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RESEARCH ARTICLE

PRODUCTIVITY, EFFICIENCY AND ENTREPRENEURIAL - INNOVATIVE UNIVERSITY INDEX: AN ANALYSIS FOR UNIVERSITIES IN TÜRKİYE

İsmail YENİLMEZ[1,*]

[1] Department of Statistics, Science Faculty, Eskişehir Technical University, Eskişehir, Türkiye
ismailyenilmez@eskisehir.edu.tr - 0000-0002-3357-3898

Abstract

The productivity and efficiency of universities were analysed in this study. The data and results of the Entrepreneurial and Innovative University Index-EIUI, which is calculated by TÜBITAK every year by considering various information for universities, were used. The study aimed to discuss the index, productivity, and efficiency results comparatively. Four-year data (2019-2022) and the index values were used. Balanced panel data analysis was performed on universities consistently included in the list each year. In the calculation of the index, a weighted sum of values standardized by the min-max method was taken into account. This is available in the calculation methodology of the index. Total factor productivity and stochastic frontier model methods were used for the analysis of productivity and efficiency, respectively. Universities that enter the index list every year and are at the top are effective, but they could not increase their productivity in the previous years. Universities established before 1992 may have approached the saturation level in terms of the input-output relationship, but it can be said that they can maintain their effectiveness. Some public and private universities that were established in 1992 and later have raised their productivity and efficiency. Although the index value and efficiency values overlapped to a certain extent, the significant differences in productivity were remarkable. While the studies in the literature focused on the meta-analysis of the index and the efficiency analysis of universities with various methods, this study presented an inclusive and comparative analysis in terms of index, productivity, and efficiency with panel data analysis.

Keywords

Total Factor Productivity,
Stochastic Frontier Model,
Triple Helix Model of Innovation,
Innovation Helix Framework,
Balanced Panel Data

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1. INTRODUCTION

Efficiency and productivity are often used interchangeably and confused in literature. Although they overlap, they have different meanings. Productivity is referred to as the ratio of outputs to inputs of a production process; efficiency represents the comparison between observed and optimal inputs - outputs [1]. For the measurement of productivity and efficiency, detailed research was carried out and the process related to the analysis was associated with three criteria. The basic criteria are macro/micro; frontier/non-frontier and deterministic/econometric [2]. These criteria are also presented as frontier/non-frontier, parametric/nonparametric (and semi-parametric), and stochastic/deterministic [3]. For a detailed reading, an introduction to efficiency and productivity analysis can be examined [4].

The activities of institutions and organizations can be examined, but the efficiency and productivity of higher education can be considered one of the most critical issues. The efficiency of higher education units has been investigated with multilevel frontier analysis. [5]. The 2018 performance of the top 10

*Corresponding Author: ismailyenilmez@eskisehir.edu.tr

Entrepreneurial and Innovative Turkish universities has been examined through multiple-criteria decision making methods [6]. Data envelopment analysis and Malmquist total factor productivity index have been used for the efficiency analysis of Turkish universities [7]. The productivity and efficiency of 43 state universities in Türkiye for the 2014–2015 academic year using data envelopment analysis and super efficiency models have been evaluated and followed by Tobit and beta regression analysis to identify factors affecting efficiency [8]. The efficiency of ten research universities and five candidate research universities in Türkiye, established in 2017 have been investigated using 2017 input and output data. The findings indicated that the number of scientific research projects negatively impacts efficiency, while citation rates per publication and the rate of PhD graduates per PhD program positively influence efficiency [9]. A two-stage DEA model to measure the efficiency of Turkish state universities has been employed focusing on graduate education and scientific research competency, confirming efficiency rankings aligned with criteria set by the Council of Higher Education [10].

In a similar but broader perspective, this study aims to draw attention to and analysis the terms productivity and efficiency for innovation in universities. The productivity and efficiency of universities directly affect the innovation process. In addition to efficiency and productivity, the emphasis on innovation, another important term, is on the world agenda. The impact of higher education has been examined for entrepreneurship and innovation [11]. In this case, a different perspective can be presented to the industry-technology-university-innovation quartet with productivity and efficiency measures. When the context expressed is examined, it overlaps with a term in the literature. The triple helix model of innovation concept is the interaction between academia, industry, and government to promote economic and social development in the system where concepts such as knowledge economy and knowledge society are defined [12]. The triple helix model of innovation is a conceptualization that is used as a basis for innovation and is frequently used in the literature. However, this situation has not been addressed for universities in Türkiye in the literature. The efficiency of regional innovation ecosystems was examined within the framework of the Triple-Helix Model for 81 provinces in Türkiye and the period 2011-2015, and it was concluded that the contribution of universities and public supports differ at the regional level [13]. According to the Triple Helix model, Türkiye's capacity to create innovation has been examined. It has been seen that the Triple Helix approach is not valid for Türkiye within the scope of the examined period [14]. As can be seen from the literature, the concepts of efficiency, productivity, and innovation index have not been discussed cumulatively for universities, which are the source of innovation, and these concepts have not been examined separately in depth.

