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A Study on the Efficiency and Performance of Research and Candidate Research Universities in Türkiye

Türkiye'deki Araştırma ve Aday Araştırma Üniversitelerinin Etkinliği ve Performansı Üzerine Bir Çalışma

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Abstract

Analyzing the efficiency of research and candidate research universities in Türkiye plays a crucial role in shaping higher education policies and strategically allocating resources to universities. How efficiently universities utilize their resources impacts their competitive power at both national and international levels. To assess the efficiency of resource usage, this study aims to measure the efficiency of research and candidate research universities in Türkiye via data envelopment analysis (DEA) along with the super-efficiency DEA model and the Malmquist total factor productivity (TFP) index between 2017-2022. Subsequently, efficiency scores obtained from the super-efficiency DEA model were analyzed alongside performance scores announced by TÜBİTAK, the Scientific and Technological Research Council of Türkiye, on an efficiency/performance diagram. The results show that the most efficient period was 2020-2021, attributed to an increase in the numbers of PhD graduates and publications. Moreover, the productivity of research and candidate research universities increased during 2017-2022 period mostly due to technological improvements and advancements in research and education. Notably, Sakarya University emerged as a strong candidate for becoming a research university in the upcoming years. This study has some important implications for both universities and the government. Utilizing the findings, universities can identify the areas for improvement in resource utilization, while the government can strategically allocate university budgets to foster the development of research-oriented university landscape in Türkiye.

Keywords: Data Envelopment Analysis, Efficiency, Malmquist Total Factor Productivity Index, Research University, Super-efficiency DEA Model

Özet

Türkiye'deki araştırma ve aday araştırma üniversitelerinin etkinliklerinin analiz edilmesi, yükseköğretim politikalarının şekillenmesinde ve üniversitelere kaynakların stratejik olarak tahsis edilmesinde önemli bir rol oynamaktadır. Üniversitelerin kaynaklarını ne kadar etkin kullandıkları, onların ulusal ve uluslararası düzeydeki rekabet güçlerini etkilemektedir. Bu kaynakların ne kadar etkin kullanıldığını değerlendirmek amacıyla bu çalışma, veri zarflama analizi (VZA) ile birlikte süper-etkinlik VZA modeli ve Malmquist toplam faktör verimliliği (MTFV) endeksini kullanarak Türkiye'deki araştırma ve aday araştırma üniversitelerinin 2017-2022 yılları arasındaki etkinliğini ölçmeyi hedeflemektedir. Sonrasında, süper-etkinlik VZA modelinden elde edilen etkinlik puanları, Türkiye Bilimsel ve Teknolojik Araştırma Kurumu (TÜBİTAK) tarafından açıklanan performans puanlarıyla birlikte etkinlik/performans diyagramı üzerinde analiz edilmektedir. Sonuçlar, doktora mezun ve yayın sayısındaki artışa bağlı olarak en verimli dönemin 2020-2021 olduğunu göstermektedir. Buna ek olarak, 2017-2022 yılları arasında araştırma ve aday araştırma üniversitelerinin verimliliğinin, büyük ölçüde teknolojik gelişmeler ve araştırma ve eğitimdeki ilerlemeler nedeniyle arttığı görülmektedir. Özellikle Sakarya Üniversitesi önümüzdeki yıllarda araştırma üniversitesi olma yolunda güçlü bir aday olarak ortaya çıkmaktadır. Bu çalışmanın hem üniversiteler hem de politika yapıcılar açısından bazı önemli sonuçları bulunmaktadır. Çalışmanın ortaya koyduğu bulguları kullanarak üniversiteler, kaynak kullanımında iyileştirmeye açık olan alanları belirleyebilir, politika yapıcılar ise Türkiye'deki araştırma odaklı üniversite ortamının gelişimini teşvik etmek için üniversite bütçelerini stratejik olarak tahsis edebilirler.

Anahtar Kelimeler: Araştırma Üniversitesi, Etkinlik, Malmquist Toplam Faktör Verimliliği Endeksi, Süper-etkinlik VZA Modeli, Veri Zarflama Analizi

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Research universities are institutions which play critical roles in producing new knowledge, with research as their primary mission. In Türkiye, the "Research-Focused Specialization Program" was developed in 2017 under the framework of the "Mission Differentiation and Specialization Project in Higher Education." Based on this program, research and candidate research universities were introduced by the Council of Higher Education (CHE) (CHE, n.d.). As of 2017, there were 11 research universities and five candidate research universities. Since then, the performance of each university has been measured annually and various supports have been provided to those universities. These supports mainly include faculty staff support, additional quota, and supplementary research budget from TÜBİTAK, the Scientific and Technological Research Council of Türkiye.

With the new regulations implemented by the CHE, private universities have also attained research university labels. Furthermore, the status of candidate research university has been removed. As of 2024, there are a total of 23 research universities in Türkiye, comprising 20 state universities and three private universities (CHE, 2022). Although there are no longer candidate research universities in Türkiye, "Research University Candidate Monitoring Program" was initiated in 2023 (CHE, 2023). According to this program, the universities that meet the criteria within two years will be recognized as research universities. Table 1 displays the research universities and those participating in the "Research University Candidate Monitoring Program," referred to as "candidate research universities" for this study.

Literature comprises many studies that measure the efficiency of universities. One widely used method is Data Envelopment Analysis (DEA) which is a non-parametric method developed by Charnes et al. (1978). This method, named CCR, measures the efficiency of decision-making units (DMUs) relative to others assuming constant returns to scale. Afterwards, the BCC method was developed by Banker et al. (1984) and it assumes variable returns to scale. Table 2 summarizes the input-output structures and methodologies of some of the previous studies in literature.

Agasisti and Dal Bianco (2006) measured the efficiency of 58 Italian state universities with input-oriented DEA and they found that a group of higher education institutions were consistently efficient under different input and output specifications. In another study, the research efficiency among Chinese universities was calculated via DEA (Jiang et al., 2020). It was found that the research efficiency of universities varied according to region and the type of university. Xie et al. (2023) analyzed whether more investment enhances the performance of universities by utilizing DEA. The findings revealed that universities receiving more investment from the government did not show superior performance compared with universities receiving lower investment.

Besides international studies, there are many studies which utilize DEA to measure the efficiency of Turkish universities. Turkan and Ozel (2017) measured the efficiency of 43 Turkish state universities by using DEA and ranked those universities according to the super-efficiency DEA model. They found that 22% of state universities in Türkiye were efficient due to the increase in the number of graduate students and h-index values. Mammadov and Aypay (2020) measured the efficiency of Turkish research universities with input- and output-oriented CCR and BCC models. The findings revealed that Ankara, Boğaziçi, Gazi, IHIT, and METU were efficient with the input-oriented CCR model while Erciyes, ITU, and YTU were efficient with the input-oriented BCC model. They also showed that the citation rate per article and PhD graduates per program positively contributed to the efficiency of research universities while the number of scientific research projects negatively influenced the efficiency scores.

