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18 December 2013

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Abstract

This paper investigates 53 public HEIs in Turkey between 2005 and 2010 including 5 full academic terms to estimate both their cost frontier and inefficiencies. The initial findings of six different models imply that Turkish universities perform quite well concerning their overall efficiency values albeit with variations among them. Besides, within this five-year time span, Turkish universities have not shown any improvement in their efficiencies based on Battese and Coelli's (1992) time variant model. In addition to that, the determinants of inefficiencies in Turkish HEIs are dependent upon certain variables. The size of HEIs is seen to be the most influential factor behind inefficiencies referring to the fact that small size universities are expected to experience relatively higher efficiency results. Subsequently, the impact of load factor is as important as the size effect. The negative coefficient implies that, universities with higher load factor demonstrate better efficiency performances. Moreover, age of the university, the percentage of foreign students, percentage of full-time faculty and having medical school are the other variables reducing efficiency in HEIs based on the only one model. Percentage of professors does not have any influence on the inefficiencies according to the both two models.

JEL classification: C23, C24, D24, I23

Keywords: Panel Data Models, Stochastic Frontier Analysis, Cost efficiency, Universities

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*I'd like to express my sincere gratitudes to Dr Gabriella Legrenzi, Prof Gauthier Lanot and Prof David Leece for their valuable comments and feedback, usual disclaimer applies.

1 Introduction

Number of studies measuring the efficiency levels of higher education institutions (HEIs) has dramatically boosted in the frontier analysis literature especially during the last decade (Johnes and Johnes, 2009; Daghbashyan, 2011) . The evident decline in state appropriations (share of government's financial support) to universities as well as increasing costs in higher education can be put forward as the main driving forces behind this proliferation (Robst, 2001). This in turn leads decision-makers in higher education to be more cautious on efficiency performances of their institutions. Accordingly, works in this particular area of research are being put forward as recommendation papers both to the administrative bodies of universities and governmental institutions. That is to say, 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, 2011a).

Although the number of researches on higher education concerning efficiency analysis has risen, literature of econometric research on HEIs in Turkey is relatively scarce in comparison with other equivalent countries. This paper that fills this salient gap in the literature investigates 53 public universities in Turkey between the full academic year of 2005-2006 and 2009-2010 covering 5-year time span. In this research, number of undergraduate students, postgraduate students and research funding are taken as outputs, capital and labour expenses as input prices and eventually annual expenses as total cost. Moreover, university-based characteristics are integrated to the model so as to capture possible heterogeneities among the universities.

This research aims to give meaningful answers to the following questions:

1.What are the fundamental components of cost function of HEIs in Turkey?

2.What is the cost elasticity of each factor of production?

3.How do the public HEIs in Turkey perform concerning efficiency levels?

4.Is there any improvement in 5-year time span?

5.What are the determinants of inefficiencies in Turkish public higher education?

The outline of this paper is as follows: section II reviews literature on the efficiency analysis of higher education institutions; section III clarifies methodological underpinnings of the research. Section IV defines dataset and describes variables composed of input prices, outputs, total cost and university-based characteristics. The empirical model constructed to perform this analysis is revealed in section V. Section VI is the interpretation of results that discusses both the parameters of regression and determinants of inefficiency. Although stochastic frontier analysis is the prominent way of conducting efficiency analysis, it does have limitations. These limitations are touched upon in the concluding section VII.

2 Estimating Economic Efficiencies of HEIs with Stochastic Frontier Analysis (SFA)

The efficiency performances of HEIs have become a central question in higher education policy-making over the course of recent decades. Accordingly, decision-making process as regards financing of higher education commenced to include performance indicators of universities on the basis of empirical findings. The first and foremost motivation for governmental bodies to set out certain performance measurements in this particular sector is the belief that these findings "will control higher education costs and force institutions to provide an education more efficiently" (Robst, 2001). Moreover, government's interest in efficiency is seen as a crucial subject "as it seeks to demonstrate to the taxpayer that resources are being wisely spent"(Izadi et al., 2002).

The increasing awareness among policy-makers concerning resource allocation in higher education led academic researchers to dwell on this area more cautiously. Hence, both the number of academic and policy-reflection papers has gone up in a remarkable way. In those papers, to be able to illustrate and examine efficiency levels of HEIs, two separate methodologies, stochastic frontier analysis (SFA) and data envelopment analysis (DEA), have been applied to the university-orientated cases. As this chapter's analytical approach is SFA, this section is consisted of the review of the papers in which stochastic frontier framework is implemented.

The pioneering work on this area of research is Robst's (2001) piece that is mainly concentrated on figuring out the impact of financial support of the state (called as appropriations) on cost efficiencies of HEIs in South Carolina. Conducting both OLS and MLE techniques with half-normal model on 440 institutions for a five-year period, Robst concludes that universities with smaller state appropriations are not more efficient than the universities with higher state appropriations. This argument that seems to contradict with the conventional wisdom, asserts the fact that the amount of state's financial support does not have any evident association with efficiency performances of universities.

Besides, thanks to the time-varying inefficiency model where the level of inefficiency is allowed to vary year by year, Robst's paper reveals the fact that "most institutions' state share of revenues fell, but institutions with smaller state share declines increased efficiency more than institutions with larger state share declines". It is noticeable from this statement that in South Carolina case, HEIs faced fewer declines in financial support (coming from state appropriations) are more adaptive to the *ex post* conditions as well as have shown betterments in efficiency levels than their counterparts confronted larger declines.

Following this study, Izadi et al. (2002) undertook a research on 99 UK universities for 1994-1995 full academic year concerning CES multi-product cost function with half normal model. The main aim of that paper is to "produce measures of scale and scope economies, and to provide information about the technical efficiency of each institution" in the given sample. In doing so, both the increase in output level (economies of scale) and the diversification of it (economies of scope) in UK higher education are taken into consideration. After taking required analytical steps, researchers come up with the conclusion that British universities are suffering from inefficient usage of resources which renders discussion over the level of autonomy among universities as well as "requires a study of principal–agent issues within higher education", nonetheless there is not any comprehensive discussion and/or conclusion on the determinants of inefficiencies. Besides, whereas "economies of scope are absent" in British universities, there are economies of scale for post-graduate teaching and research outputs.