In this context, the general motivation of this study is to analyze the productivity and efficiency of universities with a different approach to the triple helix model of innovation. When the literature is examined, efficiency analyses on this subject are grouped under certain methods. The special motivation is to evaluate the efficiency and productivity from the perspective of Türkiye by using data from Turkish universities. Because universities are one of the sources of innovation in Türkiye, as well as all over the world. Moreover, the existence of a system that supports the triple helix model of innovation for Türkiye can be seen. For instance, it is seen that the Ministry of Industry and Technology of the Republic of Türkiye follows The Scientific and Technological Research Council of Türkiye - TÜBİTAK's study, closely[1]. There are also important collaborations between the Ministry of Industry and Technology of the Republic of Türkiye and TÜBİTAK.

From another perspective, the literature-based theoretical comparison for the criteria of the TÜBİTAK Entrepreneurial and Innovative University Index (EIUI) has been carried out in terms of the prominent operational areas of the entrepreneurial university in higher education journals [15]. In this context, it aims to comparatively discuss the index, productivity, and efficiency using EIUI data in this study. In

[1] https://www.sanayi.gov.tr/medya/haber/deneme2

other words, the study aims to deal with the index, productivity, and efficiency analysis cumulatively with the help of EIUI data regularly shared by TÜBITAK.

The study is designed as follows: In the second part of this study, the theoretical and computational methods used in the study were presented. In the third part, the results of the analysis were shared. In the last section, all the findings were discussed.

2. DATA

The data and results of the EIUI were used. The EIUI is announced annually by the TUBITAK, and fifty universities are listed. The EIUI has been calculated by TÜBITAK every year by considering various information for universities. Although the index was calculated with five components for the first time in 2012, it has been calculated by reducing it to four components since 2018. The four relevant components are economic and social contribution / cooperation and interaction / intellectual property pool / scientific and technological research competence. Twenty-three sub-components are quantitatively measured values that constitute the relevant four main components. All of the sub-components in EIUI are as follows: i) Number of Scientific Publications, Number of Citations, Number of Projects, Amount of Funds Obtained from Projects Number of National and International Science Awards, Number of PhD Graduates. ii) National Patent Document Number, Number of National Utility Model Certificates, Number of International Patent Applications, Number of International Patent Documents. iii) Number of Projects Done with Industry Cooperation, Amount of Funds Obtained from Projects Done with Industrial Cooperation, Number of Projects Done with International Cooperation, Amount of Funds Obtained from Projects Done with International Cooperation, Number of Teaching Staff / Students in Circulation, Number of Students Registered in the Industrial Doctorate Program. iv) Number of Academician Companies, Number of Student / Graduate Companies, Net Sales Income of Academic Companies, Net Sales Revenue of Student/Graduate Companies, Number of Licensed Patents / Utility Models / Industrial Designs, Number of Bigg Companies, 4004-4005 Number of Projects. In this study, analysis was conducted only for the first component: scientific and technological research competence [16]. In other components, the abundance of empty cells and the fact that the imputation rate would be very high if filled was seen as an obstacle. Using the balanced panel data analysis methodological framework within the scope of the study can be considered as another important reason for conducting analyses through the first component.

4-year data (2019-2022) and index values were used. The 4-component index offered by TUBITAK was used, the 5-component index presented before 2019 was not taken into account. The weights of the sub-dimensions of the index considered have changed as of 2019. This is the reason why 2018 and earlier was not included in the analysis. The 2023 data has not been released yet. As a result, a data for 4 years was compiled. The top 50 universities are listed in the index result document. Universities included in the relevant list each year were included in the analysis. Thus, balanced panel data analysis was performed.