Karagoz et al. (2020) applied the output-oriented BCC model to measure the efficiency of the top 50 Turkish universities listed in the "Entrepreneur and Innovative University Index," calculated by TÜBİTAK. The results showed that 35 out of 50 universities were inefficient in utilizing their resources. Kocak and Orkcu (2021) measured the graduate education performances and the competence in scientific and technological research of Turkish state universities with two-stage DEA in terms of graduate education performances and the scientific and technological research competency. The results showed that GTU, Hacettepe, ITU, IHIT, and METU were efficient in terms of both performance scores. Maral (2023) examined the efficiency of Turkish research universities by using the output-oriented BCC model. The analysis showed the number of citations is an important factor for universities to achieve efficiency. Dogan (2023) evaluated the teaching and research efficiencies of Turkish research universities via two-stage Network DEA with shared inputs model. The findings revealed that six out of 23 research universities were efficient in both teaching and research activities. The study also showed that higher ranked universities might exhibit low efficiency while lower ranked universities might show high efficiency due to their ability to use their resources efficiently.

The CHE monitors each research university on an annual basis to analyze their educational performance and research outcomes for budget allocation purposes, necessitating a continuous assessment of their efficiency. Moreover, candidate research universities are also being monitored to evaluate their capability for becoming a research university in the upcoming periods. In this context, efficiency refers to how universities utilize their resources, as this significantly impacts their competitive power at both national and international levels. To assess the efficiency of resource usage, this study aims to give

a comprehensive and up-to-date efficiency analysis of research and candidate research universities in Türkiye. Specifically, it employs basic DEA models, namely CCR and BCC, considering the period from 2017 to 2022. Since the DEA method typically captures a snapshot of a DMU's performance, it may not provide a longitudinal perspective on the DMU's performance. To overcome this problem, the Malmquist total factor productivity (TFP) index was applied. This method allows us to observe changes in efficiency over a specific period, enabling us to track the evolution of efficiency. Hence, we can gain a comprehensive understanding of the research landscape in Türkiye. The CHE provides supplementary budgets to the top five research universities (CHE, n.d.). Therefore, it is important to see the position of each research university to be able to distinguish between their performances. Since the DEA model does not differentiate between efficient DMUs, we used a super-efficiency DEA model to rank research and candidate research universities. In addition to these analyses, this study also presents an efficiency/performance diagram by using the scores obtained from the super-efficiency DEA model together with the performance measurements of TÜBİTAK. This diagram presents a two-way performance evaluation of universities by displaying the efficiency scores calculated in this study and the entrepreneur and innovative university scores calculated by TÜBİTAK.

The rest of the paper is organized into four main sections: the method section introduces the research design and the models used for data analysis. The results section includes the findings based on our models. The discussion section interprets our results and compares them with the existing literature. Finally, the conclusion section highlights the key findings and offers recommendations for future research.

Method

This study employs the basic DEA models, the super-efficiency DEA model, and the Malmquist TFP index to assess the efficiency of research and candidate research universities in Türkiye.

Data Envelopment Analysis (DEA)

DEA is a non-parametric method utilized to measure the efficiency of DMUs relative to others. CCR developed by Charnes et al. (1978) and BCC developed by Banker et al. (1984) are the two classic DEA models. The former assumes constant returns to scale (crs) implying that any change in input produces a proportional change in output whereas the latter considers variable returns to scale (vrs) which allows different scales (e.g., increasing returns to scale (irs), decreasing returns to scale (drs)). Typically, multiple inputs and outputs are considered for a DMU, and its efficiency is calculated as the ratio of the weighted sum of its outputs to the weighted sum of its inputs. DEA constructs an efficient frontier considering the best-performing units where it is not possible to improve the output without increasing the input (Cooper et al., 2011). The DMUs which are located on the efficient frontier receive the maximum score of one, indicating that they are efficient; whereas the DMUs which are located below the efficient frontier, i.e., they are inefficient, are assigned efficiency scores based on their proximity to the efficient frontier (Zheng et al., 2022). DEA employs different efficiency metrics to differentiate between crs and vrs. Among these metrics, technical efficiency (TE) breaks down into pure technical efficiency (PTE) and scale efficiency (SE). TE is used under crs assumption while PTE is used under vrs assumption (Kumar & Gulati, 2008). SE, on the other hand, is obtained as the ratio of crs to vrs, and shows how a DMU utilizes its resources/inputs to produce its outputs based on its scale.

DEA models can be formulated as either input-oriented or output-oriented. In input-oriented models, the aim is to determine the optimal combination of inputs required to produce a given level of output. On the other hand, the output-oriented models maximize the output for a given level of input (Cooper et al., 2011). Considering the literature, this study uses output-oriented CCR and BCC models to measure the efficiency of research and candidate research universities in Türkiye. Table 3 summarizes the formulation of the output-oriented CCR and BCC models. The main distinction between CCR and BCC model is the addition of the scaling factor which is used to balance the differences between inputs and outputs.

Super-efficiency DEA Model

According to classical DEA models of CCR and BCC, efficient DMUs have a score of one and inefficient DMUs get scores below one. However, those models do not differentiate between efficient DMUs. For this reason, a super-efficiency DEA model was proposed by Andersen and Petersen (1993) to rank efficient DMUs and differentiate between them. This so-called AP model allows DMUs to get scores larger than one so ranks the efficient DMUs (Xie et al., 2023). The difference between the original CCR model and the super-efficiency DEA model is the exclusion of the kth DMU from the input set (Seiford & Zhu, 1999). The output-oriented CCR super-efficiency DEA model is given below:

$$\begin{aligned} & min \sum_{i=1}^{m} v_i x_{ik} \\ & \text{s.t.} \\ & \sum_{r=1}^{s} u_r y_{rk} = 1 , \\ & \sum_{i=1}^{m} v_i x_{ij} - \sum_{r=1}^{s} u_r y_{rj} \geq 0 \quad j = 1, \dots, n \text{ and } j \neq k , \\ & u_r, v_i \geq 0 ; r = 1, \dots s ; i = 1, \dots m. \end{aligned} \tag{1}$$