In another study in which SFA is employed to estimate cost efficiencies of English and Welsh universities, Stevens (2001) put forward that those universities are showing remarkable amount of inefficiencies. The paper argues that there is a strong sign of "convergence in the efficiency of institutions" implying the fact that less efficient universities are in the route of 'catch-up' to the well-practising universities that are nearer to the cost-frontier. Besides, the introduction of tuition fees appears to be influential for less efficient institutions to reorganise their cost structures. Lastly, it is worth emphasising here that Stevens' work has a unique aspect in the sense that his paper remains the first research modelling inefficiency levels of universities as a function of their student and staff characteristics.

Mensah and Werner (2003) extended preceding analyses and integrated financial flexibility arguments in efficiency literature. Whereas financial autonomy is seen indispensable for universities to keep up their on-going activities, the extent of its borders has always been questioned. The level of autonomous decision-making to allocate resources in HEIs that are mainly consisted of governmental support and donations specifies the degree of financial flexibility among them. In their paper, Mensah and Werner disclosed a "positive relationship between the degree of financial flexibility and cost inefficiency for all types of private higher education institutions" in the selected sample. Therefore, a common belief stating that greater financial flexibility would lead universities to be more efficient is challenged by that result which encourages more restrictions on financial decisions.

Panel data analysis on 121 British universities for three full academic years conducted by Johnes and Johnes (2009) is another substantial study worth examining and emphasising in this section. In that paper, parametric frontier model is constructed to become closer to DEA by the means of random parameter model. The main motivation behind this attempt is to differentiate inefficiencies from unobserved heterogeneities among universities motivated particularly by 'idiosyncratic cost technologies' that have been counted as inefficiencies in the earlier researches. That is to say, this research alleviates the problem of unobserved heterogeneity in the estimation of cost efficiencies within higher education sector "by allowing parameters to vary across institutions, cost functions for institutions that are obviously quite different from one another can be estimated within a single, unified framework, obviating the need for separate equations to be estimated for exogenously determined groups of institutions."

In addition to its distinctive form of methodology, findings derived from the piece mentioned above need to be stated here. Firstly, the results are nearly in line with the prior literature for British HEIs regarding efficiency scores as well as economies of scale and scope. Secondly, authors argue that technical efficiency is higher in top 5 and civic universities (located in large cities), whilst Colleges of Higher Education experiences relatively lower efficiency values. And thirdly, they revealed product-specific returns to scale for British universities by claiming that the universities exhaust economies of scale for undergraduate students whereas for post-graduate education they do not.

Another research that has significance in the efficiency of HEIs literature is Daghbashyan's (2011) recent paper on the economic efficiency of 30 Swedish universities. In addition to the estimation of economic efficiencies of chosen universities, that paper sheds light on the arguments around the determinants of inefficiency in higher education. The chief conclusion from those findings is that Swedish universities are not demonstrating identical efficiency performances, although their average score is relatively high. Therefore, for the second step, it is necessary for a researcher to examine and illuminate the driving forces behind this variation. Daghbashyan (2011) argues that efficiency variations among the universities are significantly correlated with university-specific factors including "size, load, staff and student characteristics" by employing truncated inefficiency term model.

3 Methodology

Stochastic cost frontier analysis (SCFA hereafter) basically defines minimum cost in a given output level and input prices relying on existing technology of production (Farsi et al., 2005). In this way of measurement, efficiency level of a particular institution or a firm is gauged with respect to the inefficient usage of inputs within a given cost function. The key difference between stochastic and deterministic models is that stochastic analysis comprises error term (Karim and Jhantasana, 2005), therefore it can separate the inefficiency effect from statistical noise. That is to say, deterministic models are not capable of differentiating the influence of irrelevant factors or unexpected shocks on output level.

The cost function of a firm represents the minimum amount of expenditure for a production of a given output; therefore if the producer is operating inefficiently its production costs must be greater than theoretical minimum. Then, it is quite obvious that frontier cost function can be assigned as an alternative to frontier production function (Greene, 1997). In a similar vein, frontier production function can be converted to frontier cost function via changing the sign of inefficiency term (u_i) component consisting of both technical and allocative inefficiency (Kumbhakar and Lovell, 2000). Decomposition of the inefficiency term into the technical and allocative components is set out by Aigner et al. (1977) for Cobb Douglas functions and Kopp and Divert (1982) for general Translog cases.

Unlike in the estimation of technical efficiency relying on output-oriented approaches, SCFA prioritise input-oriented approaches to estimate efficiency on the cost frontier (Zhao, 2006). Furthermore, Zhao (2006) puts forward that estimating cost efficiency differs from technical efficiency estimations in the sense of 'data requirements, number of outputs, quasi-fixity of some inputs and decomposition of efficiency itself'. Eventually, following the econometric framework put forward by the pioneering works in this area (Aigner et al. 1997; Meeusen and Van den Broeck, 1977) the function is specified as:

$$ln(C_i) = lnC(p_i, q_i; \theta) + v_i + u_i \tag{1}$$

Where C_i is the observed cost, p_i is a vector of input prices, q_i is a vector of output prices, θ is a vector of technology parameters to be estimated, u_i is a non-negative stochastic error capturing the effects of inefficiency and v_i is a symmetric error component reflecting the statistical noise. Cost efficiency can be illustrated as:

$$CE_i = \frac{C(p_i, q_i; \theta) exp(u_i)}{C_i} \tag{2}$$

Where CE_i reflects the ratio of the minimum possible cost, given inefficiency u_i ,to actual total cost. If $C_i = C(p_i, q_i;).exp(u_i)$, then $CE_i = 1$ and we can say that firm i is fully efficient. Otherwise actual cost for firm i exceeds the minimum cost so that $0 < CE_i \leq 1$.