In calculation of the EIUI, weighted sum of values standardized by min-max method was considered. It is available in the calculation methodology of the relevant index. This information was last presented as a footnote in the 2020 data announced in 2021 [17]. 4-year data and index values were accessed from TÜBİTAK (for 2019, 2021, and 2022 years) and Yeditepe University (for 2020 year) websites as public data[2]. Ratio data, one of the data types, was conducted in this analysis. Since TUBITAK data were prepared by considering the weighted sum of the values standardized with the min-max method, these

[2] https://www.tubitak.gov.tr/sites/default/files/gostergebazliveri_tablo.pdf
https://tubitak.gov.tr/sites/default/files/gyue2021.pdf
https://tubitak.gov.tr/sites/default/files/18842/2020-gyue-2020-print.pdf
https://tto.yeditepe.edu.tr/sites/default/files/2019_gyue.pdf

data were used for analysis without the need for any other transformation. This introduces phenomena such as categories, rank order, true zero, and equal intervals between data. It can be clearly stated that ratio data is superior to nominal, ordinal, and interval data according to the characteristics of the values.

In addition, the year 1992 was taken as the border in the study. In this context, the type (the abbreviations *pu* and *pr* represent public and private universities, respectively.) and establishment years of the universities used in the study are presented in Table 1. 20 of the 38 universities were founded before 1992, and only 1 of them is a private university. The number of universities established in 1992 and later is 18, and 11 of them are private universities.

Table 1. Type and Establishment of Universities Used in the Study

Universities	***Year***	***Public/State-Private***	***Universities***	***Year***	***Public/State-Private***
ISTANBUL U.	1933	PU	IZM. INST OF TECH	1992	PU
ISTANBUL TECH U.	1944	PU	GEBZE TECH U.	1992	PU
ANKARA U.	1946	PU	KOCAELİ U.	1992	PU
EGE U.	1955	PU	SAKARYA U.	1992	PU
KARADENIZ TECH U.	1955	PU	PAMUKKALE U.	1992	PU
ATATURK U.	1957	PU	S. DEMIREL U.	1992	PU
MIDD EAST TECH U.	1959	PU	KOC U.	1993	PR
HACETTEPE U.	1967	PU	SABANCI U.	1996	PR
BOGAZICI U.	1971	PU	YEDITEPE U.	1996	PR
CUKUROVA U.	1973	PU	ATILIM U.	1997	PR
BURSA ULUDAG U.	1975	PU	BAHCESEHIR U.	1998	PR
SELCUK U.	1975	PU	IST. OKAN U.	1999	PR
FIRAT U.	1975	PU	YAŞAR U.	2001	PR
ERCIYES U.	1978	PU	TOBB ETU	2003	PR
YILDIZ TECH U.	1982	PU	ÖZYEĞİN U.	2007	PR
GAZI U.	1982	PU	H. KALYONCU U.	2008	PR
DOKUZ EYLÜL U.	1982	PU	IST. MEDIPOL U.	2009	PR
AKDENİZ U.	1982	PU	A. GUL U.	2010	PU
MARMARA U.	1982	PU			
İ.D. BILKENT U.	1984	PR			

3. METHODS

3.1. Total Factor Productivity

The total factor productivity (TFP) model was used to analysis productivity in this study. Based on the basic definition, TFP can be written as:

$$TFP_{nt} = \frac{Y_{nt}}{X_{nt}} \tag{1}$$

where X_{nt} and Y_{nt} are the aggregate input – output of the n^{th} firm in period t, respectively. TFP changes are specified as being the ratio of the index (output quantity index/input quantity index) [18]. Such index numbers can be represented as multiplicatively complete [19]. Among the multiplicatively complete indices, the Hicks-Moorsteen TFP index is one of the multiplicatively complete indices and it can be estimated without requiring price data (Arjomandi et al., 2015). Hicks-Moorsteen TFP index is represented as:

$$TFP_{HM}^{t,t+1} = \sqrt{\left[\left(\frac{D_O^{t+1}(x^{t+1},y^{t+1})D_O^t(x^t,y^{t+1})}{D_O^{t+1}(x^{t+1},y^t)D_O^t(x^t,y^t)}\right)\left(\frac{D_I^{t+1}(x^t,y^{t+1})D_I^t(x^t,y^t)}{D_I^{t+1}(x^{t+1},y^{t+1})D_I^t(x^{t+1},y^t)}\right)\right]} \tag{2}$$

where $D_I(x,y)$ and $D_O(x,y)$ are input – output distance functions, respectively.

