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EFFICIENCY ANALYSIS OF PUBLIC HIGHER EDUCATION INSTITUTIONS IN TURKEY WITH PARAMETRIC AND NON-PARAMETRIC APPROACHES

by

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Abstract

Although the number of researches measuring the efficiencies of higher education institutions has grown especially for the last two decades, literature of both parametric and non-parametric research on HEIs in Turkey is relatively scant compared to the countries alike. This PhD research that fills this noticeable gap in the literature scrutinises 53 public universities in Turkey between the full academic year of 2005-2006 and 2009-2010 covering 5-year time span. In this research, albeit the slight changes in the non-parametric estimation, 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 features are included into the model so as to apprehend potential heterogeneities among the universities.

The initial conclusions coming out of parametric estimation have certain suggestions for public 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 certain models. 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 results of the non-parametric estimation claims that, firstly, public HEIs in Turkey are performing in unsatisfactory levels although some of them are doing fairly well. The lower results for the non-parametric estimation then the parametric one –which is totally within the expectations-, are referring to the fact that the former method is not able to differentiate the inefficiency from the statistical noise. However, as the non-parametric model gets closer to the full input/output set, both individual and overall efficiency scores are getting relatively higher values. Secondly, even though there is not any systemic increase during this five-year time span, efficiencies of public HEIs in Turkey have increased at the course of last two years.

Keywords: *Cost Efficiency, Technical Efficiency, Public Sector Organizations, Higher Education Institutions, Stochastic Frontier Analysis, Data Envelopment Analysis, Turkey*

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CHAPTER I: Introduction and Research Agenda

I. BACKGROUND and CONTEXT

Rising economic inquiry on the provision of goods and services by public institutions recently sparked an investigative research on the efficient allocation of resources within public sector organizations (Kang, 1997; Duncombe, Miner, and Ruggiero 1997; Pedraja-Chaparro et al., 2005). Whereas neo-classical assumptions on the theory of firm put forward by Coase (1937) and Alchian and Demsetz (1972) assume that a firm is always expected to operate at the efficient production frontier, unpredicted divergences from the neo-classical firm postulations attracted attentions of researchers working not only on the private firms but also on the public sector organizations (Lewis, 2004; Bloom and Van Reenen, 2007). Accordingly, this particular PhD research stems from the current literature on the economics and efficiency of public sector organizations, which then carries out its own analysis on public higher education institutions in Turkey based on the featured arguments in the aforementioned literature.

In addition to the theoretical motivation of this dissertation, it is apt to reveal its policy-orientated inspiration here. By the beginning of 21st century, public higher education has gone through a "state of crisis" in which share of public funding allocated to higher education reduced by almost 33% throughout the last decade (Ehrenberg, 2006). This dramatic contraction in the budget schemes primarily had an impact on faculty salaries that became higher in private universities (Ehrenberg, 2003) as well as raised awareness among the decision-makers in public higher education concerning efficient usage of resources. Consequently, administrative bodies both within universities and governmental institutions started to reorient their funding choices through benefiting from the researches measuring the efficiency performances of the higher education institutions (Robst, 2001).

This change occurred globally, encouraged national and regional entities particularly European countries to readjust their positions in economically feasible ways. For instance, Sorbonne and Bologna Declarations (1998, 1999 respectively) as well as Lisbon Strategy (2000) had a remarkable influence on policy-making of higher education among EU member and candidate states. Consequently, governments preferred to support new initiatives that have capabilities to provide cutting-edge research and education facilities to the lecturers and students by the means of more efficient allocation mechanisms. Turkey -as a candidate country to join EU- is one of the leading countries to rejuvenate its higher education system through both opening up new public universities and encouraging non-profit entrepreneurs to establish universities. Currently, almost 170 universities (including public and non-profit ones) are operating in Turkish higher education sector (YÖK, 2013).

So as to measure the efficiency performances of HEIs as for the other types of organizations, certain analytical procedures need to be carried out leaning on the fundamental postulations of microeconomics. In microeconomic theory, the objective of a typical firm is proposed as producing maximum amount of output via employing given inputs with minimum cost, which is a valid postulation for public sector organizations as well. This microeconomic conception requires or presumes that firms –within the framework of free market rules- should allocate input and output efficiently with the aim of obtaining maximum profit and/or minimum cost. Until now, productive efficiency of a firm has been calculated by measuring the distance to a particular frontier such as the revenue frontier, profit frontier, cost frontier and production frontier.