While departing from traditional multi-product cost functions which formulates total cost as a function of level of output, input prices and some exogenous factors, cost function of HEIs –which will be estimated by stochastic frontier analysis– can be described as follows:

$$C = c(y, w, z, \beta, \lambda, \gamma) \tag{3}$$

The chief obstacle to estimate cost function particularly for multi-output cases is opting for appropriate functional relationship between cost variable and independent variables. Previous researches have bifurcated into restrictive (Cobb-Douglas, CES, Leontief) and flexible (Translog, Quadratic, Generalised Translog) cost function models that have both pros and cons. Whereas the former group has simplistic structure and demands less data for analysis, researchers prefer the latter "because they are less restrictive and provide local second-order approximation to any well-behaved underlying cost function" (Daghbashyan, 2011).

For higher education case, authors relating to different data structures used these aforementioned models.Robst (2001) opted for translog cost function for South Carolina universities; Izadi et al. (2002) estimated CES function for UK universities, and Johnes and Johnes (2009)preferred quadratic cost function model for UK universities. In the recently published paper, Daghbashyan (2011) used Cobb-Douglas functional form due to its "simplicity enables to focus on the inefficiency problem which is the major concern of this analysis". Last but not least, the choice of functional form becomes more central when the numbers of outputs and inputs as well as observations increase.

4 Data and Empirical Model

The dataset of this research is a balanced panel that covers 53 public HEIs in Turkey over the time span from 2005 to 2010, and corresponding to 265 observations. The sample includes all public HEIs that had operated during the specified period. Hence, universities opened up 2005 and onwards are excluded from this sample. Besides, sample comprises 14 institutions established in Istanbul, Ankara and Izmir that are the three largest cities of Turkey, and rest of them are dispersed almost homogenously all around the Turkey.

The large extent of the data consisting of number of undergraduate and postgraduate students, number of academic staff and profile of them are collected from the statistics of The Council of Higher Education (YOK) as well as the Almanac of Student Selection and Placement Centre (OSYM). Moreover, the detailed information on derived input prices is published in Statistical Year Book of Ministry of Education. Lastly, the Scientific and Technological Research Council of Turkey (TUBITAK) releases report on the amount of research funds granted to the universities annually. The descriptive statistics of the whole dataset is presented below at Table-1:

Table 1: Descriptive statistics

Variables	**Abbreviation**	**Mean**	**Std. Dev.**	**Min.**	**Max.**
Output					
Number of Undergraduate Students	UG	43262.79	148209.7	623	1581743
Number of Postgraduate Students	PG	2222.034	2556.401	76	12909
Research Grants	RES	2856732	4613204	7600	4.76E+07
Input Prices					
Price of Labour	LAB	44734.24	10632.56	1663.751	83045.56
Price of Capital	CAP	1494.715	1723.414	12	14418
Total Cost					
Total Annual Expenditures	TC	1.28E+08	8.48E+07	8055000	5.10E+08
University-based Characteristics					
Age of University	AGE	27.26415	13.78013	12	66
Size of University	SIZE	45484.82	148317.2	1408	1584003
Teaching Load	LOAD	28.66435	83.9492	1.22863	888.6197
Percentage of Professors	PROF	0.115158	0.064291	0.028874	0.378363
Percentage of Full Time Staff	FTS	0.856985	0.241984	0.071222	1
Percentage of Foreign Students	FORGN	0.009205	0.012179	0	0.066902
Dummy for Medical School	MED	0.679245	0.46765	0	1
Note : Prices are in Turkish Liras (TLs)					

To estimate cost function of public HEIs in Turkey, two separate specifications are carried out. The former model is Cobb-Douglas cost function that is narrated as:

$$
\begin{aligned}
ln(TC) = {} & \beta_0 + \beta_1 lnUG + \beta_2 lnPG + \beta_3 lnRES + w_1 lnLAB + w_2 lnCAP \\
& + z_1 AGE + z_2 SIZE + z_3 LOAD + z_4 PROF + z_5 FTS + z_6 FORGN \\
& + z_7 MED + v_{it} + u_{it} \qquad (4)
\end{aligned}
$$

and the latter one is Translog cost function, which is shown below:

$$
\begin{aligned}
ln(\frac{TC}{CAP}) = {} & \beta_0 + \beta_1 lnUG + \beta_2 lnPG + \beta_3 lnRES + w_1 ln(\frac{LAB}{CAP}) \\
& + 0.5\beta_{11}(lnUG)^2 + 0.5\beta_{22}(lnpG)^2 + 0.5\beta_{33}(lnRES)^2 + w_{11} ln(\frac{LAB}{CAP})^2 \\
& + \beta_{1L} lnUGln(\frac{LAB}{CAP}) + \beta_{2L} lnPGln(\frac{LAB}{CAP}) + \beta_{3L} lnRESln(\frac{LAB}{CAP}) \\
& + \beta_{12} lnUGlnPG + \beta_{13} lnUGlnRES + \beta_{23} lnpGlnRES + z_1 AGE \\
& + z_2 SIZE + z_3 LOAD + z_4 PROF + z_5 FTS + z_6 FORGN \\
& + z_7 MED + v_{it} + u_{it} \qquad (5)
\end{aligned}
$$

where TC is the observed annual cost for each and every HEI ; β ,w and z are the parameters to be estimated; u is a non-negative stochastic error capturing the effects of inefficiency and may have half-normal and truncated distributions and lastly v is a symmetric error component reflecting the statistical noise.