Malmquist Total Factor Productivity (TFP) Index

The Malmquist TFP index is used to measure the efficiency and productivity change of DMUs over time. This method originates from Malmquist's study, which defines an index that measures productivity change while considering the shifts in the production frontier (Malmquist, 1953). Caves et al. (1982) introduced the Malmquist TFP index and defined the input and output-based productivity indexes. The Malmquist TFP index was incorporated into DEA calculation by Färe et al. (1994). They decomposed productivity into technical change and efficiency change. Improvements in the efficiency change were interpreted in terms of "catching up" and the improvements in the technical change were interpreted in terms of "innovation." Färe et al. (1994) formulated an output-based Malmquist TFP index under crs for two periods of time t and t+1 in the form of

$$M_0(x^{t+1}, y^{t+1}, x^t, y^t) = \left[\left(\frac{D_0^t(x^{t+1}, y^{t+1})}{D_0^t(x^t, y^t)}\right)\left(\frac{D_0^{t+1}(x^{t+1}, y^{t+1})}{D_0^{t+1}(x^t, y^t)}\right)\right]^{\frac{1}{2}} \quad (2)$$

where $D_0^t(x^t,\ y^t)$ is the distance function from inputs and outputs to the production frontier, showing the efficiency of a DMU with respect to other DMUs. The index was further decomposed into technical change and efficiency change as follows.

$$efficiency\ change = \frac{D_0^{t+1}(x^{t+1}, y^{t+1})}{D_0^t(x^t, y^t)} \quad (3)$$

$$technical\ change = \left[\left(\frac{D_0^t(x^{t+1}, y^{t+1})}{D_0^{t+1}(x^{t+1}, y^{t+1})}\right)\left(\frac{D_0^t(x^t, y^t)}{D_0^{t+1}(x^t, y^t)}\right)\right]^{\frac{1}{2}} \quad (4)$$

Efficiency change was further decomposed into two components in terms of pure efficiency change and scale efficiency change. In our study, Coelli (1996)'s notations were utilized in interpreting the results of the Malmquist TFP index. In literature, technical change is interchangeably used with technological change, and our study will use the latter. For the efficiency change, the term technical efficiency change will be adopted in the rest of the paper. To apply the Malmquist TFP index, a non-parametric production frontier is constructed for all data points (García-Aracil, 2013). Movement towards the production frontier shows a change in technical efficiency while shift of the production frontier implies a change in technology. Considering Färe et al. (1994)'s computations, we can simply calculate the Malmquist TFP index as follows.

TFP=technical efficiency change × *technological change*, (5)

where technical efficiency change is decomposed into pure technical efficiency change and scale efficiency change. To interpret productivity, we look at the TFP values to determine whether they exceed the value of one or not. The TFP value which is greater than one *(TFP > 1)* shows that total factor productivity for the respective DMU has increased from *t* to *t+1*. TFP value which is equal to *(TFP = 1)* one shows that there is no change in the total factor productivity for the respective DMU from *t* to *t+1*. TFP value lower than one *(TFP < 1)* shows that total factor productivity for the respective DMU has decreased from *t* to *t+1*.

Technical efficiency shows how efficiently a DMU is transforming its input into output. If the change in technical efficiency is greater than one, this shows that the respective DMU is achieving higher output due to efficient resource allocation. Pure technical efficiency shows how efficiently a DMU is producing its outputs with a given level of input without scale efficiency. It is generally used to understand managerial performance (Kumar & Gulati, 2008). In the context of research universities, pure technical efficiency can be interpreted as the performance of academic units or departments in allocating resources and producing outputs. If the change in pure technical efficiency is greater than one, this shows that the production of the DMU is getting closer to the production frontier (García-Aracil, 2013). Scale efficiency shows how efficiently a DMU adjusts its scale of operations to maximize its productivity. If the change in scale efficiency is greater than one, it shows irs for the respective DMU.

Data Set

Inputs and outputs used in this study were chosen considering the literature and the performance measures used by the CHE. The inputs are *the number of academic staff*, *the number of administrative staff*, *the number of students*, and *budget allowance* of each university. The number of academic staff describes all academic personnel except lecturers and part-time faculty members. The number of administrative staff includes only filled staff positions in the university. The number of students consists of all associate degrees, undergraduate, master's and PhD students for the respective academic year. Budget allowance describes the starting allowance allocated to the university from the Central Government Budget at the beginning of the respective academic year. The outputs are *the number of PhD graduates*, *the number of publications* and *the number of citations*. The number of publications includes the annual number of publications in SCI, SSCI and AHCI indexed journals.

Input and output data were obtained from different resources. The number of academic staff, the number of students, and the number of PhD graduates were obtained from Higher Education Council Information Management System (YBYS, 2023). The number of administrative staff and budget allowance were obtained from the annual activity reports of each university from 2017 to 2022. The number of publications and the number of citations were obtained from the Institution Indicator Reports of Turkish Higher Education Quality Council (YOKAK, 2023).

Since the income of private universities mostly depends on student fees and resources of the foundation, the components comprising their budgets vary from those of state universities. Moreover, since private universities in Türkiye are subject to the foundation higher education institution regulation, financial assistance by the government depends on some criteria. Therefore, the efficiency of private universities may be influenced by different factors than those examined in this study. For this reason, private research universities (Bilkent, Koç and Sabancı) were not included in the efficiency analysis. İstanbul University-Cerrahpaşa was also excluded from the analysis as it was established in 2018 through the separation from İstanbul University. Therefore, data for 2017 and 2018 were not available for Cerrahpaşa. After excluding those universities from the analysis, the study examined a total of 25 universities with 19 classified as research universities and six classified as candidate research universities. For the data analysis, output-oriented CCR and BCC analyses were conducted to determine the efficiency scores of each university. The models for DEA and the Malmquist TFP index were solved by DEAP version 2.1 (Coelli, 1996) and the super-efficiency DEA model was solved by GAMS 45.7.0 (GAMS Development Corporation, 2024).

Results

This section presents the results obtained from DEA, the super-efficiency DEA model, the Malmquist TFP index, and the efficiency/performance diagram.

Results from DEA

Table 4 presents the CCR and BCC efficiency scores for each university between 2017-2022. When we examine the average CCR efficiency scores, a slightly increasing trend can be observed from 2017 (0.746) to 2022 (0.766), which indicates an improvement in overall efficiency among research and candidate research universities. Similarly, the BCC efficiency scores showed a slightly increasing trend from 0.792 to 0.818 over the same period.

According to the CCR analysis, Boğaziçi, Gazi, and YTU were technically efficient for all years. METU and IHIT reached efficiency across all years except for 2022. In addition, GTU maintained efficiency throughout all years except for 2018. According to the BCC analysis, Boğaziçi, Gazi, GTU, Hacettepe, ITU, İstanbul, IHIT, METU, and YTU attained pure technical efficiency for all years. Ankara became efficient across all years except for 2018 and 2019. Marmara maintained efficiency throughout all years except for 2017 and Sakarya was efficient for all years except for 2022. When comparing research universities to candidate research universities, it can be observed that research universities generally outperformed candidate research universities. This shows the efficiency of resource utilization and superior operational practices among research universities. When we compare both models, we see that the total number of efficient universities for the whole period is three in the CCR model and nine in the BCC model. Since the BCC model assumes vrs it takes the scale adjustments into account, resulting in more efficient units.

