Efficiency Measurement of Turkish Public Universities with Data Envelopment Analysis (DEA)

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Motivation of the Paper

- **Global Trend in the Economics of Higher Education**
  The apparent decrease in state appropriations to universities as well as increasing costs in higher education (Robst, 2001)
- **Turkish Higher Education**
  Dramatic increase in the number of universities between 2005 and 2012 (from 53 to 110)
- **Sources of Inefficiencies and Policy Impact**
  Findings of these papers would have "policy-making implications to the decision makers to set the priorities in the resource allocation for higher education sector" (Erkoc, 2011)

What does this paper do?

- Measures technical and cost efficiencies of public HEIs in Turkey
- Non-Parametric Approach - Data Envelopment Analysis
- VRS with Input and Output Orientations
- Panel Data (Bootstrapping and Malmquist Index)
- Figures out likely sources of inefficiencies - Tobit Regression

Research Questions

To what extent public HEIs in Turkey allocate their resources efficiently?

- What are the overall technical and cost efficiency levels of public HEIs in Turkey concerning different input/output specifications and production/cost frontier?
- How efficiency scores are behaving when bootstrapping procedures are taken?
- To what extent efficiency scores are changing throughout 5-year time span?
- What are the determinants of inefficiencies among public HEIs? Do environmental factors matter for universities concerning efficiency performances?
- What is/are the limitation(s) of this particular analysis? Are the results reliable for forthcoming academic and policy-based researches?

Review of Literature

- Johnes and Johnes (1995) - Coelli (1996) - Madden, Savage, and Kemp (1997)
- Macmillan and Datta's (1998) - Determinants of Inefficiency
- Abbott and Doucouliagos's work (2003) - Australian Universities
- Flegg et al. (2004) - 45 British universities with multi-period DEA

Review of Literature - 2

- Casu and Thanassoulis (2006) - UK universities' central administrative services
- Johnes (2006) - Universities in England & Bootstrapping
- Worthington and Lee (2008) - inter-temporal analysis , Australian universities - Malmquist index
- Ying Chu NG and Sung-ko LI (2009) and Maria Katharakia and George Katharakis (2010)
- **Kutlar (2004), Baysal et al. (2005) Babacan et al. (2007), Ozden (2008)**

Methodology

The efficiency of DMU_0 can be written using the duality property of linear programming; an equivalent form of this envelopment system with variable returns to scale (VRS) is illustrated as:

$$Min\ \theta_0 - \epsilon(\sum_{i=1}^{m} s_i^- + \sum_{r=1}^{n} s_r^+) \tag{1}$$

subject to

$$\sum_{j=1}^{k} \lambda_j X_{ij} + s_i^- = \theta X_{i0}\ , (i = 1, 2, \ldots\ldots, m) \tag{2}$$

$$\sum_{j=1}^{k} \lambda_j Y_{rj} + s_r^+ = Y_{r0}\ , (r = 1, 2, \ldots\ldots, n) \tag{3}$$