As the distribution of inefficiency term as well as incorporating environmental factors would influence cost function and efficiency performances of universities, different frontier models that are described below need to be developed:
Model A1: Cobb-Douglas cost function, without environmental variables, normally distributed inefficiency terms, and panel data
Model A2: Cobb-Douglas cost function, with environmental variables, normally distributed inefficiency terms, and panel data
Model A3: Cobb-Douglas cost function, with environmental variables, normally distributed inefficiency terms, and pooled data
Model B1: Translog cost function, without environmental variables, normally distributed inefficiency terms, and panel data
Model B2: Translog cost function, with environmental variables, normally distributed inefficiency terms, and panel data

Model B3: Translog cost function, with environmental variables, normally distributed inefficiency terms, and pooled data.

In the following section, thanks to developing hypothesis testing, statistical superiority of the models will be compared and contrasted which provide meaningful insights to come up with best-fitted model.

5 Interpretation of Results

This section is the summary of the stochastic cost frontier results of public HEIs in Turkey concerning different cost specification models, the structure of inefficiency values and the influence of environmental variables. Furthermore, the conclusions of hypothesis testing for cost function as well as the Spearman rank correlations are revealed to check the robustness of the results. Last but not least, the determinants of inefficiencies are discussed by the means of truncated inefficiency (or conditional mean) model.

5.1 Cost Frontier Parameters

In this sub-section, parameters of cost function (β, w and z) will be revealed pertaining to the various scenarios comprising pooled data and panel data characteristics as well as different cost specification functions including Cobb-Douglas and Translog. For the panel data analysis, Battese and Coelli's (1992) time-variant inefficiency model is preferred so as to capture and illustrate probable improvements during this particular time-period. Besides, all cost frontiers are estimated with Maximum Likelihood Estimation (MLE) by the means of *LIMDEP Version 9.0*.

5.1.1 Cobb-Douglas Specification

The cost frontier estimates for Cobb-Douglas specification concerning three different models are shown below in Table-2.

The statistical power of frontier models is profoundly influenced by the lambda values that represent the relative shares of inefficiency term (u_i) and statistical term (v_i) into the traditional error term (e_i). If λ is firmly differing from 0, this signs the fact that the share of inefficiency term is forming the significant part of the error term. That is to say, divergence from cost frontier is significantly motivated by inefficiency component; hence the frontier model comprises consequential information for the efficiency performances of decision-making units (DMUs).

All these three models examined below have higher values than 0 for λ as well as they are significantly different from 0 corresponding to the fact that all estimations are eligible for efficiency analysis. Besides, likelihood ratio (LR) test indicates that Model A3 has superiority over to the other two models due to the fact that it has the likelihood value 198.4807, whereas the Model I and Model II have 35.00389 and 48.52817 respectively.

In relation to the estimates of parameters, although there are evident discrepancies among the technology parameters, they by and large resemble each other particularly in Model A2 and Model A3. In three models, the coefficients of prices of labour and capital are significantly differing from 0 and accordingly forming the major components of total cost. Besides, as the Table-2 points out apparently, the share of labour seems to be greater than the share of capital in the total cost excluding Model A1 in which environmental variables are not included.

The estimated parameters of outputs (βs) have positive signs that were expected as well as statistically significant for all three models. As its easily seen from the cost frontier estimates, incorporation of environmental variables has reduced the extent of the impact of the number of postgraduate students and research output over to the total cost. Moreover, undergraduate teaching is highly influential in the cost function when it is compared with the research output. Its cost elasticity is five times greater than research output in Model A1, and almost eleven times greater in Model A2 and A3.

The final analysis for this part is the interpretation of *(Z)*s representing the coefficients of environmental variables. Table-2 reveals that each and every environmental variable is significantly correlated with total cost regarding different significance levels. The age and size of the university as well as the percentage of professors and foreign students are increasing the costs as would be anticipated. The proportion of foreign students seems to be the most influential variable among all the other ones both in the Model A2 and Model A3.The load factor of the university that is the ratio of students over academics is negatively affecting total cost. Although the rise in the load of the academic staff may end up with lower quality of teaching and research, it is significantly diminishing the total costs in the universities. And eventually, having medical over and above the percentage of full-time academic staff is increasing costs in both models (Model A2 and A3).

Table 2: Cobb Douglas Cost-Frontier Results

Variables	**Model A1**	**Model A2**	**Model A3**
Constant	1.6942***	3.9848***	3.9868***
	(-0.5431)	(-0.00027)	(-0.193)
lnUG	0.6191***	0.5466***	0.0299***
	(-0.0344)	(-0.00037)	(-0.021)
lnPG	0.2182***	0.0290***	0.5458***
	(-0.0175)	(-0.00016)	(-0.0102)
lnRES	0.1159***	0.0556***	0.0558***
	(-0.0149)	(-0.00012)	(-7.00E-04)
lnLAB	0.3288***	0.4838***	0.4833***
	(-0.0406)	(-0.00027)	(-0.0149)
lnCAP	0.5202***	0.3625***	0.3627***
	(-0.03899)	(-0.00022)	(-0.0207)
lnCAP	0.5202***	0.3625***	0.3627***
	(-0.03899)	(-0.00022)	(-0.0207)
AGE		0.0054***	0.0054***
		(-0.00019)	(-0.0004)
SIZE		0.0097***	0.0000096***
		(-0.0002)	(-5.70E-08)
LOAD		-.0179***	-.0177***
		(-3.40E-03)	(-5.70E-04)
PROF		0.1993***	0.1975*
		(-0.00035)	(-0.123)
FTS		0.0646***	0.064***
		(-0.00077)	(-0.0214)
FORGN		3.1711***	3.1939***
		(-0.0002)	(-0.915)
MED		0.0923***	0.0921***
		(-0.00073)	(-0.0143)
λ	2.5361***	368.184***	3393.506***
	(-0.07407)	(-0.0009)	(-1691.77)
σ_u	0.4072***	0.2297***	0.22880***
	(-0.01661)	(-0.004)	(-0.0006)
η	0.0042	0.01***	
	(-0.025635)	(-0.0045)	
log-L	35.00389	48.52817	198.407

Notes : 1. ***, **and *indicate 1%, 5% and 10% significance levels respectively.

