Başaran, 2021; Yavuzçehre, 2016). However, research is currently insufficient regarding how varying levels of regional socio-economic development shape the efficiency of research universities. Regional development has the potential to affect research universities' resources, research, and competitiveness. Universities situated in wealthier regions are likely to have certain advantages, while those in poor regions may face distinct challenges. It is crucial to examine whether the regional socio-economic development level impacts the overall efficiency of research universities.

This research assesses and compares the overall efficiency, along with the teaching and research efficiency, of Turkish research universities by applying the two-stage NDEA with shared inputs method. The study investigates the impact of prioritizing activities and the optimal distribution of academic workforce between teaching and research. Moreover, it assesses the influence of regional socio-economic development on research university efficiency. The research questions addressed in this study are:

- RQ1: What is the current level of overall efficiency of research universities in Türkiye?
- RQ2: What level of research and teaching efficiency could Turkish research universities achieve by prioritizing teaching activities?
- RQ3: What level of research and teaching efficiency could Turkish research universities achieve by prioritizing research activities?

- RQ4: What academic workforce ratio between teaching and research activities would establish efficiency for Turkish research universities?
- RQ5: Does regional socio-economic development impact the overall efficiency of research universities in Türkiye?

## LITERATURE REVIEW

One of the most frequently published areas in the DEA literature is education (Liu et al., 2013). However, most of these studies used the standard DEA method, thus neglecting the sub-processes of decision units (Abbott and Doucouliagos, 2003; Avkiran, 2001; Doğan, 2018; Flégl et al., 2013; Halásková et al., 2022; Johnes and Johnes, 1995; Nazarko and Šaparauskas, 2014; Özel, 2014; Tomkins and Green, 1988). Due to the drawbacks of this single-stage model, the NDEA is recommended for efficiency measurement (Chen et al., 2010; Cook et al., 2010; Färe and Grosskopf, 1996, 2000; Färe et al., 2007). In NDEA, the overall efficiency of universities is calculated by considering the activities of sub-processes.

It can be observed that in recent years, more studies have been conducted using the two-stage NDEA to measure efficiency in universities. Lu (2012) measured the cost-effective teaching-research efficiency of Taiwanese universities using a two-stage NDEA. In a study comparing the efficiency of 9 faculties at Iran's Al-Zahra University, Saniee Monfared and Safi (2013), examined the overall efficiency of faculties as well as their teaching and research efficiency using a two-stage NDEA. They assumed that faculty members spend one-third of their time on teaching and two-thirds on research. Chodakowska (2015), calculated the teaching and research efficiency of Polish universities using both the standard DEA method and the two-stage NDEA method and compared the results obtained using both methods. Lee and Worthington (2016) measured the efficiency of Australian universities' research processes using a two-stage DEA. Shamohammadi and Oh (2019), assessed the teaching and research efficiency of Korean private universities and their overall efficiency using a two-stage DEA. Yang et al. (2018), measured the efficiency of 64 Chinese research universities using two-stage DEA: teaching-research efficiency and science-technology transformation efficiency.

Tavares et al. (2021), studied the efficiency of 45 Brazilian federal universities in three stages with NDEA. Ding et al. (2021), divided the research processes of Chinese universities into faculty research process and student research process and measured the research efficiency of universities with two-stage DEA. Chen et al. (2021), used the two-stage NDEA to measure and compare the teaching and research efficiency of 52 Chinese universities for two different situations in which these universities prioritized the research and teaching process. Koçak and Örkçü (2021), studied and compared the overall efficiency of Turkish state universities using both the single stage DEA and the two-stage NDEA. To identify the factors that cause inefficiency, they evaluated and compared the efficiency of graduate education and technological-scientific research processes, which they separated for the NDEA, under both the independent model (single-stage DEA) and the dependent model (two-stage NDEA).

With the increasing importance of research university initiatives in Türkiye, there is a need for more scientific research to be conducted in this field. One of the main issues in this regard is the performance and therefore efficiency analysis of research universities. The studies by Çağlar and Gürler (2020) and Mammadov and Aypay (2020) are pioneering works on efficiency analysis of Turkish research universities. However, these studies also use the traditional DEA for efficiency measurement, which has the disadvantages mentioned above. There has been no study in the literature that analyzes the overall efficiency levels of Turkish research universities together with their teaching and research components using two-stage NDEA with shared inputs model. This research is important in terms of contributing to filling this gap in the literature and encouraging more work in this field.

## MATERIALS AND METHOD

### Two-Stage NDEA with Shared Inputs Model

The NDEA methodology is an extension of the traditional DEA approach that evaluates the efficiency of interconnected units or sub-technologies in a network. Essentially, the aim of NDEA is to pinpoint the most efficient units or sub-technologies within the network and provide valuable insights that can be used to enhance the overall efficiency of the network (Färe and Grosskopf, 2000; Kao, 2014; Lewis and Sexton, 2004). Various NDEA models have been developed and continue to be developed over time based on the number of activities and stages in the organization and the differences in the relationship structure of these stages with each other. In this section, we describe the two-stage NDEA with shared inputs model of Chen et al. (2010) and how we have adapted it and applied it to our data.

The generic of the two-stage NDEA process in which inputs are shared between the stages is shown in Figure 1. The $n$ decision units subjected to analysis are represented by $DMU_j\left(j=1,2,\ldots,n\right)$, and the total $m$ inputs used by these decision units in both the first and second stages are represented by $X_{ij}\left(i=1,2,\ldots,m\right)$. Suppose these common inputs are assigned to the first and second stages as $a_i X_{ij}$ and $\left(1-a_i\right)X_{ij}\left(0\le a_i\le 1\right)$, respectively. The decision units receive two types of outputs from the inputs they use in the first stage. One of these types of outputs is not final outputs, but intermediate outputs that are used as inputs to the second stage and are labelled $Z_{dj}\left(d=1,2,\ldots,t\right)$. Other first stage outputs are final outputs and can be represented as $Y^1_{r_1 j}\ \left(r_1\in O_1\right)$. The final outputs at the end of the second stage can be represented as $Y^2_{r_2 j}\ \left(r_2\in O_2\right)$.

The overall efficiency of the two-stage process for any decision unit can be calculated using the linear programming Model 1. Although the overall efficiency of the two-stage network process calculated according to Model 1 is unique, the efficiency values of the individual subprocesses are not since they may be an alternative optimal solution of the model in question. Keeping the overall efficiency of the whole process, the maximum efficiency values of the first stage can be calculated using Model 2 and the maximum efficiency values of the second stage can be calculated using Model 3 (Chen et al., 2009; Chen et al.,


Electronic ISSN 1803-1617 Printed ISSN 2336-2375

2010; Chen et al., 2021; Kao and Hwang, 2008). In all models $\beta_i^1 = \omega_i^1 a_{ik}; \beta_i^2 = \omega_i^2 a_{ik}$ for linearity and it is assumed that $\mu_{r_1}^1 = \mu_{r_2}^2$, $\pi_d^1 = \pi_d^2$, $\omega_i^1 = \omega_i^2$, $\beta_i^1 = \beta_i^2$, like the assumptions of Kao and Hwang (2008) and Liang et al. (2008).