$$\sum_{j=1}^{k} \lambda_j = 1\ , (j = 1, 2, \ldots\ldots, k) \tag{4}$$

$$s_r^+, s_i^-, \lambda_j \geq 0\ , (j = 1, 2, \ldots., k) \tag{5}$$

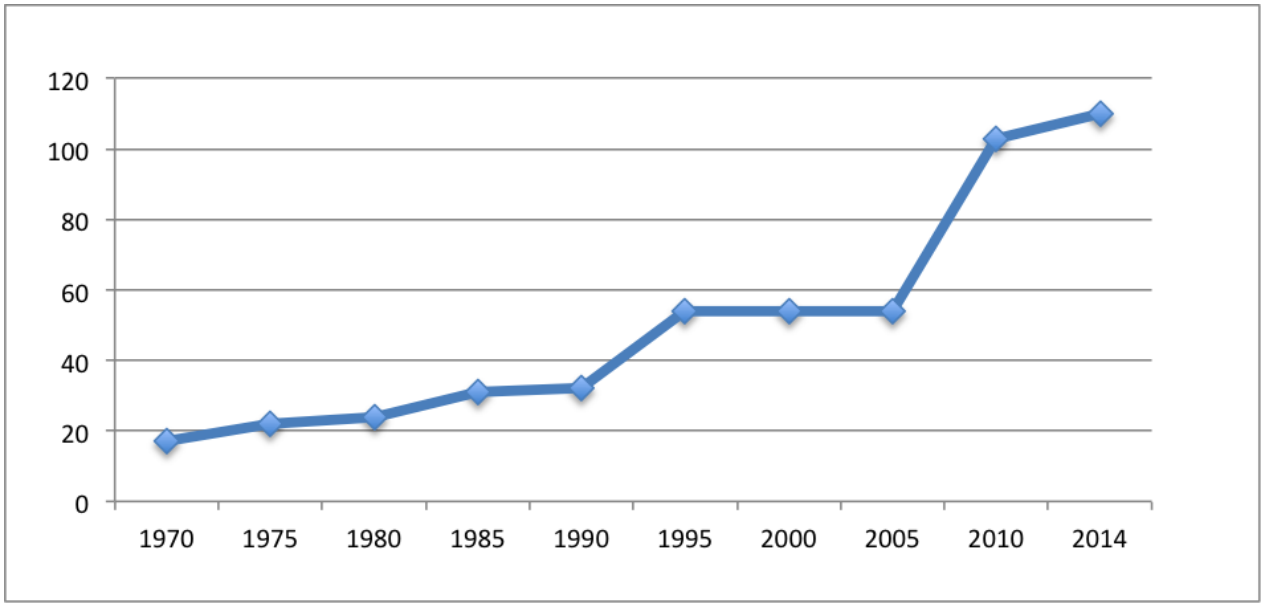
As a result of all these linear programming iterations, the efficiency level of the observed DMU is equal to 100% if and only if:
$\theta_0 = 1$

$s_r^+$and $s_i^- = 0$ for all (i=1,2,. . . .,m) and (r=1,2,. . . .,n).

Methodology - 2

- Bootstrapping
  Provides statistical properties to DEA estimations (Coelli et al., 2005:202)
  're-sampling technique'
- Malmquist Index (Total Factor Productivity)
  MI-TFP evaluates the efficiency change over time.

Glimpse on Public Higher Education in Turkey



- The number of public universities from 1970 to 2014
- 2005 is a critical juncture - 41 public universities mostly in the less developed cities were established as a part of regional development policy
- "governmental aspiration for provision of mass education" (Onder and Onder, 2011).

Variables

- **Output Measures**
  - FT Undergraduate Students
  - FT Postgraduate Students
  - Publications per Faculty (SCI, SSCI and AHCI)
  - Research Grants
- **Input Measures**
  - Number of Faculty
  - Labour Expenditures
  - Capital Expenditures
  - Goods and Services Expenditures
- **Environmental Variables**
  - Age of the university
  - Size of the university
  - Teaching Load per faculty
  - % of full-time staff
  - % of professors among faculty
  - % of foreign students
  - Dummy variable for having medical school (MED).

Data and Models - 1

- 53 public universities
- 2005 and 2010 - 5 academic years
- 265 observations
- Data Sources
  - The Council of Higher Education (YOK)
  - Measurement, Selection and Placement Centre (OSYM)
  - Ministry of Education of Turkey
  - The Scientific and Technological Research Council of Turkey (TUBİTAK)

Data and Models - 2

Table : Descriptive Statistics

Variables	Abbreviation	Obs	Mean	Std.Dev	Min	Max
Outputs						
Number of Undergraduate Students	UG	265	43262.79	148209.7	623	1581743
Number of Postgraduate Students	PG	265	2222.034	2556.401	76	12909
Number of Publications	PUB	265	0.231741	8.03E-02	1.93E-03	0.482192
Amount of Granted Research Project	RES	265	2856732	4613204	7600	4.76E+07
Inputs						
Number of Faculty	FAC	265	1028.16	275	5437	1510.21
Labour Expenditures	LAB	265	68121700	51690600	3744000	297693000
Capital Expenditures	CAP	265	25017500	10661600	500000	83533000
Goods and Services Expenditures	G&S	265	22117700	17283400	2627000	109375000
Financial Output						
Total Annual Expenditures	TC	265	1.28E+08	8.48E+07	8055000	5.10E+08
Environmental Control Variables						
Age of University	AGE	265	27.26415	13.78013	12	66
Size of University	SIZE	265	45484.82	148317.2	1408	1584003
Load of Academic Staff	LOAD	265	28.66435	83.9492	1.22863	888.6197
Percentage of Professors	PROF	265	0.115158	0.064291	0.028874	0.378363
Percentage of Full Time Staff	FTS	265	0.856985	0.241984	0.071222	1
Percentage of Foreign Students	FORGN	265	0.009205	0.012179	0	0.066902
Dummy for Medical School	MED	265	0.679245	0.46765	0	1