3.2. Stochastic Frontier Model

The stochastic frontier model (SFM) was used for the analysis of efficiency. In fact, the SFM is obtained by adding statistical information to the deterministic model which is:

$$y_i = f(x_i;\beta)TE \tag{3}$$

y_i and x_i are the observed scalar output of the producer and the vector of N inputs used by the producer, respectively. $f(x_i;\beta)$ is the frontier production function. TE denotes the technical efficiency and is defined as the ratio of observed output to maximum feasible output. The maximum producible output expressed as technical inefficiency cannot be obtained from Eq. 3. An alternative models including shocks [one-sided [20] and modification for one-sided [21] are presented in Eq. 4-5 as the model included statistical information.

$$y_i = f(x_i;\beta) + \varepsilon_i \tag{4}$$

$$y_i = f(x_i;\beta) + v_i + u_i \tag{5}$$

In fact, the error term (ε_i) in Eq. 4 is accepted as $\varepsilon_i = v_i + u_i$. In this way, Eq.5 is obtained. v_i and u_i represent random effects (statistical noise, measurement errors, random factors outside the firm's control and random variables that are not included in the production function) and technical efficiency (non-negative random variable representing inefficiency), respectively.

4. RESULTS

The sub-components of Component-1 (scientific and technological research competency - STRCI) have been focused on the analysis of the activities of the universities in the index list. The first of the four components was represented with STRCI, and it was the main component discussed in the research. Balanced panel data analysis was performed and the universities that were included in the list each year for the 4 years examined in the research were obtained with the help of a pivot table.

Thirty-eight universities were included in the analysis, and the universities were presented in Table 2. In calculating the Total Index, the weighted sum of the values of each sub-component standardized by the min-max method has been considered. STRCI is obtained from the first component's sub-components. The ranking has been based on the ranking averages on the list for 4-year data. In addition, the index averages of the universities included in the list for 4-year data have been presented in Table 2.

The first column (*Universities*) was created by taking into account the general ranking numbers of the universities in the EIUI for every year. It can be considered as a general ranking. The second column (*Total Index*) shows the average of the index values. The third column (STRCI) presents the averages according to the Component-1. The ranking presented in parentheses represents the order to be created according to these column values for both.

Depending on the number of personnel and the high occupancy rate of the cells for each university, productivity and efficiency have been examined in this context. The number of academic staff and 5 sub-components of the STRCI have been accepted as input and output, respectively. TFP and SFM were used to analysis productivity and efficiency. Productivity and efficiency values for thirty-eight universities have been presented in Table 3 as *Pro* and *Eff*. All results have been shown in Table 3.

Table 2. General Ranking and EIUI- STRCI average Values and Rankings (in parenthesis) of Universities

Universities	***Total Index***	***STRCI***
MIDDLE EAST TECHNICAL U.	83,0775 (1)	12,4725 (1)
SABANCI U.	76,9275 (2)	10,3150 (6)
ISTANBUL TECHNICAL U.	73,9425 (3)	11,3075 (5)
İHSAN DOĞRAMACI BILKENT U.	72,3000 (4)	11,4950 (3)
YILDIZ TECHNICAL U.	68,0375 (5)	9,2950 (10)
BOGAZICI U.	67,5925 (6)	9,5775 (9)
KOC U.	65,8850 (7)	11,6850 (2)
GEBZE TECHNICAL U.	63,0150 (8)	8,8425 (14)
ÖZYEĞİN U.	61,5150 (9)	6,1100 (28)
IZMIR INSTITUTE OF TECHNOLOGY	61,2150 (10)	9,2675 (11)
HACETTEPE U.	60,0450 (11)	11,4675 (4)
EGE U.	58,5575 (12)	9,1500 (13)
ERCIYES U.	56,3925 (13)	8,1050 (16)
ANKARA U.	54,7850 (14)	9,9525 (8)
ISTANBUL U.	54,4100 (15)	10,0550 (6)
GAZI U.	53,8725 (16)	9,2000 (12)
TOBB ETU	52,1975 (17)	5,9125 (29)
DOKUZ EYLÜL U.	51,2800 (18)	8,1850 (15)
BURSA ULUDAG U.	48,5425 (19)	6,4600 (25)
KOCAELİ U.	45,8175 (21)	5,5800 (33)
AKDENİZ U.	46,0425 (20)	6,9075 (22)
MARMARA U.	44,4825 (24)	7,4550 (18)
SAKARYA U.	45,2075 (22)	6,4750 (24)
SELCUK U.	44,6675 (23)	7,1350 (21)
ATILIM U.	44,4125 (26)	5,7200 (31)
YEDITEPE U.	44,4150 (25)	5,7775 (30)
ISTANBUL MEDIPOL U.	42,6725 (27)	5,6700 (32)
CUKUROVA U.	41,9775 (28)	6,4425 (26)
BAHCESEHIR U.	40,0525 (32)	5,0800 (35)
KARADENIZ TECHNICAL U.	41,6800 (29)	7,2925 (19)
HASAN KALYONCU U.	40,4550 (30)	3,8500 (37)
ATATURK U.	39,5200 (34)	7,4650 (17)
ABDULLAH GUL U.	39,7275 (33)	7,1825 (20)
FIRAT U.	39,4625 (35)	6,8925 (23)
YAŞAR U.	40,4275 (31)	4,6250 (36)
PAMUKKALE U.	38,1550 (37)	5,1175 (34)
SULEYMAN DEMIREL U.	38,7350 (36)	6,1875 (27)
ISTANBUL OKAN U.	35,9975 (38)	3,4350 (38)