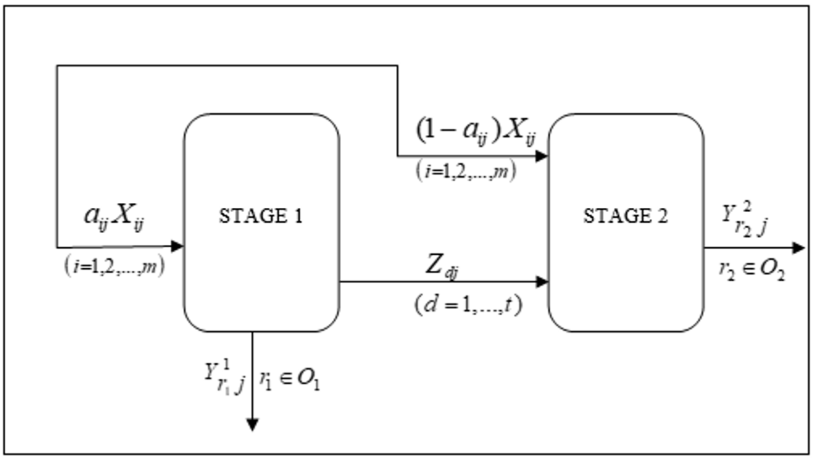


**Figure 1: Two-stage network process with shared inputs (source: own elaboration based on Chen et al., 2010: 341)**

$$\begin{gathered}
\theta_k^* = Max \sum_{r_1 \in O_1} \mu_{r_1}^1 Y_{r_1 k}^1 + \sum_{d=1}^{t} \pi_d^1 Z_{dk} + \sum_{r_2 \in O_2} \mu_{r_2}^2 Y_{r_2 k}^2 + U^1 + U^2 \\
s.t. \sum_{i=1}^{m} \beta_i^1 X_{ik} + \sum_{i=1}^{m} \omega_i^2 X_{ik} - \sum_{i=1}^{m} \beta_i^2 X_{ik} + \sum_{d=1}^{t} \pi_d^2 Z_{dk} = 1 \\
\sum_{r_1 \in O_1} \mu_{r_1}^1 Y_{r_1 j}^1 + \sum_{d=1}^{t} \pi_d^1 Z_{dj} + U^1 - \sum_{i=1}^{m} \beta_i^1 X_{ij} \le 0 \\
\sum_{r_2 \in O_2} \mu_{r_2}^2 Y_{r_2 j}^2 + U^2 - \left[ \sum_{i=1}^{m} \omega_i^2 X_{ij} - \sum_{i=1}^{m} \beta_i^2 X_{ij} + \sum_{d=1}^{t} \pi_d^2 Z_{dj} \right] \le 0 \\
\beta_i^1 \le \omega_i^1; \beta_i^2 \le \omega_i^2 \\
\mu_{r_1}^1, \pi_d^1, \omega_i^1, \beta_i^1, \mu_{r_2}^2, \pi_d^2, \omega_i^2, \beta_i^2 \ge \varepsilon; U^1, U^2 \, free \\
j = 1, \ldots, n; i = 1, \ldots, m; d = 1, \ldots, t; r_1 \in O_1; r_2 \in O_2
\end{gathered} \tag{1}$$

$$\begin{gathered}
\theta_k^{1*} = Max \sum_{r_1 \in O_1} \mu_{r_1}^1 Y_{r_1 k}^1 + \sum_{d=1}^{t} \pi_d^1 Z_{dk} + U^1 \\
s.t. \sum_{i=1}^{m} \beta_i^1 X_{ik} = 1 \\
\sum_{r_1 \in O_1} \mu_{r_1}^1 Y_{r_1 j}^1 + \sum_{d=1}^{t} \pi_d^1 Z_{dj} + U^1 - \sum_{i=1}^{m} \beta_i^1 X_{ij} \le 0 \\
\sum_{r_2 \in O_2} \mu_{r_2}^2 Y_{r_2 j}^2 + U^2 - \left[ \sum_{i=1}^{m} \omega_i^2 X_{ij} - \sum_{i=1}^{m} \beta_i^2 X_{ij} + \sum_{d=1}^{t} \pi_d^2 Z_{dj} \right] \le 0 \\
\sum_{r_1 \in O_1} \mu_{r_1}^1 Y_{r_1 k}^1 + \sum_{d=1}^{t} \pi_d^1 Z_{dk} + \sum_{r_2 \in O_2} \mu_{r_2}^2 Y_{r_2 k}^2 + U^1 + U^2 \\
-\theta_k^* \left[ \sum_{i=1}^{m} \beta_i^1 X_{ik} + \sum_{i=1}^{m} \omega_i^2 X_{ik} - \beta_i^2 X_{ik} + \sum_{d=1}^{t} \pi_d^2 Z_{dk} \right] = 0 \\
w_1^* . \left[ \sum_{r_1 \in O_1} u_{r_1}^1 Y_{r_1 k}^1 + \sum_{d=1}^{t} \eta_d^1 Z_{dk} + U^1 \right] - \theta_k^* \le 0 \\
\beta_i^1 \le \omega_i^1; \beta_i^2 \le \omega_i^2 \\
\mu_{r_1}^1, \pi_d^1, \omega_i^1, \beta_i^1, \mu_{r_2}^2, \pi_d^2, \omega_i^2, \beta_i^2 \ge \varepsilon; U^1, U^2 \, free \\
j = 1, \ldots, n; i = 1, \ldots, m; d = 1, \ldots, t; r_1 \in O_1; r_2 \in O_2
\end{gathered} \tag{2}$$