Note: *Turkish Liras (TLs)

Data and Models - 3

Table : Model Specifications

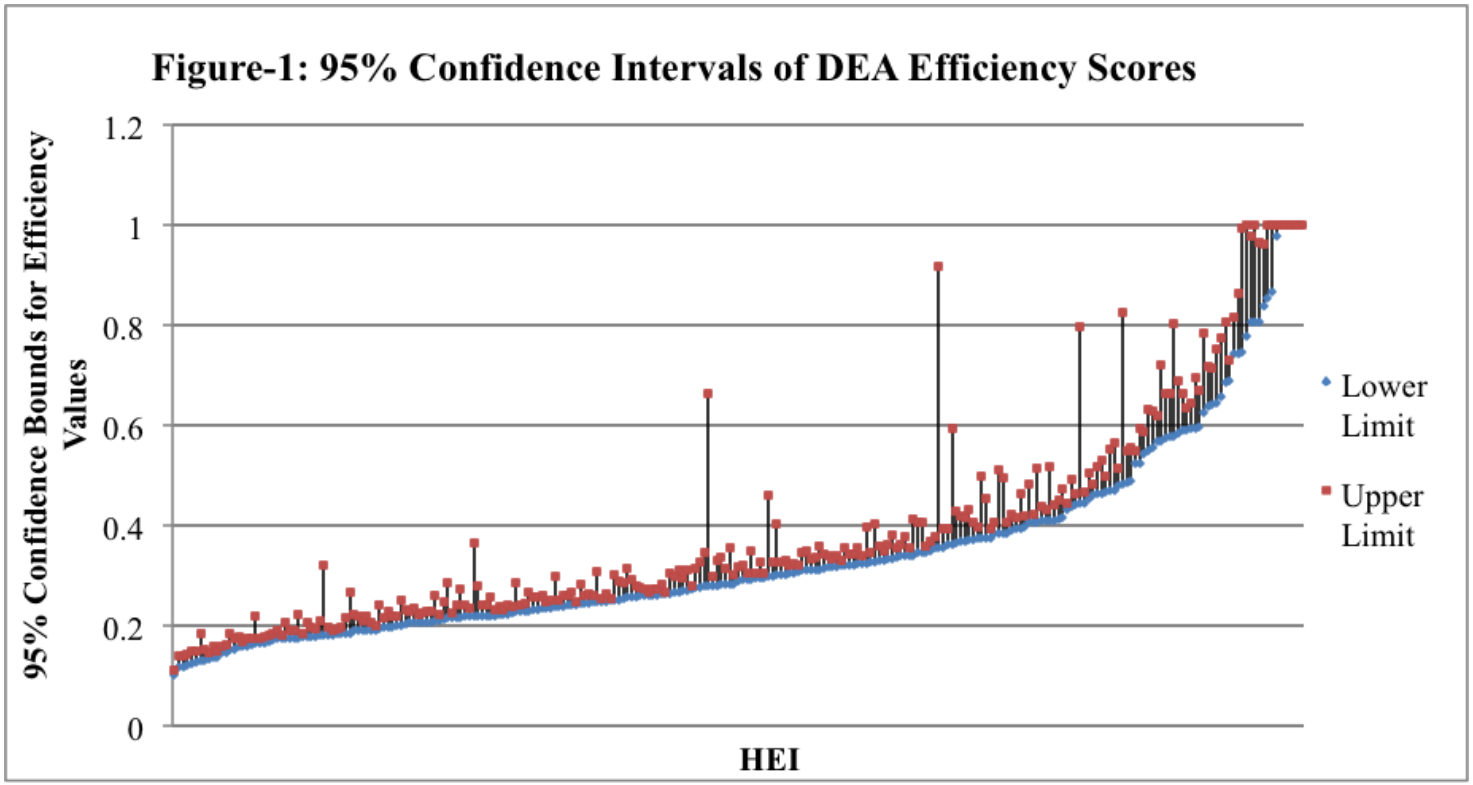
Variables	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6
Outputs						
UG	X	X	X	X	X	X
PG	X	X	X	X	X	X
PUB			X	X		X
RES	X	X	X	X	X	X
Inputs						
FAC				X		
LAB	X	X	X	X		
G&S		X	X	X		
CAP	X	X	X	X		
Financial Variable						
TOTEXP					X	X