Table 3. Productivity and Efficiency Results and Rankings of Universities

Ranking	***Universities***	***Pro.***	***Universities***	***Eff.***
1	AJ Uni, Pr, 92 or Post-92	1,2711	G Uni, Pu, Pre-92	0,9988
2	AF Uni, Pr, 92 or Post-92	1,1755	AA Uni, Pr, 92 or Post-92	0,9368
3	M Uni, Pu, Pre-92	1,1448	U Uni, Pr, Pre-92	0,9216
4	AG Uni, Pr, 92 or Post-92	1,1285	H Uni, Pu, Pre-92	0,9194
5	AE Uni, Pr, 92 or Post-92	1,1172	B Uni, Pu, Pre-92	0,9065
6	J Uni, Pu, Pre-92	1,1020	AB Uni, Pr, 92 or Post-92	0,8270
7	Y Uni, Pu, 92 or Post-92	1,0867	A Uni, Pu, Pre-92	0,8061
8	T Uni, Pu, Pre-92	1,0854	C Uni, Pu, Pre-92	0,7979
9	X Uni, Pu, 92 or Post-92	1,0851	I Uni, Pu, Pre-92	0,7678
10	Z Uni, Pu, 92 or Post-92	1,0756	O Uni, Pu, Pre-92	0,7452
11	AK Uni, Pr, 92 or Post-92	1,0640	V Uni, Pu, 92 or Post-92	0,7430
12	F Uni, Pu, Pre-92	1,0575	P Uni, Pu, Pre-92	0,7376
13	AI Uni, Pr, 92 or Post-92	1,0563	D Uni, Pu, Pre-92	0,7336
14	AB Uni, Pr, 92 or Post-92	1,0558	AL Uni, Pr, 92 or Post-92	0,7089
15	N Uni, Pu, Pre-92	1,0544	R Uni, Pu, Pre-92	0,6562
16	S Uni, Pu, Pre-92	1,0454	N Uni, Pu, Pre-92	0,6498
17	K Uni, Pu, Pre-92	1,0452	F Uni, Pu, Pre-92	0,5985
18	W Uni, Pu, 92 or Post-92	1,0422	T Uni, Pu, Pre-92	0,5977
19	AL Uni, Pr, 92 or Post-92	1,0325	E Uni, Pu, Pre-92	0,5846
20	C Uni, Pu, Pre-92	1,0306	W Uni, Pu, 92 or Post-92	0,5758
21	L Uni, Pu, Pre-92	1,0281	L Uni, Pu, Pre-92	0,5720
22	O Uni, Pu, Pre-92	1,0271	S Uni, Pu, Pre-92	0,5538
23	E Uni, Pu, Pre-92	1,0262	M Uni, Pu, Pre-92	0,5526
24	AH Uni, Pr, 92 or Post-92	1,0261	Y Uni, Pu, 92 or Post-92	0,5191
25	Q Uni, Pu, 92 or Post-92	1,0233	K Uni, Pu, Pre-92	0,5179
26	D Uni, Pu, Pre-92	1,0205	J Uni, Pu, Pre-92	0,5165
27	AA Uni, Pr, 92 or Post-92	1,0201	Q Uni, Pu, 92 or Post-92	0,4960
28	P Uni, Pu, Pre-92	1,0200	AI Uni, Pr, 92 or Post-92	0,4898
29	AC Uni, Pr, 92 or Post-92	1,0185	AH Uni, Pr, 92 or Post-92	0,4740
30	AD Uni, Pr, 92 or Post-92	1,0096	AC Uni, Pr, 92 or Post-92	0,4632
31	V Uni, Pu, 92 or Post-92	1,0032	AD Uni, Pr, 92 or Post-92	0,4586
32	R Uni, Pu, Pre-92	1,0013	AK Uni, Pr, 92 or Post-92	0,4546
33	B Uni, Pu, Pre-92	0,9938	X Uni, Pu, 92 or Post-92	0,4473
34	H Uni, Pu, Pre-92	0,9856	Z Uni, Pu, 92 or Post-92	0,4103
35	I Uni, Pu, Pre-92	0,9827	AE Uni, Pr, 92 or Post-92	0,4072
36	G Uni, Pu, Pre-92	0,9807	AG Uni, Pr, 92 or Post-92	0,3708
37	U Uni, Pr, Pre-92	0,9788	AJ Uni, Pr, 92 or Post-92	0,3086
38	A Uni, Pu, Pre-92	0,9730	AF Uni, Pr, 92 or Post-92	0,2754