$$
\begin{aligned}
&\theta_k^{2*} = Max \sum\nolimits_{r_2 \in O_2} \mu_{r_2}^2 Y_{r_2 k}^2 + U^2 \\
&\sum\nolimits_{i=1}^{m} \omega_i^2 X_{ik} - \beta_i^2 X_{ik} + \sum\nolimits_{d=1}^{t} \pi_d^2 Z_{dk} = 1 \\
&\sum\nolimits_{r_1 \in O_1} \mu_{r_1}^1 Y_{r_1 j}^1 + \sum\nolimits_{d=1}^{t} \pi_d^1 Z_{dj} + U^1 - \sum\nolimits_{i=1}^{m} \beta_i^1 X_{ij} \le 0 \\
&\sum\nolimits_{r_2 \in O_2} \mu_{r_2}^2 Y_{r_2 j}^2 + U^2 - \left[ \sum\nolimits_{i=1}^{m} \omega_i^2 X_{ij} - \sum\nolimits_{i=1}^{m} \beta_i^2 X_{ij} + \sum\nolimits_{d=1}^{t} \pi_d^2 Z_{dj} \right] \le 0 \\
&\sum\nolimits_{r_1 \in O_1} \mu_{r_1}^1 Y_{r_1 k}^1 + \sum\nolimits_{d=1}^{t} \pi_d^1 Z_{dk} + \sum\nolimits_{r_2 \in O_2} \mu_{r_2}^2 Y_{r_2 k}^2 + U^1 + U^2 \\
&-\theta_k^* \left[ \sum\nolimits_{i=1}^{m} \beta_i^1 X_{ik} + \sum\nolimits_{i=1}^{m} \omega_i^2 X_{ik} - \beta_i^2 X_{ik} + \sum\nolimits_{d=1}^{t} \pi_d^2 Z_{dk} \right] = 0 \\
&w_2^* . \left[ \sum\nolimits_{r_2 \in O_2} \mu_{r_2}^2 Y_{r_2 k}^2 + U^2 \right] - \theta_k^* \le 0 \\
&\beta_i^1 \le \omega_i^1 ; \beta_i^2 \le \omega_i^2 \\
&\mu_{r_1}^1, \pi_d^1, \omega_i^1, \beta_i^1, \mu_{r_2}^2, \pi_d^2, \omega_i^2, \beta_i^2 \ge \varepsilon ; U^1, U^2 \ free \\
&j = 1, \ldots, n; i = 1, \ldots, m; d = 1, \ldots, t; r_1 \in O_1; r_2 \in O_2
\end{aligned}
\tag{3}
$$

## Data Sources and Empirical Application

The efficiency score is sensitive to the choice of inputs and outputs (Mikušová, 2017). Therefore, the choice of input and output indicators is very important in assessing the efficiency of universities. Previous studies in this field show that different types and numbers of input and output variables are used (Avkiran, 2001). The input and output variables used in this study were selected from the input and output variables used in previous studies in this field (Avkiran, 2001; Chen et al., 2021; Chodakowska, 2015; Saniee Monfared and Safi, 2013), considering data availability, and reflecting the teaching and research processes of Turkish research universities as best as possible and shown in Figure 1. The dataset of the study consists of data from 23 research universities in the academic year 2020-2021. The names of these universities and their abbreviations in our study are given in Table 1 (in the Appendix). Three of these universities (IDBU, KU, SU) are private and the rest are public universities. The data on these universities comes from the Higher Education Information Management System (CHE, 2022) and University Ranking by Academic Performance (URAP) Research Center, which measures their academic performance by the quality and quantity of their scholarly publications (URAP, 2021). The data set used in the study is given in Table 2 (in the Appendix).

Research universities in Türkiye have two basic processes, one for teaching and one for research. To measure the overall, teaching and research efficiency of the research universities in Türkiye, a two-stage NDEA with shared inputs model shown in Figure 2 was used in this study. The first stage of this model defines teaching activities while the second stage defines research activities. The number of professors ($X_1$), associate professors ($X_2$), assistant professors ($X_3$), lecturers ($X_4$), and research assistants ($X_5$) is the same for both teaching and research processes. Academic staffs devote part of their time to teaching (α) and another part to research (1-α). The outputs of the teaching process are the number of undergraduate students ($Y_1$), master's students ($Z_1$), and doctoral students ($Z_2$). Among these variables, the number of master's students (Z1) and doctoral students ($Z_2$) are also the inputs of the research process. The output of the research process is the URAP score[1, 2] ($Y_2$), which is calculated based on the university's research performance indicators. URAP score provides important information about the research output performance of universities. Descriptive statistics of the variables are presented in Table 3.

1 URAP is a ranking system for the world's universities based on their academic performance as measured by six indicators: Articles, citations, total documents, total article impact, total citation impact, and international collaboration. The scores from these indicators are weighted to determine the final rankings of the institutions. The weights are assigned by a group of experts using the Delphi method. The ranking covers 3000 institutions with the highest number of publications, and the data are processed and cleaned to ensure reliability (URAP, 2021).

2 The URAP score does not have any limits or normalization. It is simply the sum of the weighted scores of each indicator. Therefore, it can vary depending on the number and quality of publications and citations of each institution.

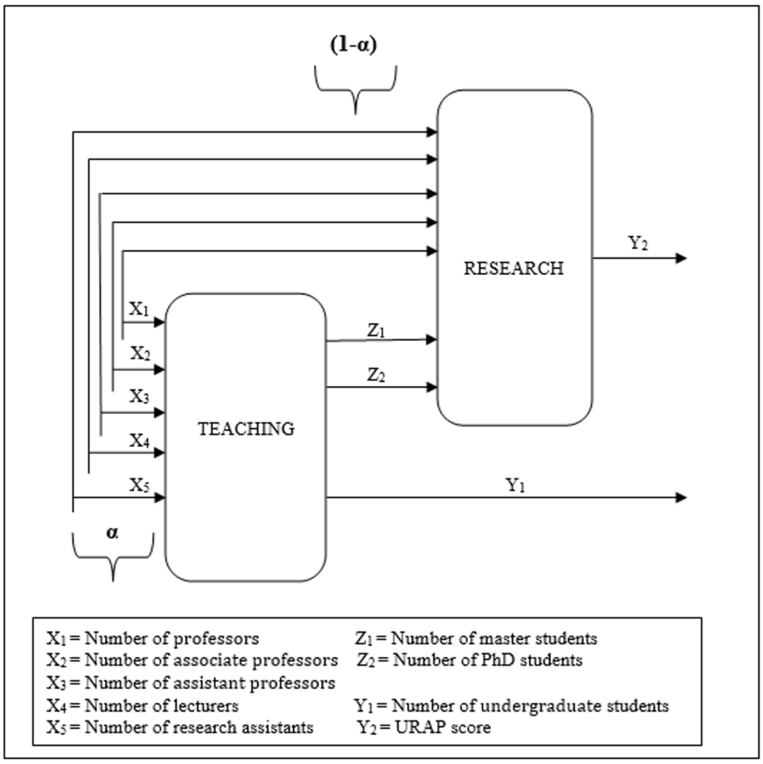


**Figure 2: Two-stage NDEA model for teaching and research activities of universities (source: own elaboration)**

| Variable | Min | Max | Mean | Median | Std. dev. |
|---|---|---|---|---|---|
| $X_1$ | 81 | 1,160 | 515 | 523 | 310.37 |
| $X_2$ | 47 | 427 | 228 | 230 | 119.31 |
| $X_3$ | 61 | 649 | 332 | 334 | 171.42 |
| $X_4$ | 104 | 707 | 386 | 375 | 188.01 |
| $X_5$ | 8 | 1,520 | 730 | 821 | 417.04 |
| $Z_1$ | 777 | 9,703 | 4,480 | 5,207 | 2,716.40 |
| $Z_2$ | 381 | 6,207 | 2,439 | 2,255 | 1,678.47 |
| $Y_1$ | 4,156 | 382,226 | 46,560 | 28,321 | 77,854.61 |
| $Y_2$ | 158.29 | 332.02 | 241.98 | 238.73 | 37.71 |