Table 5 presents the scale efficiency scores (CCR/BCC) and returns to scale (rts) information for each university. The average scale efficiency scores show that there is not a specific trend throughout the years. However, the maximum number of universities that reached scale efficiency is nine in 2019 which is highest compared to other years. Boğaziçi, Gazi, and YTU maintained their scale efficiencies across all years.

Results from the Super-efficiency DEA

Table 6 shows the super-efficiency score of each university between 2017-2022. The universities with scores exceeding one are highlighted in bold. The results showed that the ranking of efficient universities changed over the six-year period. IHIT was the most efficient university for three consecutive years from 2017 to 2019, having super-efficiency scores of 1.6337, 1.5487, and 1.6028, respectively. After 2019, Gazi became the most efficient university for 2020 and 2021, having super-efficiency scores of 1.5448 and 1.5923, respectively. For 2022, GTU had the highest super-efficiency score of 1.5588 among the universities. When the most efficient universities were examined, some universities maintained their efficiency throughout the period. These universities are Boğaziçi, YTU, and Gazi. IHIT and METU were also efficient over the period except 2022. This implies that these research universities are good at resource allocation, and they optimize their research outputs compared to other universities.

When candidate research universities are evaluated, Sakarya can be highlighted. For 2019 and 2021, Sakarya was one of the most efficient universities, ranking seventh in both years. Although it was not efficient for other years, Sakarya still managed to take place within the top tier of the list. This indicates the potential of Sakarya for becoming one of the research universities in the near future.

Results from the Malmquist TFP Index

Table 7 shows the results obtained by the Malmquist TFP index. It is observed that there are fluctuations in TFP from 2017 to 2022. The average TFP score of 1.088 implies that there is an increasing trend in productivity over the six-year period, indicating an 8.8% increase in the productivity of research universities. The overall increase in TFP can be attributed to the change in technical efficiency change and technological change. There is a 0.3% increase in technical efficiency while there is an 8.5% increase in technology over the period. This shows that the change in technology explains most of the variability in TFP. It can

be noted that research universities in Türkiye benefited significantly from the technological improvements in research and education. When technical efficiency change is analyzed, we see that 0.3% of the increase in average technical efficiency results from an increase in average scale efficiency of 0.5%. Consequently, there is a 0.2% decrease in pure technical efficiency on average. This indicates that although research universities became more efficient in optimizing their scale of operations relative to their size, the managerial performance declined in utilizing resources to maximize productivity.

When we look at the TFP values for each year in relation to the previous year, the 2020-2021 period has the highest TFP score, showing an increase in productivity of 17.1%. This increase mostly results from the increase in technology during this period (13.7%). On the other hand, the 2021-2022 period shows a decrease in productivity of 0.8% because of the decrease in technical efficiency (3.1%), pure technical efficiency (2%) and scale efficiency (1.1%). Although there was a 2.4% increase in technology, it failed to offset the decline in total factor productivity.

Table 8 presents the results obtained by the Malmquist TFP index for each university between 2017 to 2022. TFP scores show that only four universities experienced a decline in their productivity over the period (i.e., the last four universities having TFP scores of below 1). These universities are Boğaziçi, GTU, IHIT, and METU. Other than these universities, all other research universities increased their productivity. This increase in TFP was mostly driven by the increase in technology, as mentioned before. Marmara has the highest productivity score of 1.212 while IHIT has the lowest productivity score of 0.936. This difference in productivity is again attributed to technological advancements varying between universities. In other words, Marmara experienced a 20.6% technological progress whereas IHIT experienced a 4.4% decline in its technology over the period.

Technical efficiencies of universities implied that only eight universities (Atatürk, Boğaziçi, Erciyes, Fırat, Hacettepe, IHIT, Sakarya, and METU) were inefficient. Since technical efficiency shows the ability of the university to transform its resources into output, these universities had shortfalls in this transformation process. Except for Hacettepe and IHIT, the decrease in technical efficiency of six universities was due to the decrease in pure technical efficiency. This implies that those universities might enhance their management practices and research strategies to increase their productivity. However, the decrease in technical efficiency of Hacettepe and IHIT was attributed to the decrease in scale efficiency. The scale efficiency scores of Hacettepe and IHIT are 0.988 and 0.979, respectively. This indicates that these universities are operating at a suboptimal scale. Therefore, they might increase their scale by making efficient resource allocation.