5. DISCUSSION

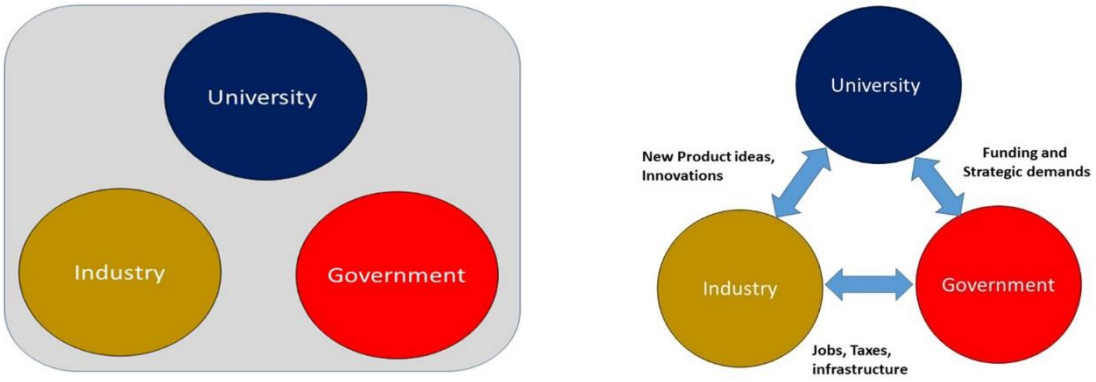
The harmony between the General Ranking (Column 1 in Table 2) and the Total Index Ranging (Column 2 in Table 2) deteriorates at certain intervals after the twentieth university. STRCI Ranking (Column 3 in Table 2) differ significantly from the Total Index Ranking. The top 10 universities for the Total Index

Ranking are as follows: Middle East Technical University, Sabancı University, Istanbul Technical University, İhsan Doğramacı Bilkent University, Yıldız Technical University, Boğaziçi University, Koç University, Gebze Technical University, Özyeğin University, İzmir High Technology Institute. According to the STRCI Ranking, the top 10 universities are listed as follows: Middle East Technical University, Koç University, İhsan Doğramacı Bilkent University, Istanbul Technical University, Sabancı University, Boğaziçi. University, Yıldız Technical University. The universities in the top 10 in both rankings are as follows: Middle East Technical University, Sabancı University, Istanbul Technical University, İhsan Doğramacı Bilkent University, Yıldız Technical University, Boğaziçi University, Koç University.

Three universities (Hacettepe University, Istanbul University, Ankara University) are not in the top 10 according to STRCI ranking. Three Universities established in 1992 and later (Gebze Technical University, Özyeğin University, İzmir High Technology Institute) are not in the top 10 according to the Total Index, but they are in the STRCI top 10 rankings.