**Table 3: Descriptive statistics of the variables (source: own elaboration based on values shown in Table 2)**

## Data Analysis

Two-stage NDEA is based on linear programming models, and therefore programs such as MATLAB, GAMS, LINDO, and MICROSOFT EXCEL, which provide solutions for linear programming models, are commonly used in the analysis. Due to the legal obligation for faculty members in Turkish research universities to allocate a certain portion of their time to teaching activities in addition to research activities, lower and upper limits $(0.3 \le \boldsymbol{a}_i \le 0.7)$ have been determined for the proportional time allocated for teaching activities. Therefore, constraints similar to those of Cook and Hababou (2001), Saniee Monfared and Safi (2013) and Cinar (2016) were added to the linear programming models shown in Models 1, 2, and 3 by adding $0.3\boldsymbol{\beta}_i^1 \le \boldsymbol{\omega}_i^1 \le 0.7\boldsymbol{\beta}_i^1; 0.3\boldsymbol{\beta}_i^2 \le \boldsymbol{\omega}_i^2 \le 0.7\boldsymbol{\beta}_i^2$, and the MICROSOFT EXCEL SOLVER add-in was used to solve these models. A total of 69 linear programming models were created and solved since the efficiency of 23 decision units was compared, and three different models were created for each decision unit.

The 23 universities were grouped into three terciles by their region's socio-economic development index (SEDI) using the Socio-Economic Development Ranking of Provinces and Regions Report (SEGE, 2019) in this study. The SEDI measures the socio-economic region's (SER)[3] socio-economic development level (L), with higher values indicating more development. The groups are:

- L1: (8 universities, $\mathbf{SEDI} > 3$)
- L2: (8 universities, $1.5 \le \mathbf{SEDI} \le 3$)
- L3: (7 universities, $\mathbf{SEDI} < 1.5$)

The distribution of research universities according to the level of socio-economic development of the regions in which they are located is shown in Figure 3 (in the Appendix). Using IBM SPSS Statistics software version 21 and the Kruskal-Wallis test, we compared the efficiency scores of the three development level groups.

3 We refer to NUTS II regions because they are an appropriate territorial scale for national and regional analysis and are designated as the basic development planning units in the context of regional policies (Development Agencies, 2023).

## RESULTS

Table 4 (in the Appendix) shows the overall efficiency scores of research universities ($\theta_k^*$) when *the teaching stage is maximized* under the assumption of VRS (Banker et al., 1984), and the teaching efficiency scores ($\theta_k^{1*}$) and research efficiency scores ($\theta_k^2$) that are its components. Table 5 (in the Appendix), on the other hand, shows the overall efficiency scores of research universities ($\theta_k^*$) when *the research stage is maximized* under the assumption of VRS, and the teaching efficiency scores ($\theta_k^1$) and research efficiency scores ($\theta_k^{2*}$) that are its components.

The first column of the Table 4 and Table 5 (in the Appendix) shows the abbreviated names of research universities analyzed, the second column shows the codes of socio-economic regions (SER) where universities are located, the third column shows the level of development of the group to which the region belongs (L), the fourth column shows the overall score of the efficiency of the two-stage process ($\theta_k^*$). The fifth and sixth columns of the tables show teaching and research efficiency, respectively, with different priorities ($\theta_k^{1*}$ and $\theta_k^2$ for teaching, $\theta_k^1$ and $\theta_k^{2*}$ for research). On the other hand, the optimal weighting of teaching stage ($w_1^*$) is shown in the seventh column and the optimal weighting of research stage ($w_2^*$) is shown in the eighth column. The optimal distribution ratios of the five shared inputs used in both stages between stages ($\alpha_1^*, \alpha_2^*, \alpha_3^*, \alpha_4^*, \alpha_5^*$) are given between the ninth and thirteenth columns.

We find that the overall efficiency scores of the universities vary from 0.344 to 1.000, and the overall efficiency average is 0.739. While the first 6 universities in the Table 4 and Table 5, IDBU, SU, IIT, KU, GTU, and IU are efficient in both teaching and research processes, the remaining 17 universities are not efficient in at least one of these processes. It can be said that efficient universities efficiently allocate their resources to teaching and research activities and maximize their outputs.

It may be that universities focus more on some activities than others, in other words, they assign different priorities to teaching and research activities. Although the overall efficiency values of universities calculated according to Model 1 are unique with respect to the two-stage network process, there are alternative solutions for the teaching and research efficiency values. When the teaching phase is given priority, Model 2 is used to maximize this phase. As seen in Table 4, when the teaching stage is prioritized, 6 of 17 inefficient universities METU, IUC, ITU, AU, GU and YTU are efficient at the teaching stage, but inefficient at the research stage. As is well known, research universities focus more on research activities and give priority to these activities. When priority is given to the research phase, Model 3 is used to maximize this phase. As seen in Table 5, when the research stage is prioritized, 4 of 17 inefficient universities METU, IUC, ITU and HU are efficient in the research stage, but inefficient in the teaching stage.

Another dimension of the study is to test whether there is a statistically significant difference between the efficiency of research universities according to the level of socio-economic development of the regions in which they are located. The average efficiency scores of the research universities, based on the level of socio-economic development of their regions, are shown in Figure 4 (in the Appendix). Since the data did not fulfil the condition of normal distribution, the Kruskal-Wallis test, a non-parametric test, was used to compare the efficiency of three independent groups. There was no significant difference found in the efficiency scores between regions with high socio-economic development levels and those with relatively low socio-economic development levels regarding overall ($\chi^2 = 3.48, p > 0.05$), teaching ($\chi^2 = 5.33, p > 0.05$), and research ($\chi^2 = 4.06, p > 0.05$).

## DISCUSSION

This study evaluated the efficiency of 23 research universities in Türkiye. It used a two-stage NDEA with shared inputs model. The main objective of this study is to compare the efficiency of research universities in Türkiye and to identify inefficient processes and take measures. The findings showed that only six universities, three public and three privates, are overall efficient. This suggests that 100 of private universities and 15 of public universities in the research university program are overall efficient. This efficiency rate is quite low and requires the relevant administrators to take measures in this regard.