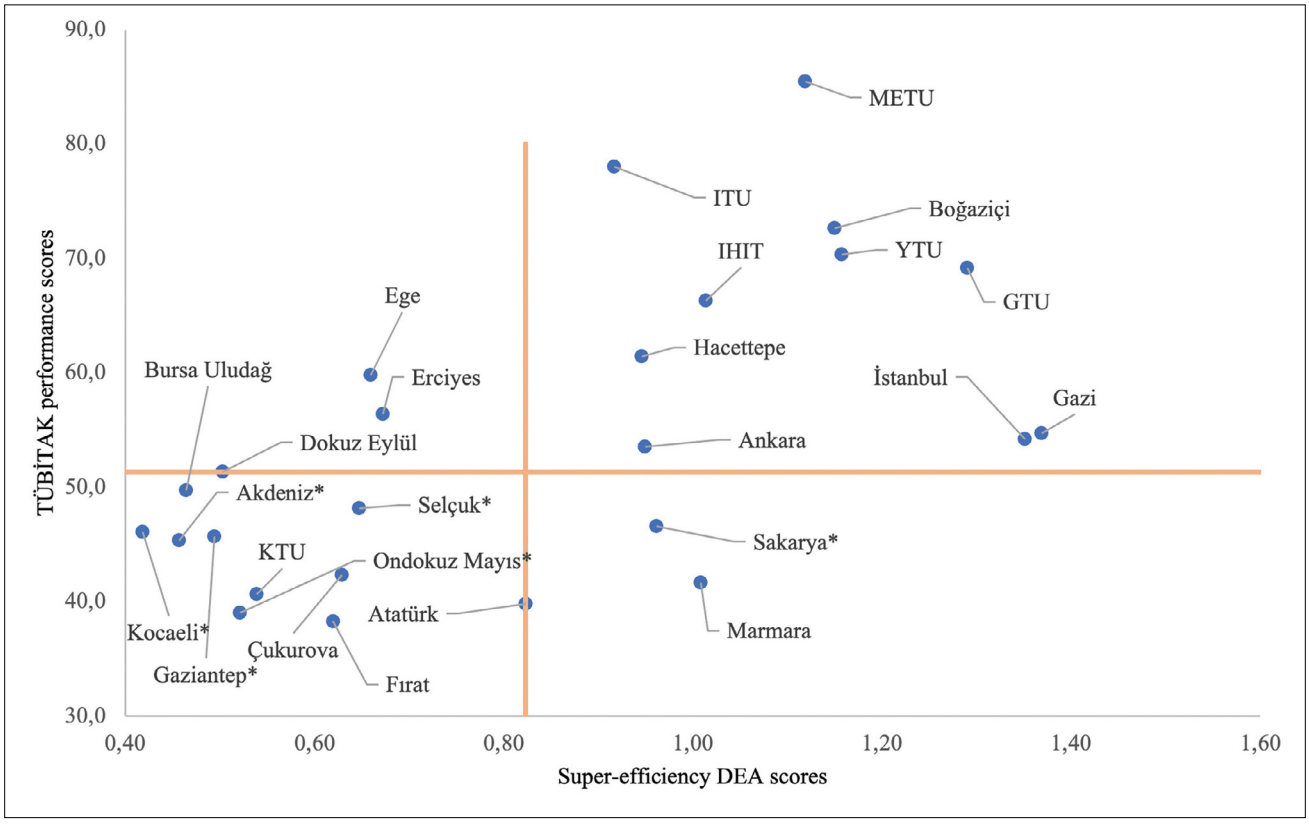
Efficiency/Performance Diagram

Entrepreneurial and innovative structure of universities plays an important role in their competitive positioning. To provide a holistic perspective on the performance of research universities, an efficiency/performance diagram was plotted. In this analysis, "Entrepreneur and Innovative University Index" developed by TÜBİTAK was utilized. This index ranks universities based on 23 indicators across dimensions such as scientific and technological research competence, intellectual property pool, collaboration and interaction, and economic contribution and commercialization. Each university is then assigned an overall score by aggregating scores from each dimension. TÜBİTAK annually publishes the rankings of the 50 most entrepreneurial and innovative universities in Türkiye, with the aim to foster entrepreneurship and innovation-oriented competition among universities.

Figure 1 exhibits the efficiency/performance diagram of research and candidate research universities between 2017-2022. The x-axis and y-axis show the average super-efficiency scores and average TÜBİTAK performance scores (out of 100) of universities over the six-year period, respectively. After positioning each university on the diagram, the medians of the average super-efficiency scores and average TÜBİTAK performance scores were calculated. The line parallel to the y-axis is the median score of all average super-efficiency scores while the line parallel to the x-axis is the median score of all average TÜBİTAK performance scores. These two lines divide the diagram into four regions. Atatürk and Dokuz Eylül have median scores of 0.8 and 51.3 respectively; therefore, they are located on the median lines. The universities which perform better in both efficiency and performance measurements are located in the upper-right region of the diagram. METU has the highest average TÜBİTAK performance score of 85.5 while Gazi has the highest average super-efficiency score of 1.4. On the other hand, the universities that demonstrate low performance in both efficiency and performance measurements are located in the bottom-left region of the diagram. These universities are Bursa Uludağ, Selçuk, Kocaeli, Akdeniz, Gaziantep, KTU, Ondokuz Mayıs, Çukurova and Fırat. Kocaeli has the lowest average super-efficiency score of 0.4 while Fırat has the lowest average TÜBİTAK performance score of 38.3.

When evaluating candidate research universities, it is observed that five out of six candidate research universities are located in the bottom-left region of the diagram, implying that they have low efficiency and performance measurements over the period. However, Sakarya, a candidate research university, is performing better than other candidate research universities. Although it has a low average TÜBİTAK performance score of 46.6, it has a relatively higher average super-efficiency score of 0.96. This shows that if Sakarya emphasizes the importance of entrepreneurial and innovation activities, it has the potential to improve its position on the diagram.

Figure 1
Efficiency/Performance Diagram



Discussion

This study measured the efficiency of research and candidate research universities in Türkiye from 2017 to 2022 using an output-oriented DEA along with the super-efficiency DEA model and the Malmquist TFP index. Subsequently, efficiency scores obtained from the super-efficiency DEA model were analyzed alongside performance scores announced by TÜBİTAK on an efficiency/performance diagram. This comprehensive analysis enables a thorough assessment of universities in terms of efficiency and performance metrics, which in turn provide insights into their comparative strengths and weaknesses over the six-year period.

Our findings revealed that the mean CCR and BCC efficiency scores of both research and candidate research universities in Türkiye peaked in 2021. Additionally, the results obtained from the Malmquist TFP index illustrated that the 2020-2021 period has the highest TFP score among all other years, showing an increase in productivity of 17.1%. This increase is mostly attributed to the increase in the number of PhD graduates and the number of publications. At this point, we need to note the effects of Covid-19 pandemic on higher education in Türkiye. Starting from March 2020, all education activities were suspended in Türkiye. Afterwards, the CHE announced to switch to distance education (CHE, 2020a) and gave university students an option for freezing their registrations for the 2019-2020 academic year (CHE, 2020b). Therefore 2020 has the lowest number of PhD graduates compared to other years. However, the total number of PhD graduates increased by approximately 13.5% in 2021 compared with the previous year. Although Covid-19 pandemic negatively influenced higher education in Türkiye in terms of distance education practices (Karadag et al., 2021), it positively influenced the publication performance of academic staff (Dogan & Akbal, 2021; Parlar & Kart, 2022). Consequently, the publication numbers increased in terms of increased productivity due to reduced social activities, converted accumulated work into publications, additional time given for evaluation and revision, increased collaboration, and opportunity to publish pandemic related articles (Parlar & Kart, 2022). Additionally, 19 universities in our data set have medical schools which had the opportunity to carry out research related to pandemic during this period.

When analyzing the efficiency of research universities, the BCC analysis revealed that Boğaziçi, Gazi, GTU, Hacettepe, ITU, İstanbul, IHIT, METU and YTU attained pure technical efficiency for all years. Among these efficient universities, IHIT ranked first for three consecutive years from 2017 to 2019, Gazi ranked first for 2020 and 2021 and finally GTU ranked first for 2022

according to the super-efficiency DEA model. Besides these efficient research universities, Sakarya, which is a candidate research university, should be highlighted. For 2019 and 2020, it became efficient and ranked seventh for both years. Despite being inefficient for other years, Sakarya still managed to attain a position within the top tier of the list. Other studies in the literature also demonstrate that Sakarya has attained efficiency across various time periods (Arslan & Guven, 2018; Gunay et al, 2017; Turkan & Ozel, 2017).