2.Asymptotic standard errors are in parentheses.

5.1.2 Translog Specification

Prior to illustrate regression results of Translog specification, it is worth stating here that although Translog function provides more flexible analysis than Cobb-Douglas, cost frontier model may suffer from multicollinearity problem which would lead inconsistent estimates of parameters. The sign of the second-order condition for number of postgraduate students (which is negative) violates the fundamental rule of cost function that should be non-decreasing in outputs and input prices and accordingly signals the problem of multicollinearity.

At this point, there is a precise need to reveal the fact that the strong positive correlation between first order and second order terms in the Translog cost function provides still unbiased and efficient parameters for maximum likelihood estimation; nonetheless the standard errors may get higher values which cause smaller t-ratios for parameters (Gujarati, 2003). From another perspective Dong (2009) argues "multicollinearity may not be a severe problem when efficiency scores are used purely for forecasting purposes". Since the rest of the parameters have expected signs that are in line with the assumptions of conventional cost function, cost frontier estimates of Translog specification are added to this analysis.

The cost frontier estimates of Translog function pertaining to three different models are shown in Table-3. All three models have higher λ values than 0 that proves the fact that the distance from the frontier is significantly motivated by inefficiency terms . The cost frontier parameters for these aforementioned models resemble to each other with slight dissimilarities. The coefficient of price of labour is statistically significant with having expected signs. The cost elasticity with respect to the price of labour is considerably highly across the three models ranging from 1.463 to 2.139. That is to say, 1% increase in price of labour would end up with 1.75% increase in total cost on average.

Number of undergraduate students seems to have insignificant parameter even though it has expected sign. As the second order term of it has reasonable coefficient for a cost function with positive sign, the insignificance of it might be the consequence of multicollinearity that motivated standard error to get higher values. Moreover, the coefficient of number of postgraduate students is 0.28 in the Model B2 that indicates that if the number of postgraduate students is raised by 1%, total cost will go up by 0.28%. In a similar vein, the parameter of research output gets the values of 0.2 both in Model B2 and B3 claiming that 1% increase in the amount of research output will influence total cost to rise by 0.2%. Therefore, it could be argued that the magnitude of the coefficient of number of postgraduate students seems to be higher than the coefficient of research output.With regards to the environmental variables, the age and size of the university as well as the load of academic staff are the highly significant variables for all three models with their anticipated signs. The rest of the university-based variables except percentage of professors among academic staff have significant coefficients at least in two models.

The last discussion points for the panel data analysis (both Cobb-Douglas and Translog specifications) is whether or not inefficiency terms change over time. In the analysis conducted above, Models A1, A2 and B1, B2 have assumed inefficiencies alter throughout five years on the basis of Battese and Coellis (1992) time-varying efficiency estimation. The estimated (η)s concerning four different models have got insignificant values except in Model A2. This inference leads to reach to the conclusion that inefficiency terms are not varying because of time, but other factors. This may be the consequence of narrow time-span, thus extending dataset for future research would contribute more sophisticated results in relation to time-specific effects.

Table 3: Translog Cost-Frontier Results

Variables	**Model B1**	**Model B2**	**Model B3**
Constant	9.097305	-0.35439835	-0.354398
	(7.355)	(0.5667)	(1.3788)
lnUG	-0.9550621	0.1419931	0.1419931
	(1.0081)	(0.1083)	(0.2261)
lnPG	0.157686	0.2876***	0.2876278
	(0.3396)	(0.0423)	(0.1784)
lnRES	-0.3330358	0.2067***	0.206725*
	(0.5858)	(0.026)	(1.10E-01)
$ln(P_l/P_k)$	1.463***	2.1398***	2.13988***
	(0.4583)	(0.0459)	(0.2364)
0.5 lnUGxlnUG	0.393***	0.2945***	0.29457***
	(0.0584)	(0.0125)	(0.0381)
lnUGxlnPG	-.07205**	-.0577***	-.05775**
	(0.034)	(0.0048)	(0.023)
lnUGxlnRES	-0.0289111	-.0754***	-.076**
	(0.0689)	(0.0042)	(0.0175)
0.5 lnPGxlnPG	0.050955	-.0155***	-0.0145
	(0.0311)	(0.0057)	(0.0173)
lnPGxlnRES	0.013529	0.0149***	0.014945
	(0.0213)	(0.0033)	(0.0108)
0.5 lnRESxlnRES	0.024719	0.0301***	0.031***
	(0.026)	(0.003)	(0.0085)
0.5 $ln(P_l/P_k)$x$ln(P_l/P_k)$	0.278***	0.1517***	0.1521***
	(0.046)	(0.0051)	(0.0441)
lnUGx$ln(P_l/P_k)$	-0.3577***	-0.2548***	-0.2614***
	(0.04108)	(0.0073)	(0.0394)
lnPGx$ln(P_l/P_k)$	0.046443	0.0523***	0.0519*
	(0.0367)	(0.0042)	(0.028)
lnRESx$ln(P_l/P_k)$	0.0848**	0.004532	0.004429
	(0.0369)	(0.0032)	(0.022)

Table 3 : Translog Cost-Frontier Results (cont'd)

Variables	**Model B1**	**Model B2**	**Model B3**
AGE		0.0054***	0.0052***
		(0.0009)	(0.0007)
SIZE		0.00001***	0.000012***
		(2.00E-07)	(8.70E-07)
LOAD		-0.02048***	-0.02051***
		(6.00E-04)	(1.30E-03)
PROF		0.00431235	0.00421345
		(0.0617)	(0.208)
FTS		0.0519***	0.0521***
		(0.0143)	(0.0344)
FORGN		3.2903***	3.3102***
		(0.8812)	(1.0668)
MED		0.0527	0.025
		(0.1048)	(0.1052)
λ	2.4406***	9.0280***	9.0310***
	(0.07096)	(0.0285)	(3.29802)
σ_u	0.3114***	0.1994***	0.20068***
	(0.0069)	(0.002)	(0.00054)
η	0.01	0.01	
	(0.0236)	(0.006)	
log-L	76.31421	-2184.374	214.1277

Notes : 1. ***, **and *indicate 1%, 5% and 10% significance levels respectively.