Interestingly, some of the big and famous universities in Türkiye were inefficient; these include HU, BU, METU, ITU and AU. On the other hand, some of the relatively smaller and less famous universities, such as IIT and GTU, were overall efficient. This finding supports Altbach's (2015) view that the rankings made by ranking organizations may be problematic because they mainly focus on the effectiveness dimension of organizational performance, which is the outputs or outcomes of the institutions, rather than the efficiency dimension, which is the inputs and processes of the institutions (Lindsay, 1982). For example, according to the URAP World University Rankings (URAP, 2021), at the time of this study, HU ranked 500th in the world and 1st in Türkiye, while IIT ranked 1926th in the world and 44th in Türkiye. However, our analysis shows that HU is not efficient, IIT is efficient. This implies that HU uses more input resources than IIT to achieve the same level of output. Ranking organizations may overlook the efficiency of small universities, which use their limited input resources efficiently, because they only use output-oriented indicators and do not consider the inputs of the universities. Erdoğmuş and Esen (2016) observed that small universities could perform better than medium and big universities in rankings where both output and input indicators were taken into account. Similarly, Chen et al. (2021), using the two-stage NDEA method to evaluate the efficiency of Chinese universities, found that the world-renowned Peking and Tsinghua Universities are not efficient, while some lower ranked universities in China are efficient.

The efficiency analysis results offer valuable insight to higher education administrators, facilitating comparative evaluations of their institutions' development potential, strengths, and weaknesses. This information also assists in identifying areas within higher education institutions requiring attention (Jauhar et al., 2018; Nazarko and Šaparauskas, 2014). Therefore, thepotential managerial and practical implications of the findings are anticipated to be considerable. The two-stage NDEA with shared inputs model used to measure efficiency in this study provides a unique solution for the overall efficiency score, while offering alternative solutions for the efficiency scores of the sub-processes of inefficient decision units. This allows decision units that focus more on one process than another to clearly see the efficiency levels of their sub-processes and the processes that cause inefficiency. In our study, we found that 6 out of 17 inefficient universities were efficient in the teaching stage in the first scenario where teaching activities were prioritized, and that these universities could not be overall efficient due to inefficiency in research stage. Therefore, managers need to develop strategies to increase their outputs in the research stage (number of publications, citations, patents, projects, etc.) for these universities to be overall efficient.

In the second scenario where research activities were prioritized, it was found that 4 out of 17 inefficient universities were efficient in the research stage and that these universities could not be overall efficient due to inefficiency in the teaching stage. The managers of these universities must develop strategies to increase their output in the teaching stage (number of undergraduate, master, and doctoral students) for these universities to be overall efficient. On the other hand, CHE can evaluate and take necessary measures for 13 research universities that are inefficient in the research stage despite prioritizing research activities.

One objective of this study was to measure the efficiency of Turkish research universities in various socio-economic regions with a two-stage NDEA method. The results indicate that there is no significant difference in efficiency scores between regions of varying development, suggesting that the efficiency of research universities in Türkiye is independent of the socio-economic status or features of their respective regions. This indicates that the efficiency of research universities hinges on their internal management and governance rather than their regional circumstance. The result corroborates earlier research that identified no substantial dissimilarities in university efficacy based on geographical location (Agasisti et al., 2011; Chen et al., 2021). However, unlike previous studies, we classified regions using an index of socio-economic development calculated by the relevant government agency. The index includes various indicators including income, education, health, and innovation. By doing so, we can closely examine how regional development impacts the efficiency of research universities.

The finding that the efficiency scores of research universities did not vary significantly across regions implies that, regardless of the socio-economic conditions, these universities managed their resources and operations in a manner that led to comparable levels of efficiency. This consistency suggests a certain resilience or adaptability within these institutions, allowing them to maintain efficiency regardless of the external context. By emphasizing the role of internal management and governance in university efficiency, this study agrees with other research in the field of higher education that internal factors, such as management, governance, staff quality, and research culture, are more important than external factors for university efficiency (Egorov and Serebrennikov, 2023; Kempkes and Pohl, 2010; Kupriyanova et al., 2018; Zinchenko and Egorov, 2019).

This study not only confirms previous findings that university efficiency is independent of geographical location (Agasisti et al., 2011; Chen et al., 2021), but also adds to the existing body of knowledge by providing a more comprehensive classification of regions based on an index of various socio-economic indicators. By emphasizing the importance of internal factors such as the quality of academic staff, the research culture, the management and governance, and the incentive mechanisms rather than regional conditions, this approach provides valuable insights for policymakers and university administrators seeking to improve the efficiency of research universities.

Our findings carry implications for higher education policies and practices in Türkiye. This study may suggest that research universities located in less developed regions do not face efficiency-related disadvantages when compared to their peers located in more developed regions. Therefore, these universities have the potential to enhance their teaching and research activities, improve their performance, and contribute to the development of their respective regions. However, there is potential for enhancement in the efficiency of research universities across all regions, as only a small number of them attained complete efficiency scores. Research universities must optimize their resource allocation and utilization to attain superior outcomes. Conversely, our findings indicate that regional development policies should focus on enhancing the effectiveness and impact of research universities in addressing regional needs and challenges, instead of improving their efficiency. Policy makers should encourage research universities to collaborate with local stakeholders, including businesses, NGOs, and public institutions, to address regional issues and opportunities. Additionally, university managers can adopt best practices from other institutions in different regions to enhance quality and innovation.

### Study Limitations

This study possesses certain limitations that warrant acknowledgement. The availability of data from CHE and private research universities was limited, thus influencing the selection of input and output variables. Financial variables were not included in the analysis due to lack of access to financial data.

Another limitation of this study was the unavailability of detailed data on sub-components of the socio-economic development index of the regions where the universities are located. These sub-components include education, health, and innovation. This limitation hindered the identification of targeted improvement areas by preventing a nuanced analysis of how particular socio-economic factors may impact university performance.

If the data for these sub-components were available, the study could potentially bring into focus certain socio-economic factors that may have a significant association with university performance. The information could play a crucial role for university administrators in forming strategic decisions concerning resource allocation, program development, and policy implementation.

## CONCLUSIONS

The purpose of this research was to evaluate the efficiency of 23 Turkish research universities utilizing a shared inputs model in a two-stage NDEA and to explore the influence of regional socio-economic status on research university efficiency. The research indicated that only 25 of the research universities demonstrated efficiency on all dimensions and that their overall efficiency scores were affected by the prioritization of teaching or research activities. The efficiency level of research universities remained unaffected by the socio-economic status of regions, according to the study. Additionally, the validity of rankings based on output or outcome measures was questioned. The study recommended incorporating efficiency indicators for a more objective and equitable comparison between universities. The study asserted that utilizing the two-stage NDEA with shared inputs model provided a more complete and practical approach to gauge efficiency in higher education systems characterized by complex network structures.