The results obtained from the Malmquist TFP index showed that the variability in productivity of research and candidate research universities mostly resulted from the change in technology. Since all these universities have technology development zones in their landscape (Ministry of Industry and Technology, 2024), they benefited from technological improvements and advancements in research and education. When we analyze average technical efficiency, we see that it increased due to the increase in average scale efficiency although there is a decline in average pure technical efficiency. This implies that although research universities are good at optimizing their scale of operations, managerial performance declined in utilizing resources. Analysis of TFP scores for each university showed that Marmara has the highest productivity whereas IHIT has the lowest productivity. Although IHIT was found efficient until 2022, the decrease in productivity resulted from scale inefficiency. In line with our findings, Telli (2023) also identified IHIT as an efficient university during the 2016-2021 period. However, its productivity declined after 2021, suggesting that IHIT could enhance productivity by making efficient resource allocation in terms of identifying underutilized and overutilized areas. In contrast, while Telli (2023) identified that METU was inefficient due to decreasing technological efficiency during the 2016-2021 period, our study, covering 2017-2022, implies that the decrease in METU's productivity was driven by a decrease in technical efficiency rather than a decrease in technological efficiency. This difference can be attributed to the use of different input-output structure and time period. It can also be argued that while METU has improved its technological inefficiencies in 2022, this may have led to inefficiencies in resource allocation.

The last analysis focuses on the efficiency/performance diagram of research and candidate research universities between 2017-2022. Technological development and entrepreneurial mindset affect the efficiency of universities and their knowledge transfer activities (Berbegal-Mirabent et al., 2013). Therefore, including knowledge transfer activities such as intellectual or industrial property agreements in the analysis has an impact on the efficiency of universities (Torre et al., 2017). The efficiency/performance diagram shows that METU, Boğaziçi, YTU, GTU, Gazi, İstanbul, ITU, IHIT, Hacettepe and Ankara have both high efficiency and high performance compared to other universities. This implies that those research universities are not only efficient in terms of producing research outcomes but also performing better in creating an entrepreneurial and innovative atmosphere within their culture. The diagram also shows that Sakarya distinguishes itself from other candidate research universities, positioning itself as a stronger candidate to attain a research university label in the upcoming years.

Conclusion

This study aims to provide important insights both for universities and the government. Universities may identify the areas for improvement in resource utilization to become more efficient and improve their research capabilities while the government bodies may strategically allocate university budgets and provide financial support to foster the development of research-oriented universities in Türkiye. As this study gives a comprehensive efficiency analysis from 2017 to 2022 by incorporating different measurement techniques, it provides a detailed examination of research university landscape since their introduction. However, the findings of this study should be considered with its limitations. The first limitation is obtaining data from universities. Since the annual activity reports of state universities are not very transparent, only the available data were used. Moreover, since private universities do not publish a standard annual activity report, they were excluded from the study. Future studies might include private universities as well by using different input and output structures to see the efficiency of research university environment in Türkiye. This study also does not explain the overall efficiency of higher education in Türkiye. Future studies might consider other universities as well and use different measurement methods to assess the overall efficiency of higher education in Türkiye.

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Table 1
Research universities in Türkiye[a] (in alphabetical order)

Research Universities		Candidate Research Universities
1. Ankara University	14. İstanbul Technical University (ITU)	1. Akdeniz University
2. Atatürk University	15. İstanbul University	2. Gaziantep University
3. Bilkent University	16. İstanbul University- Cerrahpaşa	3. Kocaeli University
4. Boğaziçi University	17. İzmir Higher Institute of Technology (IHIT)	4. Ondokuz Mayıs University
5. Bursa Uludağ University	18. Karadeniz Technical University (KTU)	5. Sakarya University
6. Çukurova University	19. Koç University	6. Selçuk University
7. Dokuz Eylül University	20. Marmara University	
8. Ege University	21. Middle East Technical University (METU)	
9. Erciyes University	22. Sabancı University	
10. Fırat University	23. Yıldız Technical University (YTU)	
11. Gazi University		
12. Gebze Technical University (GTU)		
13. Hacettepe University		

[a] (CHE, 2021)

Table 2
A summary of previous studies in literature

Author(s)	Inputs	Outputs	Method
Agasisti and Dal Bianco (2006)	• Avg # of teachers • # of students • Public funds • # of regular students	• # of graduates • Indicator of research activities • External research grants and contracts • # of formative credits	• Input-oriented BCC model
Turkan and Ozel (2017)	• Total expenses • # of instructors • # of lecturers	• # of supported public and infrastructure projects • # of citations • # of publications • # of total undergraduate students • # of graduate students	• Output-oriented BCC model • Super-efficiency DEA model • Tobit model • Beta regression
Mammadov and Aypay (2020)	• Faculty members/# of programs • # of scientific research projects/# of programs	• Citations/publications • Research project revenue share/budget allowance • # of PhD graduates/# of doctoral programs	• Input-oriented and output-oriented CCR and BCC models • Tobit model
Karagoz et al. (2020)	• # of Professors and Associate Professors • # of other academic staff • # of PhD students	• Entrepreneur and innovative university index score	• Output-oriented BCC model • Malmquist TFP index
Kocak and Orkcu (2021)	First Stage • # of faculty members • # of graduate students/total • # of students Second Stage • Educational budget per faculty member • # of articles	First Stage • Educational budget per faculty member • # of articles Second Stage • # of citations • # of graduate students • # of proposed projects • # of supported projects • Project budget	• Two-stage DEA
Maral (2023)	• Annual budgets of universities • # of academic personnel	• # of publications • # of citations	• Output-oriented BCC model • OLS regression analysis

Table 3
Output-Oriented CCR and BCC Models

CCR model (Charnes et al., 1978)	BCC model (Banker et al., 1984)
$$min \sum_{i=1}^{m} v_i x_{ik}$$ s.t. $$\sum_{r=1}^{s} u_r y_{rk} = 1$$ $$\sum_{i=1}^{m} v_i x_{ij} - \sum_{r=1}^{s} u_r y_{rj} \geq 0 \quad j = 1, \dots, n$$ $$u_r, v_i \geq 0 ; r = 1, \dots s ; i = 1, \dots m$$	$$min \sum_{i=1}^{m} v_i x_{ik} - v_k$$ s.t. $$\sum_{r=1}^{s} u_r y_{rk} = 1$$ $$\sum_{i=1}^{m} v_i x_{ij} - \sum_{r=1}^{s} u_r y_{rj} - v_k \geq 0 \; j = 1, \dots, n$$ $$u_r, v_i \geq 0 ; r = 1, \dots s ; i = 1, \dots m$$ and v_k *is free*

The definitions of the symbols:

n: Number of DMUs
m: Number of inputs
s: Number of outputs
y_{rj}: Amount of r^{th} output produced by j^{th} DMU
x_{ij}: Amount of i^{th} input used by j^{th} DMU
y_{rk}: Amount of r^{th} output produced by the DMU under evaluation (k^{th} DMU)
x_{ik}: Amount of i^{th} input used by the DMU under evaluation (k^{th} DMU)
u_r: Weight given to the r^{th} output
v_i: Weight given to the i^{th} input

Table 4
CCR & BCC Efficiency Scores of Research and Candidate Research Universities