2.Asymptotic standard errors are in parentheses.

5.2 Hypothesis Testing for Model Specification

In the efficiency literature, figuring out the most appropriate frontier has always seen as a valuable attempt owing to the fact that efficiency scores of the DMUs are estimated with respect to the chosen frontier. Therefore, researchers in this area of interest have carried out certain tests and procedures to be able to check the statistical strength of their models as well as contribute remarkable insights to the theoretical discussions on the structure of cost and production functions. For this particular research, so as to come up with best-specified cost frontier model belonging to the public HEIs in Turkey, likelihood ratio (LR) tests which "provide a convenient way to check whether a reduced (restricted) model provides the same fit as a general (unrestricted) model" will be conducted in two steps.

In the first step, the structure of cost function will be under scrutiny through which Cobb-Douglas and Translog specifications are compared and contrasted. That is to say, first step of the hypothesis testing includes checking whether estimated parameters of second-order terms in Translog cost function are equal to zero or not. In the second step, validity of incorporating environmental variables into the model will be investigated. To put it differently, this particular test will scrutinise the likelihood of having all coefficients of environmental variables equal to zero.

Table-4 summarises the test results of first step through which the statistical power of Cobb-Douglas cost specification is examined against its Translog counterpart. The LR tests for having all the coefficients of second-order terms equal to zero are statistically rejected with the values ranging from 91.1611 to 137.9374. As a consequence of the first step hypothesis testing results, Translog specification gains an obvious superiority over to the Cobb-Douglas; hence the models beginning with B could be preferred vis a vis the models named by A.

The LR test values of the second step of the hypothesis testing are demonstrated in Table-5. In this particular analysis, incorporation of environmental factors including age, size and load of the HEIs alongside with their student and staff characteristics into the model specification is evaluated. The LR test conducted to compare B1 and B2 has the value of 4521.3 claiming that the likelihood of having all the coefficients for environmental variables equal to zero is rejected with almost 100% confidence interval. Conversely, the LR test value between A1 and A2 is equal to 0.136 corresponding to the fact that null hypothesis cannot be rejected. However, as the Translog specification has already got superiority over to the Cobb-Douglas, the former LR test value dominates to the latter one.

Table 4: Hypothesis Testing : Cobb-Douglas vs. Translog

Models	**Null Hypothesis**	**Value of LR-Test**	$Prob > \chi^2$	**Decision (5% Level)**
A1 vs. B1	$H_0 : \beta_{11}{=}\beta_{22}{=}\beta_{33}{=}w_{11}{=}\beta_{1L}{=}\beta_{2L}{=}\beta_{3L}{=}\beta_{12}{=}\beta_{13}{=}\beta_{23}{=}0$	137.9374	0.0000	reject H_0
A2 vs. B2	$H_0 : \beta_{11}{=}\beta_{22}{=}\beta_{33}{=}w_{11}{=}\beta_{1L}{=}\beta_{2L}{=}\beta_{3L}{=}\beta_{12}{=}\beta_{13}{=}\beta_{23}{=}0$	94.2554	0.0000	reject H_0
A3 vs. B3	$H_0 : \beta_{11}{=}\beta_{22}{=}\beta_{33}{=}w_{11}{=}\beta_{1L}{=}\beta_{2L}{=}\beta_{3L}{=}\beta_{12}{=}\beta_{13}{=}\beta_{23}{=}0$	91.1611	0.0000	reject H_0

Table 5: Hypothesis Testing : Incorporation of Environmental Variables

Models	**Null Hypothesis**	**Value of LR-Test**	$Prob > \chi^2$	**Decision (5% Level)**
A1 vs. A2	H_0 : All the coefficients of environmental variables are zero	137.9374	0.0000	reject H_0
B1 vs. B2	H_0 : All the coefficients of environmental variables are zero	94.2554	0.0000	reject H_0

5.3 Efficiency Level

The first and foremost requirement of this chapter is to estimate efficiency levels of public HEIs in Turkey. Even though parameters of cost frontier imply a plethora of indications for cost function, their capabilities to reveal economic efficiencies are exceedingly inadequate. So as to estimate (in) efficiencies, Jondrow et al. (1982) is preferred to be conducted. The descriptive statistics for the mean efficiency values are shown below in the Table-6.

Table 6: Descriptive Statistics for Mean Efficiency Values

	A1	**A2**	**A3**	**B1**	**B2**	**B3**
Mean	0.691	0.833	0.711	0.749	0.856	0.904
St.Dev.	0.181	0.103	0.152	0.168	0.095	0.039
Min	0.125	0.331	0.536	0.269	0.450	0.870
Max	0.961	0.989	0.965	0.969	0.985	0.990

These initial statistics mentioned above have certain suggestions for HEIs in Turkey. Firstly, mean efficiency performances of Turkish public universities are fairly dispersed ranging from 70% to 90%. This would encourage a new set of policy-making decisions to lead inefficient universities to be aware of the success of their counterparts. Secondly, despite the fact that some universities have relatively poor efficiency rates, in overall analysis their efficiency scores are indicating optimistic signs relying on particularly Model B2 and B3. Lastly, developing different models do matter for efficiency analysis in the sense that dispersion of efficiency values among Turkish universities does vary from one model to another. The comparison of the models used in this section will be performed in the following paragraphs.

In addition to the distributional behaviour of efficiency values, their inter-temporal analysis corresponds to the crucial volume of the frontier literature. Whereas microeconomic notions state that firms 'learn by doing' as well as expects improvements in efficiency, for some cases as in the Turkish higher education sector, inefficiencies persist over time. As illustrated in the Table-3, the coefficient of eta value for the Bettese and Coelli model is insignificant referring to the fact that efficiency does not alter over time. Figure-1 proves this statement in a time profile. Even if there is a very slight increase in the efficiency, the aforementioned test puts forward that it is not being motivated by inter-temporal enhancement.