Based on these findings, the study had several implications for higher education managers, policy makers and ranking organizations. First, higher education managers were recommended to identify the sub-processes that caused inefficiency and develop strategies to improve them. For example, some universities might have needed to balance their outputs in teaching and research processes, while others might have needed to allocate their resources more efficiently. Second, policy makers were suggested to reconsider their policies and incentives for research universities that were inefficient in research despite prioritizing research activities. Furthermore, regional development policies were encouraged to focus not only on increasing the efficiency of universities, but also their effectiveness and impact in addressing regional needs and challenges. Third, ranking organizations were urged to include efficiency indicators in their ranking criteria that reflected how well universities used their input resources to produce outputs in their teaching and research processes.

This study has used a two-stage DEA approach to examine the relationship between university performance and socio-economic development. However, this study could be improved by future research in two ways. First, future research could use more input and output components and include more processes besides teaching and research to evaluate university efficiency more comprehensively and realistically. Second, future research should use data on the sub-components of the socio-economic development index, such as income, health, and education. This would help understand the performance of universities in different socio-economic contexts better. It would also help develop improvement strategies and policy decisions and provide a benchmark for universities. Therefore, future research in this area should use more data and variables to understand the relationship between university performance and socio-economic development better.

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## APPENDIX

| Abbreviation | Name of Research University | Abbreviation | Name of Research University |
|---|---|---|---|
| ATAU | Atatürk University | IIT | İzmir Institute of Technology |
| AU | Ankara University | ITU | İstanbul Technical University |
| BU | Boğaziçi University | IU | İstanbul University |
| CU | Çukurova University | IUC | İstanbul University-Cerrahpaşa |
| DEU | Dokuz Eylül University | KTU | Karadeniz Technical University |
| EGEU | Ege University | KU | Koç University |
| ERCU | Erciyes University | METU | Middle East Technical University |
| FU | Fırat University | MU | Marmara University |
| GTU | Gebze Technical University | SU | Sabancı University |
| GU | Gazi University | UU | Uludağ University |
| HU | Hacettepe University | YTU | Yıldız Technical University |
| IDBU | İhsan Doğramacı Bilkent University | | |

**Table 1: Definition of abbreviations of Turkish Research Universities (source: own elaboration)**

| DMUs | $X_1$ | $X_2$ | $X_3$ | $X_4$ | $X_5$ | $Z_1$ | $Z_2$ | $Y_1$ | $Y_2$ |
|---|---|---|---|---|---|---|---|---|---|
| ATAU | 602 | 299 | 649 | 319 | 893 | 5,650 | 2,325 | 134,744 | 240.32 |
| AU | 1,160 | 318 | 284 | 707 | 1,239 | 6,770 | 6,207 | 46,540 | 271.72 |
| BU | 200 | 117 | 163 | 225 | 312 | 2,168 | 1,045 | 12,766 | 235.75 |
| CU | 537 | 182 | 327 | 443 | 763 | 3,237 | 1,615 | 32,494 | 212.53 |
| DEU | 741 | 356 | 513 | 707 | 986 | 5,207 | 2,317 | 46,348 | 249.64 |
| EGEU | 886 | 386 | 379 | 567 | 997 | 5,210 | 3,003 | 35,820 | 257.29 |
| ERCU | 469 | 218 | 427 | 318 | 851 | 6,174 | 2,218 | 41,543 | 235.06 |
| FU | 410 | 174 | 386 | 260 | 732 | 3,196 | 981 | 29,048 | 224.24 |
| GTU | 113 | 67 | 111 | 104 | 274 | 2,097 | 746 | 5,418 | 192.16 |
| GU | 912 | 352 | 221 | 564 | 1,172 | 6,141 | 3,606 | 28,321 | 255.66 |
| HU | 926 | 356 | 567 | 642 | 1,520 | 5,960 | 4,292 | 37,004 | 332.02 |
| IDBU | 106 | 64 | 192 | 381 | 8 | 813 | 438 | 10,655 | 250.63 |
| IIT | 85 | 62 | 61 | 129 | 259 | 967 | 449 | 4,795 | 158.29 |
| ITU | 523 | 247 | 334 | 463 | 720 | 8,082 | 3,881 | 25,645 | 286.40 |
| IU | 906 | 427 | 594 | 473 | 1,168 | 9,703 | 5,908 | 382,226 | 303.76 |
| IUC | 580 | 230 | 352 | 155 | 801 | 2,218 | 2,255 | 20,177 | 222.36 |
| KTU | 424 | 159 | 386 | 279 | 944 | 2,010 | 1,275 | 24,989 | 225.53 |
| KU | 210 | 77 | 128 | 192 | 19 | 851 | 753 | 7,305 | 243.87 |
| METU | 390 | 175 | 264 | 558 | 821 | 5,255 | 3,281 | 22,203 | 282.72 |
| MU | 710 | 365 | 604 | 375 | 1,021 | 9,290 | 4,340 | 50,520 | 238.73 |
| SU | 81 | 47 | 84 | 125 | 16 | 777 | 381 | 4,156 | 197.28 |
| UU | 582 | 309 | 262 | 547 | 838 | 4,614 | 2,164 | 41,358 | 213.03 |
| YTU | 294 | 254 | 345 | 340 | 447 | 6,654 | 2,626 | 26,804 | 236.46 |

*Note: X1: No. of profs, X2: No. of assoc. profs, X3: No. of asst. profs, X4: No. of lecturers, X5: No. of research assts, Z1: No. of master students, Z2: No. of PhD students, Y1: No. of undergraduate students, Y2: URAP score*