Interpretation of Results - 1
Efficiency Values (Technical and Cost Efficiency)

Table : Summary Statistics for Efficiencies (DEA)

Model	Orientation	Mean	Std.Dev	Min	Max
Model 1	Input	0.2769	0.2326	0.0476	1
	Output	0.3303	0.2425	0.0427	1
Model 2	Input	0.3735	0.2267	0.0726	1
	Output	0.3708	0.2487	0.0516	1
Model 3	Input	0.4158	0.24	0.1048	1
	Output	0.6043	0.1924	0.1695	1
Model 4	Input	0.5647	0.2114	0.2267	1
	Output	0.6182	0.1947	0.1755	1
Model 5	Input	0.2525	0.2069	0.0537	1
	Output	0.3114	0.2367	0.0416	1
Model 6	Input	0.3074	0.2367	0.0675	1
	Output	0.5822	0.1928	0.1071	1

Interpretation of Results - 2
Confidence Intervals and Bootstrapping



Interpretation of Results - 3
Malmquist Index (Inter-Temporal Analysis)

Table : Average Malmquist Results across HEIs, by period

Average/Period	Period 1	Period 2	Period 3	Period 4
TFP	1.023	0.6697	1.487	1.1156

Interpretation of Results - 4
Spearman Rank Comparison of DEA Models

Table : Spearman Rank Correlations

Models	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6
Model 1	1					
Model 2	0.896564	1				
Model 3	0.869533	0.955112	1			
Model 4	0.850428	0.880198	0.90661	1		
Model 5	0.964431	0.911273	0.871489	0.853839	1	
Model 6	0.941888	0.905349	0.903175	0.902046	0.96187	1

Determinants of Inefficiency

$$u_{it} = z_0 + z_1 AGE_{it} + z_2 SIZE_{it} + z_3 LOAD_{it} + z_4 PROF_{it} + z_5 FTS_{it} + z_6 FORGN_{it} + z_7 MED_i + \alpha_{it} \quad (6)$$

Tobit regression model
1- efficiency scores yielded in Model 1

Table : Determinants of Inefficiencies

Variables	Pooled	Panel
AGE	-0.00041009	-0.00030839
	(-0.00154432)	(-0.00177478)
SIZE	-0.149576D-05	-0.169582D-05
	(0.12252D-05)	(.17329D-05)
LOAD	0.003159	0.0031588
	(-0.00219382)	(-0.00296712)
PROF	-0.2731	-0.27300681
	(-0.41148656)	(-0.52132894)
FTS	0.12641**	0.12638375**
	(-0.0611377)	(-0.05765066)
FORGN	2.80765	2.80685771
	(-1.86065793)	(-2.61961309)
MED	0.0730076*	0.07392279
	(-0.03921196)	(-0.05037202)
Constant	0.52245***	0.52244864***
	(-0.07449951)	(-0.06441148)
σ_u	0.02243458***	0.02243458
	(-0.00997657)	(-0.02398005)
log-L	7.8755	7.875583

Summary of the Findings

- Public HEIs in Turkey are performing in unsatisfactory levels although some of them are doing fairly well
- As the model gets closer to the full input/output set, both individual and overall efficiency scores are getting relatively higher values
- Spearman Rank Correlations are very high implying that efficiency rankings of the universities are robust
- Even though there is not any systemic increase during this five-year time span, efficiencies of public HEIs in Turkey increased at the course of last two years
- The share of full-time academic staff in the whole faculty and having medical school are founded as the determinants of inefficiencies among HEIs regarding Tobit regression analysis

Limitations & Concluding Remarks

- Inherent Problems of DEA
- Quality of Outputs - Lack of Data
- More data on the environmental variables
- Robustness Checks with SFA