In the efficiency analysis, the top 10 universities are listed as follows: G Uni, Pu, Pre-92 - AA Uni, Pr, 92 or Post-92 - U Uni, Pr, Pre-92 - H Uni, Pu, Pre-92 - B Uni, Pu, Pre-92 - AB Uni, Pr, 92 or Post-92 - A Uni, Pu, Pre-92 - C Uni, Pu, Pre-92 - I Uni, Pu, Pre-92 - O Uni, Pu, Pre-92. On the other hand, considering the productivity ranking, the top 10 universities are listed as follows: AJ Uni, Pr, 92 or Post-92 - AF Uni, Pr, 92 or Post-92 - M Uni, Pu, Pre-92 - AG Uni, Pr, 92 or Post-92 - AE Uni, Pr, 92 or Post-92 - J Uni, Pu, Pre-92 - Y Uni, Pu, 92 or Post-92 - T Uni, Pu, Pre-92 - X Uni, Pu, 92 or Post-92 - Z Uni, Pu, 92 or Post-92.

The remarkable result is that there is no university in the top 10 on either list. When the lists are examined in detail, it is seen that the productivity values of universities with high-efficiency values are low, and vice versa.



(a) (b)

Figure 1. (a) Triple Helix Interactions in a Developing Country (Silo Confinement); (b) Beginning of Triple Helix Strategic Interactions in a Middle Income Country (Push-Pull) (Kimatu, J.N., 2016) [22]

There are three basic components in the triple helix model of innovation. Although a mathematical Venn diagram representation is very common in the literature (as shown in Figure 1a for LMICs), the representation in Figure 1b for DCs offers a more transitional structure with borders not separated by red lines. While the terms low- and middle-income countries (LMICs) and developing countries (DCs) can be used interchangeably, this study does not delve into their terminological differences. However, Türkiye's situation appears more suitable for Figure 1b. The primary reason for preferring Figure 1b in this research is the existence of notable points specific to Türkiye in the triangle of academia, industry, and government. For example, TUBITAK is an organization of the Ministry of Industry and Technology

and has strong cooperation with universities. Assigning it to a specific cluster in a Venn diagram might overlook its multifaceted roles. Similarly, the Union of Chambers and Commodity Exchanges of Türkiye (abbreviated in Türkish as TOBB) is a professional organization with a legal personality and the nature of a public institution, which might not fit neatly into an industrial cluster alone. The last but not-to-be-forgotten example is that Technology Transfer offices (TTO) are a formation derived from in the triple helix model of innovation. This organization, which is often located within universities, is a bridge in collaboration with the industry. It may be insufficient to belong only to the academy cluster.

Considering all these analyses, the literature, and Türkiye's dynamics, the adaptation of the Triple Helix Model and interactions for Türkiye is proposed within the scope of this study in Figure 2.

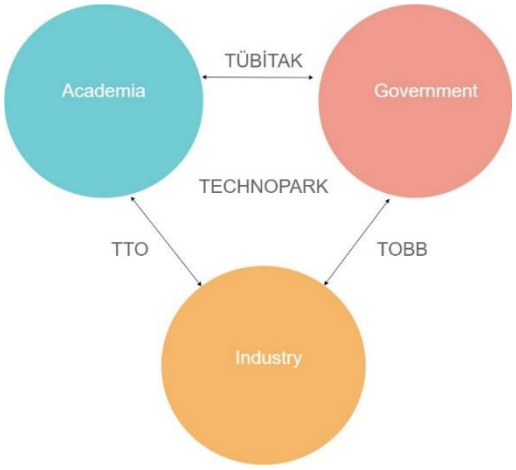


Figure 2. Triple Helix Model and interactions for Türkiye

The visual relationship presented in Figure 2 can be schematized as *the 4T's for Innovation in Türkiye*. Due to the lack of sharp lines, the Venn diagram is not given in an intersecting manner. This can be considered as an advantage rather than a disadvantage. However, according to [22], there are intersections in the developed country innovation diagram, in addition to those presented in Figure 1. Considering Türkiye as a developing country and considering that the interaction between relevant institutions and organizations will relate to protocols in the future, this scheme can be revised and a more comprehensive scheme in the context of the Quadruple and Quintuple Innovation Helix Framework can be presented in the future.