**Table 2: The data set used in this study (source: own elaboration based on CHE, 2022 and URAP, 2021)**

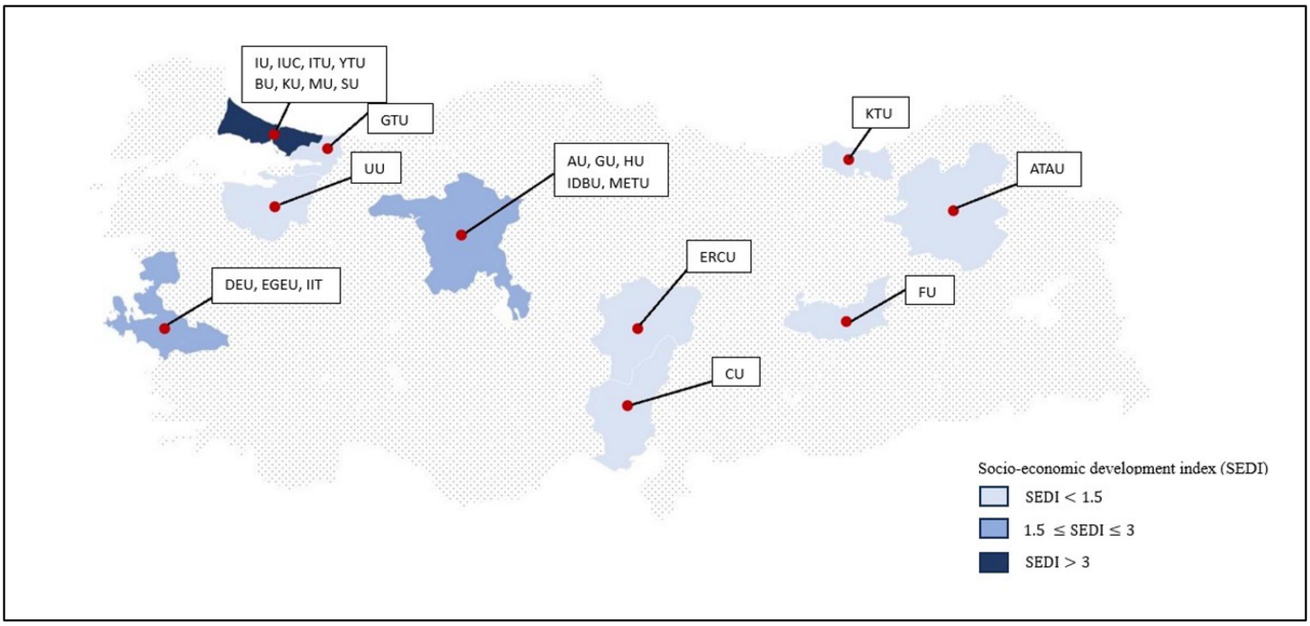


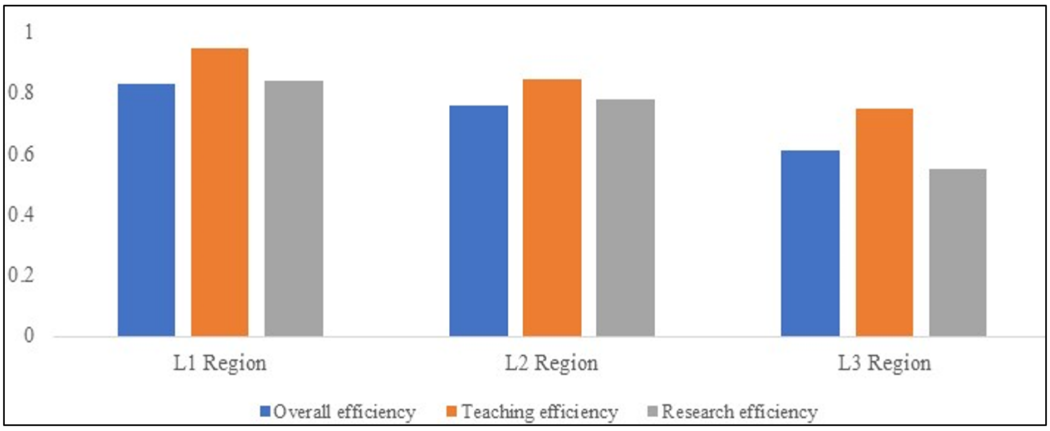

**Figure 3: Distribution of research universities according to the level of socio-economic development of the regions in which they are located (source: own elaboration based on SEDI data of NUTS II regions in SEGE, 2019 using map chart in Microsoft Excel)**

| DMUs | SER | L | $\theta_k^*$ | $\theta_k^{1*}$ | $\theta_k^2$ | $w_1^*$ | $w_2^*$ | $\alpha_1^*$ | $\alpha_2^*$ | $\alpha_3^*$ | $\alpha_4^*$ | $\alpha_5^*$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| IDBU | TR51 | 2 | 1.000 | 1.000 | 1.000 | 0.300 | 0.700 | 0.700 | 0.700 | 0.700 | 0.300 | 0.700 |
| SU | TR10 | 1 | 1.000 | 1.000 | 1.000 | 0.573 | 0.427 | 0.700 | 0.700 | 0.700 | 0.300 | 0.700 |
| IIT | TR31 | 2 | 1.000 | 1.000 | 1.000 | 0.699 | 0.301 | 0.700 | 0.700 | 0.517 | 0.700 | 0.700 |
| KU | TR10 | 1 | 1.000 | 1.000 | 1.000 | 0.253 | 0.747 | 0.700 | 0.700 | 0.700 | 0.498 | 0.700 |
| GTU | TR42 | 3 | 1.000 | 1.000 | 1.000 | 0.299 | 0.701 | 0.700 | 0.700 | 0.700 | 0.700 | 0.700 |
| IU | TR10 | 1 | 1.000 | 1.000 | 1.000 | 0.689 | 0.311 | 0.700 | 0.700 | 0.700 | 0.700 | 0.700 |
| METU | TR51 | 2 | 0.957 | 1.000 | 0.932 | 0.365 | 0.635 | 0.300 | 0.300 | 0.300 | 0.700 | 0.700 |
| IUC | TR10 | 1 | 0.928 | 1.000 | 0.904 | 0.300 | 0.700 | 0.700 | 0.700 | 0.700 | 0.300 | 0.700 |
| ITU | TR10 | 1 | 0.815 | 1.000 | 0.740 | 0.288 | 0.712 | 0.700 | 0.700 | 0.300 | 0.700 | 0.300 |
| AU | TR51 | 2 | 0.792 | 1.000 | 0.669 | 0.371 | 0.629 | 0.700 | 0.700 | 0.481 | 0.700 | 0.700 |
| BU | TR10 | 1 | 0.788 | 0.686 | 0.827 | 0.275 | 0.725 | 0.300 | 0.700 | 0.300 | 0.300 | 0.700 |
| GU | TR51 | 2 | 0.748 | 1.000 | 0.645 | 0.290 | 0.710 | 0.700 | 0.700 | 0.390 | 0.700 | 0.700 |
| HU | TR51 | 2 | 0.722 | 0.641 | 0.769 | 0.369 | 0.631 | 0.700 | 0.700 | 0.700 | 0.700 | 0.700 |
| ATAU | TRA1 | 3 | 0.677 | 0.724 | 0.570 | 0.694 | 0.306 | 0.700 | 0.700 | 0.700 | 0.700 | 0.700 |
| YTU | TR10 | 1 | 0.632 | 1.000 | 0.393 | 0.394 | 0.606 | 0.700 | 0.700 | 0.700 | 0.300 | 0.700 |
| FU | TRB1 | 3 | 0.574 | 0.559 | 0.580 | 0.298 | 0.702 | 0.700 | 0.700 | 0.700 | 0.300 | 0.700 |
| KTU | TR90 | 3 | 0.545 | 0.598 | 0.515 | 0.358 | 0.642 | 0.700 | 0.700 | 0.700 | 0.300 | 0.700 |
| ERCU | TR72 | 3 | 0.521 | 0.956 | 0.197 | 0.427 | 0.573 | 0.700 | 0.700 | 0.300 | 0.700 | 0.300 |
| UU | TR41 | 3 | 0.508 | 0.781 | 0.245 | 0.490 | 0.510 | 0.700 | 0.700 | 0.700 | 0.700 | 0.700 |
| MU | TR10 | 1 | 0.495 | 0.890 | 0.000 | 0.556 | 0.444 | 0.700 | 0.700 | 0.700 | 0.700 | 0.300 |
| EGEU | TR31 | 2 | 0.494 | 0.624 | 0.341 | 0.541 | 0.459 | 0.700 | 0.700 | 0.700 | 0.466 | 0.700 |
| CU | TR62 | 3 | 0.459 | 0.619 | 0.266 | 0.549 | 0.451 | 0.700 | 0.700 | 0.700 | 0.700 | 0.443 |
| DEU | TR31 | 2 | 0.344 | 0.496 | 0.117 | 0.599 | 0.401 | 0.700 | 0.700 | 0.300 | 0.300 | 0.700 |