Research Universities	2017		2018		2019		2020		2021		2022	
	CCR	BCC	CCR	BCC	CCR	BCC	CCR	BCC	CCR	BCC	CCR	BCC
Ankara	1	1	0.977	0.990	0.767	0.859	0.921	1	0.948	1	1	1
Atatürk	0.989	0.998	0.981	0.984	0.737	0.817	0.777	0.816	0.735	0.779	0.721	0.812
Boğaziçi	1	1	1	1	1	1	1	1	1	1	1	1
Bursa Uludağ	0.420	0.457	0.422	0.432	0.395	0.438	0.456	0.501	0.480	0.498	0.614	0.620
Çukurova	0.450	0.577	0.626	0.649	0.607	0.660	0.702	0.742	0.674	0.737	0.715	0.750
Dokuz Eylül	0.523	0.654	0.482	0.603	0.495	0.615	0.527	0.623	0.502	0.577	0.480	0.576
Ege	0.599	0.781	0.702	0.761	0.620	0.696	0.715	0.777	0.656	0.715	0.649	0.745
Erciyes	0.538	0.587	0.611	0.616	0.644	0.682	0.720	0.761	0.761	0.811	0.759	0.811
Fırat	0.496	0.551	0.600	0.629	0.513	0.595	0.647	0.706	0.731	0.826	0.721	0.865
Gazi	1	1	1	1	1	1	1	1	1	1	1	1
GTU	1	1	0.959	1	1	1	1	1	1	1	1	1
Hacettepe	0.907	1	1	1	0.904	1	0.961	1	0.953	1	0.936	1
IHIT	1	1	1	1	1	1	1	1	1	1	0.898	1
ITU	0.975	1	1	1	1	1	0.977	1	0.994	1	0.988	1
İstanbul	0.788	1	0.900	1	1	1	0.927	1	0.921	1	0.938	1
KTU	0.520	0.560	0.588	0.599	0.515	0.560	0.537	0.603	0.509	0.595	0.565	0.637
Marmara	0.963	0.963	0.983	1	0.786	1	1	1	0.957	1	1	1
METU	1	1	1	1	1	1	1	1	1	1	0.949	1
YTU	1	1	1	1	1	1	1	1	1	1	1	1
Akdeniz*	0.433	0.466	0.496	0.520	0.422	0.479	0.426	0.547	0.497	0.619	0.462	0.548
Gaziantep*	0.558	0.620	0.584	0.600	0.461	0.522	0.481	0.517	0.461	0.507	0.408	0.419
Kocaeli*	0.357	0.399	0.397	0.406	0.406	0.438	0.419	0.478	0.495	0.541	0.428	0.482
Ondokuz Mayıs*	0.504	0.530	0.496	0.496	0.454	0.490	0.532	0.595	0.635	0.652	0.506	0.585
Sakarya*	0.979	1	0.928	1	1	1	0.980	1	1	1	0.836	0.893
Selçuk*	0.653	0.654	0.745	0.784	0.630	0.761	0.645	0.749	0.629	0.758	0.583	0.697
average	**0.746**	**0.792**	**0.779**	**0.803**	**0.734**	**0.785**	**0.774**	**0.817**	**0.781**	**0.825**	**0.766**	**0.818**

*Candidate research universities

Table 5
Scale Efficiency Scores of Research and Candidate Research Universities

Research Universities	2017		2018		2019		2020		2021		2022	
	scale	rts	scale	rts	scale	rts	scale	rts	scale	rts	scale	rts
Ankara	1	crs	0.986	drs	0.893	drs	0.921	drs	0.948	drs	1	crs
Atatürk	0.991	irs	0.996	irs	0.903	drs	0.952	drs	0.944	drs	0.888	drs
Boğaziçi	1	crs	1	crs	1	crs	1	crs	1	crs	1	crs
Bursa Uludağ	0.919	drs	0.977	drs	0.903	drs	0.910	drs	0.964	drs	0.991	irs
Çukurova	0.780	drs	0.965	drs	0.920	drs	0.946	drs	0.915	drs	0.954	drs
Dokuz Eylül	0.800	drs	0.800	drs	0.805	drs	0.846	drs	0.871	drs	0.834	drs
Ege	0.767	drs	0.922	drs	0.890	drs	0.921	drs	0.917	drs	0.871	drs
Erciyes	0.916	drs	0.993	drs	0.944	drs	0.947	drs	0.938	drs	0.936	drs
Fırat	0.901	drs	0.954	drs	0.862	drs	0.916	drs	0.885	drs	0.833	drs
Gazi	1	crs	1	crs	1	crs	1	crs	1	crs	1	crs
GTU	1	crs	0.959	irs	1	crs	1	crs	1	crs	1	crs
Hacettepe	0.907	drs	1	crs	0.904	drs	0.961	drs	0.953	drs	0.936	drs
IHIT	1	crs	1	crs	1	crs	1	crs	1	crs	0.898	irs
ITU	0.975	drs	1	crs	1	crs	0.977	drs	0.994	drs	0.988	drs
İstanbul	0.788	drs	0.900	drs	1	crs	0.927	drs	0.921	drs	0.938	drs
KTU	0.929	drs	0.982	drs	0.920	drs	0.891	drs	0.855	drs	0.887	drs
Marmara	1	crs	0.983	drs	0.786	drs	1	crs	0.957	drs	1	crs
METU	1	crs	1	crs	1	crs	1	crs	1	crs	0.949	drs
YTU	1	crs	1	crs	1	crs	1	crs	1	crs	1	crs
Akdeniz*	0.929	drs	0.954	drs	0.881	drs	0.778	drs	0.803	drs	0.843	drs
Gaziantep*	0.900	drs	0.974	drs	0.884	drs	0.931	drs	0.910	drs	0.974	drs
Kocaeli*	0.896	drs	0.978	drs	0.926	drs	0.878	drs	0.916	drs	0.888	drs
Ondokuz Mayıs*	0.950	drs	0.999	drs	0.926	drs	0.893	drs	0.974	drs	0.865	drs
Sakarya*	0.979	irs	0.928	irs	1	crs	0.980	irs	1	crs	0.936	drs
Selçuk*	0.999	irs	0.950	drs	0.827	drs	0.861	drs	0.830	drs	0.837	drs
average	**0.933**		**0.968**		**0.927**		**0.937**		**0.940**		**0.930**	

*Candidate research universities

Table 6
Super-Efficiency DEA Results of Research and Candidate Research Universities