Study limitations and their explanations can be summarized as follows: i) Focusing only on the sub-components of Component-1 (scientific and technological research competency) of the components. The main cause is presented in the *Data*. ii) Although the use of panel data analysis, which contains more information and variability compared to time series and cross-sectional data, is an advantage, the use of short panels with many individuals and few time periods can be considered a limitation. This is because the date of disclosure of the data by TÜBİTAK is not very old and the calculation method has changed. iii) Since there were 4 observations for each university and relatively close values, the average was used. In case there are more observations and values that are far from each other, that is, values with high deviation, more robust statistics can be used against outliers such as median. iv) Analyses were conducted for twenty-three sub-components for thirty-eight universities. In addition, it is a constraint to evaluate universities' only outputs in terms of their innovation roles as "scientific and technological research competence". It may be possible to consider other variables in the EIUI as innovation indicators. For this, a data set with data collected for a longer period and fewer missing cells is needed. v) In the literature, the total budget used to measure the efficiency and effectiveness of universities is the number of staff, number of students, number of programs/departments, purchase of

goods and services, education expenses, research expenses, etc. inputs are available. In future studies, a more comprehensive analysis will be conducted if the relevant data is available for all universities.

6. CONCLUSION

It aimed to discuss the index, productivity, and efficiency results comparatively. Balanced panel data analysis was conducted with thirty-eight universities included in this list for 4-year data. Total factor productivity and stochastic frontier model methods were used for the analysis of productivity and efficiency, respectively. While the studies in literature focused on the meta-analysis of the index and the efficiency analysis of universities with various methods, this study presented an inclusive and comparative analysis in terms of index, productivity, and efficiency with panel data analysis. Data envelopment analysis (DEA) was used for Hicks Moorsteen type TFP in this study. DEA-based Hicks Moorsteen TFP was used due to various calculation conveniences and assumption structures. The reasons for using this method in the productivity analysis of universities have been discussed in detail, and DEA-based Hicks Moorsteen TFP has been applied to Malaysian public universities to measure productivity change in higher education [18]. On the other hand, the SFM, a parametric method based on various assumptions and used in different disciplines [23], has been applied to higher education data in the context of efficiency analysis [16]. Since 1992, a significant milestone in Turkish university history, notable developments and the establishment of numerous universities have marked a transformative period. This pivotal year serves as a reference point in research, particularly evident in studies directly focusing on this period. For instance, a comparative analysis of the strategic plans of 23 state universities established in Türkiye in 1992 has been conducted following the implementation of performance-based budgeting under the 2006 Public Financial Management and Control Law, examining their missions, visions, goals, and objectives [24].

The findings from this study can be summarized as follows:

- Universities established before 1992 that enter the index list every year and rank at the top are efficient, but their productivity has not improved in the same direction.
- Some public and private universities have been able to increase their productivity and efficiency. Although the index value and efficiency values overlap to a certain extent for certain universities, serious differences in productivity in general are striking.
- Compared to previous years, productivity appears to be upward for new (established in 1992 and later) and private universities. On the contrary, effective universities established before 1992 cannot increase their productivity rapidly compared to previous years. This may be because the relevant universities are close to saturation. It can be associated with the level of relevant inputs and outputs.
- The index points in a similar direction to efficiency. However, productivity can proceed in a different direction from efficiency and the index.

The fact that universities established before 1992 may have approached the saturation level (in the context of the input-output relationship) may prevent them from making serious progress in efficiency every year, but it can be said that they can maintain their effectiveness. Although the efficiency of private and new universities (established in 1992 and later) is not high, their productivity may show positive development compared to previous years.

The innovation term, which fundamentally affects the world and is accelerated by universities, can be perceived as self-evaluation and self-criticism by evaluating universities in the context of the innovation term. With the results obtained from here, more productive and effective universities will be the source of more innovative universities.

DISCLAIMER STATEMENT

The analysis results of this study have been presented with labels, excluding information that is publicly accessible to everyone. Comments are provided with general statements based on two groups: post-1992 (1992 and later) and pre-1992 (before 1992). The analyses in this study were conducted using publicly available data related to universities. However, it has been noted by the peer reviewer that some universities may prefer their names to remain confidential for the results of the analyses. Therefore, the names of universities in this study have been labeled, and these labels do not contain any specific judgment or evaluation towards any university. No ethical approval was required for this study because publicly available data were used, and university names were labeled in the analyses presented.

CONFLICT OF INTEREST

The author stated that there are no conflicts of interest regarding the publication of this article.

CRediT AUTHOR STATEMENT

İsmail Yenilmez: Conceptualization, Methodology, Software, Validation, Formal analysis, Investigation, Resources, Data Curation, Writing – Original Draft, Writing – Review & Editing, Visualization, Supervision, Project administration, Funding acquisition.

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