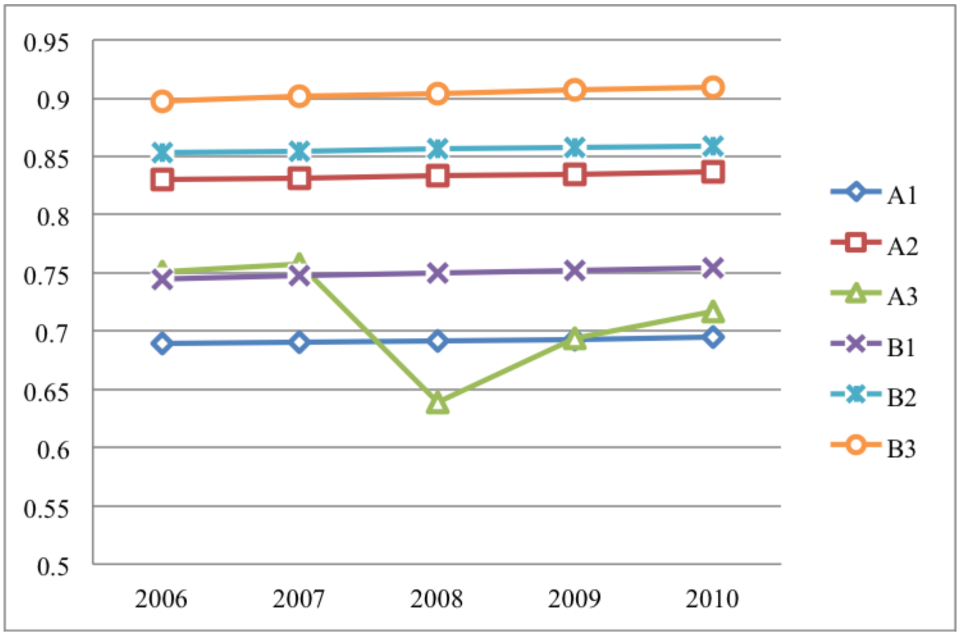

Figure-1

5.4 Comparison of Different Models with Spearman Rank Correlation

The other point of discussion worth examining here is to test whether efficiency rankings in the different models show similarities or not. The similarities or differences among the models may give an idea about the robustness of the models in the sense that different rankings would be motivated by the misspecification of the model. "Spearman's Rank Correlation" for efficiency estimates whose results are shown in Table-7 is carried out for this comparison.

The first remarkable result of these estimates is that incorporation of environmental factors into the specification does have a huge impact on efficiency rankings. Lower correlation value between A1 and A2 signals that worst and best practising universities are almost different in these models. Secondly, the correlation between B2 and B3 is almost 70% referring to the fact that pooled and panel data models do perform in a very close manner. Thirdly, the correlation between A1 and B1 is relatively higher stating that the economic efficiency estimates of Cobb-Douglas and Translog specifications without environmental variables have nearly parallel efficiency rankings. However, the lower correlation coefficients between A2 and B2

(0.54) as well as A3 and B3 (0.30) is the exact sign of the extent to which Cobb-Douglas and Translog cost frontiers are diverging from each other concerning the estimated economic efficiencies of public HEIs in Turkey.

In addition to the previous statements above, the very low correlation between A1 and B2 alongside with the A1 and B3 shows the joint impact of incorporation of environmental variables and opting for Translog specification rather than Cobb-Douglas in an apparent way. Although mean efficiency values are increased by at least 10% by adding environmental variables into the models as illustrated in Table-7, this was not sufficient to end up with a reliable conclusion regarding to the impact of environmental variables on the individual HEIs. The spearman rank correlation gives the concluding indication both for the incorporation of environmental variables and the specification of cost function.

Developing different estimation models has improved the robustness of the efficiency results for public HEIs in Turkey, which would result in more reliable statements for policy-making step. The primary influences of heterogeneity among the universities, the specification of cost frontiers and the estimation techniques are shown thanks to the Spearman rank correlation coefficient. More detailed analysis in relation to the impact of environmental variables onto the efficiency performances of HEIs will be the central theme of the following sub-section.

Table 7: Spearman Rank Correlations

	A1	**A2**	**A3**	**B1**	**B2**	**B3**
A1	1					
A2	0.465	1				
A3	0.792	0.318	1			
B1	0.684	0.401	0.552	1		
B2	0.331	0.545	0.226	0.524	1	
B3	0.239	0.392	0.300	0.345	0.692	1

5.5 Determinants of Inefficiency

In the recent stochastic frontier literature, the decisive question for the researches has become the determinants of inefficiencies among DMUs owing to particularly its key role in policy-making decisions. So as to measure it, one-step MLE will be carried out with conditional mean model for inefficiency term (u_i) (Kumbhakar and Lovell, 2000) . That is to say, the truncated efficiency distribution is carried out through assuming that the mean of inefficiency is influenced by certain variables. As Battese and Coelli (1995) indicate that both the frontier function and inefficiency equation would be influenced by the same variables, hence inefficiency equation for Turkish higher education is specified pertaining to the dataset that has already been shown in Table-1.