**Table 4: The efficiency of research universities giving priority to the teaching stage (source: own elaboration)**

| DMUs | SER | L | $\theta_k^*$ | $\theta_k^1$ | $\theta_k^{2*}$ | $w_1^*$ | $w_2^*$ | $\alpha_1^*$ | $\alpha_2^*$ | $\alpha_3^*$ | $\alpha_4^*$ | $\alpha_5^*$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| IDBU | TR51 | 2 | 1.000 | 1.000 | 1.000 | 0.300 | 0.700 | 0.300 | 0.300 | 0.300 | 0.300 | 0.700 |
| SU | TR10 | 1 | 1.000 | 1.000 | 1.000 | 0.573 | 0.427 | 0.700 | 0.700 | 0.700 | 0.300 | 0.700 |
| IIT | TR31 | 2 | 1.000 | 1.000 | 1.000 | 0.699 | 0.301 | 0.300 | 0.300 | 0.300 | 0.300 | 0.473 |
| KU | TR10 | 1 | 1.000 | 1.000 | 1.000 | 0.253 | 0.747 | 0.700 | 0.700 | 0.300 | 0.300 | 0.700 |
| GTU | TR42 | 3 | 1.000 | 1.000 | 1.000 | 0.299 | 0.701 | 0.700 | 0.700 | 0.608 | 0.300 | 0.700 |
| IU | TR10 | 1 | 1.000 | 1.000 | 1.000 | 0.689 | 0.311 | 0.700 | 0.700 | 0.300 | 0.300 | 0.300 |
| METU | TR51 | 2 | 0.957 | 0.882 | 1.000 | 0.365 | 0.635 | 0.700 | 0.700 | 0.300 | 0.300 | 0.327 |
| IUC | TR10 | 1 | 0.928 | 0.762 | 1.000 | 0.300 | 0.700 | 0.700 | 0.700 | 0.700 | 0.300 | 0.700 |
| ITU | TR10 | 1 | 0.815 | 0.376 | 1.000 | 0.288 | 0.712 | 0.300 | 0.700 | 0.300 | 0.300 | 0.300 |
| AU | TR51 | 2 | 0.792 | 0.916 | 0.719 | 0.371 | 0.629 | 0.700 | 0.700 | 0.339 | 0.700 | 0.700 |
| BU | TR10 | 1 | 0.788 | 0.603 | 0.858 | 0.275 | 0.725 | 0.300 | 0.700 | 0.700 | 0.300 | 0.700 |
| GU | TR51 | 2 | 0.748 | 0.924 | 0.676 | 0.290 | 0.710 | 0.700 | 0.700 | 0.300 | 0.700 | 0.700 |
| HU | TR51 | 2 | 0.722 | 0.245 | 1.000 | 0.369 | 0.631 | 0.700 | 0.700 | 0.700 | 0.308 | 0.700 |
| ATAU | TRA1 | 3 | 0.677 | 0.720 | 0.580 | 0.694 | 0.306 | 0.700 | 0.700 | 0.700 | 0.682 | 0.700 |
| YTU | TR10 | 1 | 0.632 | 0.922 | 0.444 | 0.394 | 0.606 | 0.612 | 0.700 | 0.700 | 0.300 | 0.700 |
| FU | TRB1 | 3 | 0.574 | 0.474 | 0.617 | 0.298 | 0.702 | 0.700 | 0.700 | 0.700 | 0.323 | 0.700 |
| KTU | TR90 | 3 | 0.545 | 0.491 | 0.575 | 0.358 | 0.642 | 0.700 | 0.700 | 0.700 | 0.300 | 0.700 |
| ERCU | TR72 | 3 | 0.521 | 0.477 | 0.553 | 0.427 | 0.573 | 0.700 | 0.700 | 0.700 | 0.310 | 0.700 |
| UU | TR41 | 3 | 0.508 | 0.776 | 0.250 | 0.490 | 0.510 | 0.700 | 0.700 | 0.700 | 0.700 | 0.700 |
| MU | TR10 | 1 | 0.495 | 0.545 | 0.431 | 0.556 | 0.444 | 0.700 | 0.700 | 0.700 | 0.420 | 0.700 |
| EGEU | TR31 | 2 | 0.494 | 0.496 | 0.490 | 0.541 | 0.459 | 0.700 | 0.700 | 0.401 | 0.438 | 0.700 |
| CU | TR62 | 3 | 0.459 | 0.616 | 0.269 | 0.549 | 0.451 | 0.700 | 0.700 | 0.700 | 0.300 | 0.700 |
| DEU | TR31 | 2 | 0.344 | 0.340 | 0.350 | 0.599 | 0.401 | 0.700 | 0.700 | 0.700 | 0.700 | 0.700 |

**Table 5: The efficiency of research universities giving priority to the research stage (source: own elaboration)**




*Note: Average teaching efficiency score: mean of the teaching efficiency scores ( $\theta_k^{1*}$ ) in Table 4.*

*Average research efficiency score: mean of the research efficiency scores ( $\theta_k^{2*}$ ) in Table 5.*

**Figure 4: Average efficiency scores of research universities based on the socioeconomic development level in their respective regions (source: own elaboration)**