Rank	2017		2018		2019	
	Universities	S-E score	Universities	S-E score	Universities	S-E score
1	IHIT	1.6337	IHIT	1.5487	IHIT	1.6028
2	METU	1.2911	METU	1.3568	Gazi	1.4849
3	Boğaziçi	1.2170	YTU	1.1401	GTU	1.2701
4	GTU	1.1604	ITU	1.1228	YTU	1.2522
5	YTU	1.0760	Boğaziçi	1.1181	Boğaziçi	1.1247
6	Gazi	1.0573	Gazi	1.0768	METU	1.0782
7	Ankara	1.0005	Hacettepe	1.0184	Sakarya*	1.0490
8	Atatürk	0.9893	Marmara	0.9830	İstanbul	1.0303
9	Sakarya*	0.9787	Atatürk	0.9808	ITU	1.0265
10	ITU	0.9747	Ankara	0.9771	Hacettepe	0.9035
11	Marmara	0.9630	GTU	0.9591	Marmara	0.7863
12	Hacettepe	0.9066	Sakarya*	0.9277	Ankara	0.7683
13	İstanbul	0.7880	İstanbul	0.9000	Atatürk	0.7374
14	Selçuk*	0.6530	Selçuk*	0.7449	Erciyes	0.6439
15	Ege	0.6095	Ege	0.7044	Selçuk*	0.6295
16	Gaziantep*	0.5708	Çukurova	0.6263	Ege	0.6213
17	Erciyes	0.5379	Erciyes	0.6114	Çukurova	0.6072
18	Dokuz Eylül	0.5314	Fırat	0.5998	KTU	0.5152
19	KTU	0.5199	KTU	0.5884	Fırat	0.5128
20	Fırat	0.5050	Gaziantep*	0.5841	Dokuz Eylül	0.4952
21	Ondokuz Mayıs*	0.5038	Akdeniz*	0.4959	Gaziantep*	0.4612
22	Çukurova	0.4497	Ondokuz Mayıs*	0.4956	Ondokuz Mayıs*	0.4538
23	Akdeniz*	0.4328	Dokuz Eylül	0.4822	Akdeniz*	0.4221
24	Bursa Uludağ	0.4199	Bursa Uludağ	0.4218	Kocaeli*	0.4058
25	Kocaeli*	0.3571	Kocaeli *	0.3971	Bursa Uludağ	0.3952

Rank	2020		2021		2022	
	Universities	S-E score	Universities	S-E score	Universities	S-E score
1	Gazi	1.5448	Gazi	1.5923	GTU	1.5588
2	GTU	1.3939	GTU	1.3989	Gazi	1.4560
3	IHIT	1.3862	YTU	1.2020	Marmara	1.2497
4	Boğaziçi	1.2720	Boğaziçi	1.1159	YTU	1.1912
5	Marmara	1.1108	IHIT	1.0396	Ankara	1.0817
6	YTU	1.0819	METU	1.0090	Boğaziçi	1.0539
7	METU	1.0310	Sakarya*	1.0003	ITU	0.9885
8	Sakarya*	0.9798	ITU	0.9939	METU	0.9489
9	ITU	0.9773	Marmara	0.9568	İstanbul	0.9379
10	Hacettepe	0.9612	Hacettepe	0.9529	Hacettepe	0.9360
11	İstanbul	0.9269	Ankara	0.9476	IHIT	0.8977
12	Ankara	0.9215	İstanbul	0.9206	Sakarya*	0.8365
13	Atatürk	0.7772	Erciyes	0.7608	Erciyes	0.7591
14	Erciyes	0.7201	Atatürk	0.7351	Fırat	0.7212
15	Ege	0.7153	Fırat	0.7310	Atatürk	0.7211
16	Çukurova	0.7020	Çukurova	0.6738	Çukurova	0.7152
17	Fırat	0.6469	Ege	0.6555	Ege	0.6492
18	Selçuk*	0.6447	Ondokuz Mayıs*	0.6350	Bursa Uludağ	0.6141
19	KTU	0.5371	Selçuk*	0.6291	Selçuk*	0.5830
20	Ondokuz Mayıs*	0.5317	KTU	0.5086	KTU	0.5654
21	Dokuz Eylül	0.5274	Akdeniz*	0.5041	Ondokuz Mayıs*	0.5062
22	Gaziantep*	0.4811	Dokuz Eylül	0.5025	Dokuz Eylül	0.4801
23	Bursa Uludağ	0.4559	Kocaeli*	0.4965	Akdeniz*	0.4616
24	Akdeniz*	0.4257	Bursa Uludağ	0.4802	Kocaeli*	0.4331
25	Kocaeli*	0.4195	Gaziantep*	0.4613	Gaziantep*	0.4084

*Candidate research universities
S-E score: super-efficiency score

Table 7
The Malmquist TFP Index Summary by Year

Year	Technical Efficiency Change	Technological Change	Pure Technical Efficiency Change	Scale Efficiency Change	TFP
2017-2018	1.058	1.011	1.010	1.048	1.069
2018-2019	0.961	1.199	0.997	0.965	1.152
2019-2020	1.001	1.064	0.994	1.008	1.066
2020-2021	1.030	1.137	1.010	1.020	1.171
2021-2022	0.969	1.024	0.980	0.989	0.992
Average	**1.003**	**1.085**	**0.998**	**1.005**	**1.088**

Table 8
The Malmquist TFP Index Summary by University from 2017 to 2022

University	Technical Efficiency Change	Technological Change	Pure Technical Efficiency Change	Scale Efficiency Change	TFP
Marmara	1.005	1.206	1.000	1.005	1.212
Çukurova	1.066	1.131	1.040	1.025	1.206
Gaziantep*	1.077	1.101	1.055	1.021	1.187
Bursa Uludağ	1.011	1.156	1.009	1.003	1.170
Dokuz Eylül	1.041	1.114	1.008	1.032	1.160
KTU	1.055	1.095	1.026	1.028	1.155
Kocaeli*	1.010	1.129	1.000	1.010	1.140
Ege	1.008	1.130	1.000	1.008	1.139
Selçuk*	1.004	1.124	0.984	1.020	1.129
İstanbul	1.039	1.085	1.000	1.039	1.127
Ondokuz Mayıs*	1.000	1.127	1.000	1.000	1.127
Akdeniz*	1.011	1.109	1.003	1.008	1.121
YTU	1.003	1.097	1.000	1.003	1.100
Atatürk	0.976	1.122	0.982	0.994	1.095
Gazi	1.000	1.079	1.000	1.000	1.079
Fırat	0.941	1.126	0.944	0.997	1.060
Hacettepe	0.988	1.066	1.000	0.988	1.054
ITU	1.003	1.044	1.000	1.003	1.047
Erciyes	0.992	1.054	0.995	0.997	1.045
Sakarya*	0.970	1.075	0.977	0.992	1.043
Ankara	1.000	1.004	1.000	1.000	1.004
GTU	1.000	0.990	1.000	1.000	0.990
Boğaziçi	0.963	1.018	0.966	0.997	0.980
METU	0.953	1.016	0.967	0.986	0.968
IHIT	0.979	0.956	1.000	0.979	0.936

*Candidate Research Universities