In addition to the formulation in (5), new specification is needed for the inefficiency term to be able to conduct one-step analysis narrated in (6). Besides, it is assumed that $v_i$and α_i are independently distributed of each other. This analysis will be carried out regarding two different models including B2 without intercept and B2 with the intercept. B2 is referring to the Translog specification with panel data random effects model with time-varying efficiency values. The pooled data analysis is ruled out, as it has not made any noteworthy impact on the efficiency estimation. The conditional mean of the inefficiency term is narrated as:

$$\begin{aligned}(u_i) = z_0 + z_1 AGE + z_2 SIZE + z_3 LOAD + z_4 PROF \\ + z_5 FTS + z_6 FORGN + z_7 MED + \alpha_i \end{aligned} \tag{6}$$

The estimation results of the inefficiencies are pointed out in the Table-8. Estimation results imply that size of the HEI is one of the salient factors behind the mean inefficiency in the given models. That is to say, the increase in the size of HEIs will end up with higher inefficiencies inside them. The previous discussions on efficiency of public sector organizations (Downs, 1965; Niskanen, 1971) claim the fact that bureaucrats are inclined to increase the size of their offices and budget schemes through hiring new employees. The positive sign for SIZE variable is supporting this theoretical argument as well. Consequently, this interpretation would influence the policy implications on the size of the university that is proxied by the number of undergraduate and postgraduate students.

The other influential variable on the inefficiency terms among university-based characteristics is load of the teaching staff. Estimates claim that the load factor has an inverse relationship with the inefficiencies, and accordingly leads HEIs to operate more efficient. Although the higher levels of load factor would have an adverse effect on the quality of teaching and student satisfaction, its primary impact on efficiency seems to be rather optimistic. Besides, this particular finding is in line with the fact that unnecessary and extravagant employment compared to the workload would cause inefficiencies in the public sector departing from Williamson's expense preference model (1967) .

The age of the university, percentage of foreign students, and dummy variable for medical school are the variables that are found to be significant in only one model. In the first model, the age of HEIs and the share of foreign students are discovered to have negative relationship with the efficiency performances of HEIs. That is to say, to these findings, older universities operate less efficiently than younger ones as well as percentage of students with foreign background decreases the efficiencies within the universities. The contradicting results for the coefficient of AGE prevent to reveal accurate comments on the inter-temporal budget growth hypothesis (Buchanan and Tullock, 1965). The second model estimated the impact of medical schools in the same direction. HEIs with medical schools are less efficient than the HEIs with none, which is in line with the expectations.

In addition to the previous conclusions, it can be inferred from the results that percentage of professors in the faculty ,which refers to the quality of labour, does not have any relationship with the cost efficiencies of public HEIs in Turkey. However, the other variable that signifies the quality of labour is found as significant in the first model. According to the regression results, the percentage of full-time staff motivates the inefficiency term to rise. This might be the result of full time faculty's additional cost items due to their research commitments; hence the unmeasured quality of research may be reflected by this relationship between the cost inefficiency and the percentage of full-time academic staff.

Table 8: Determinants of Inefficiencies

Variables	**Model B2 (Without Intercept)**	**Model B2**
AGE	0.0054***	0.044586
	(0.0009)	(0.039)
SIZE	0.00001***	0.797D-04*
	(0.0000002)	(0.450D-04)
LOAD	-0.02048***	-0.16852*
	(0.0006)	(0.098684)
PROF	0.00431235	0.044586
	(0.0617)	(12.60634)
FTS	0.0519***	4.045698
	(0.0143)	(1.381614)
FORGN	3.2903***	55.24667
	(0.8812)	(49.17822)
MED	0.0527	1.84628*
	(0.1048)	(0.964238)
Constant	NA	1.499941
		(2.63512)
σ_u	0.1994***	0.1782***
	(0.002)	(0.0031)
log-L	-2184.374	134.65

Notes : 1. ***, **and *indicate 1%, 5% and 10% significance levels respectively.
2.Asymptotic standard errors are in parentheses.

6 Limitations & Concluding Remarks

This section deals with the limitations and challenges of the application of SFA into this particular dataset. Besides, concluding remarks for the further research are visited with a brief summary of the entire paper.

The first limitation of this research is motivated by the discussions on choosing the best-fitted functional form for HEIs. This research employs two models for the cost function of Turkish HEIs a) Cobb-Douglas due to its simplistic and less data demanding structure and b) Translog for its more flexible cost specification. Therefore, Quadratic, Leontief and CES functions would be utilised for the following research papers relying on extended and enriched dataset.

Secondly, the quality of teaching and research outputs could not be integrated into the frontier model properly owing to lack of data in those areas. Employability rates of universities as well as impact of research projects should be reflected into the model to be able to gauge the actual value of outputs. For that reason, the efficiency results might be suffering from quality problem that is the chief obstacle in the economic efficiency literature.

Thirdly, the proxies for input prices as well as the lack of data in other sorts of input prices such as goods/services used in production process would influence cost frontier in a biased manner. Hence, enriched dataset particularly in the prices of input will help following researches to compute more reliable efficiency estimates in the Turkish Higher Education. Besides, the quality of inputs (in particular for academic staff) needs to be included in the frontier if and when the dataset permits it.

Lastly, estimation of the determinants of inefficiency could be suffered from omitted variable problem. In addition to the variables that are situated into the conditional mean function of inefficiencies may not be reflecting the whole effects that are significantly motivating inefficiencies among HEIs. Accordingly, this may create biased estimates of inefficiencies that were already addressed by Greene (2005) in true effects model.

This chapter investigates 53 public HEIs in Turkey between 2005 and 2010 including 5 full academic terms to estimate both their cost frontier and inefficiencies. The initial findings of six different models implied that Turkish universities perform quite well concerning their overall efficiency values; nevertheless there are lots of variations among them. Besides, within this five-year time span, Turkish universities have not shown any improvement in their efficiencies based on Battese and Coelli's (1992) time variant model.

In addition to that, the determinants of inefficiencies in Turkish HEIs are dependent upon certain variables. The size of HEIs is seen to be the most influential factor behind inefficiencies referring to the fact that small size universities are highly probable to experience relatively higher efficiency results. Subsequently, the impact of load factor is as important as the size effect. The negative coefficient implies that, universities with higher load factor demonstrate better efficiency performances. Moreover, age of the university, the percentage of foreign students, percentage of full-time faculty and having medical school are the other variables reducing efficiency in HEIs based on the only one model. Percentage of professors does not have any influence on the inefficiencies according to the both two models.

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