Revenue frontier efficiency models measure the distance between each organization's actual revenue and maximum attainable revenue; profit frontier models figure out the distance between firms' actual profit levels and maximum attainable profit; cost frontier deals with the gap between actual cost and minimum achievable cost level, and finally production frontier gauges the distance between actual amount of output of the organizations and the highest level of feasible output (Kumbhakar and Lovell, 2000:57). Whereas revenue frontier model requires output prices information for the analysis, cost frontier entails input prices. And the profit frontier needs to incorporate both output and input prices; production frontier does not demand any information about prices. This PhD research opts for cost frontier due to the fact that there is a lack of data on the output prices as well as focuses on multi-output production process that excludes the option of production frontier.

The number of studies measuring the efficiency levels of higher education institutions (HEIs) increased in the frontier analysis literature especially during the last decade (Johnes and Johnes, 2009; Dagbashyan, 2011). The evident decline in state appropriations to the universities as well as rising costs in higher education can be suggested as the main driving forces behind this proliferation (Robst, 2001). This in turn stimulates decision-makers in higher education to be more vigilant about efficiency performances of their institutions. Accordingly, works in this particular area of research are employed as recommendation papers both to the administrative bodies of universities and governmental institutions. That is to say, findings of these papers would be used as "policy-making implications to the decision makers" in the higher education sector (Erkoc, 2011a).

The growing inquiry among policy-makers concerning resource allocation in higher education has 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 university-orientated cases. In this research, efficiency performances of public HEIs in Turkey are mapped out by employing these two distinctive techniques as well as the empirical findings are revealed for further policy-making decisions.

II. OBJECTIVES OF THE DISSERTATION

Estimating technical and cost efficiencies of higher education institutions (HEIs) became an essential field of research in the literature of efficiency analysis particularly over to the course of the preceding two decades. Unlike other for-profit firms including banks, utilities and airlines companies that have been under scrutiny concerning their efficiency performances for many years, not-for-profit motive among HEIs run by either public or non-profit entrepreneurs has drawn attentions of researchers to assess the central arguments around incentive-efficiency dichotomy (Dixit, 2002; Ben-Ner, 2002; Burgess and Ratto, 2003). For instance, Ben-Ner (2002) argues that lack of profit motivation among non-profit and public organizations would lead them to experience lower efficiency performances than their for-profit counterparts. To examine this argument on the public higher education case, a remarkable number of papers have amassed on the efficiencies of HEIs that took various country settings including Britain, Sweden, Canada, Australia, China and Greece as their empirical focus (Maria Katharakia and George Katharakis, 2010; Daghbashyan, 2011).

Although the number of researches measuring the efficiencies of higher education institutions has expanded, literature of both parametric and non-parametric research on HEIs in Turkey is relatively scant compared to the countries alike. This PhD research that fills this noticeable gap in the literature scrutinises 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[1]. Moreover, university-based features are included into the models so as to apprehend potential heterogeneities among the universities.

In this dissertation, to measure the economic efficiencies of public HEIs in Turkey, SFA and DEA techniques are employed departing from the traditional measurement methods. The former method that entails parametric steps to estimate efficiencies of HEIs is applied to the Turkish dataset in the Chapter V, whilst the latter one is the main focus of the analysis carried out in Chapter VI with slight data differences. The chief aim to accommodate two different methodologies is that the results yielded from parametric technique can be compared and contrasted with the results coming out of the non-parametric technique. Accordingly, policy recommendations emerging from these two distinct efficiency estimation methodologies would have vigorous insights for the policy-makers.

To sum up, this research constructs its own original sphere in the literature by addressing certain inquiries that have vital importance for efficiency analysis framework, efficiency in public sector organizations and lastly further policy-making decisions within Turkish higher education system as follows:

a) Efficiency Analysis Framework: Due to the fact that two different methodologies are applied to the same case, empirical findings of this research will make contributions to the long-lasting debate on the robustness of parametric and non-parametric techniques. Secondly, efficiency results of

[1] The dataset for non-parametric analysis has slightly different variables to preserve the consistency in that particular literature. Additional reasons are enumerated at the end of the Chapter IV.

public HEIs in Turkey would provide additional insights to the current literature in the efficiency of higher education institutions.

b) Efficiency in Public Sector Organizations: Throughout the dissertation, efficiency performances of public HEIs in Turkey are revealed through relating the theoretical underpinnings of efficiency of public sector organizations that are mostly motivated by economic theories of bureaucracy with empirical conclusions. That is to say, the analyses of this research shed light on the extent to which public HEIs are using their resources in an efficient manner both individually and the sector as a whole within the framework of the in (efficient) allocation of resources in the public sector.

c) Policy-making in Turkish Higher Education: The conclusions will have policy reflections for the further policy-making process in Turkish public higher education. Mean efficiency scores of HEIs alongside with their individual scores have policy-making implications for higher education sector in Turkey particularly as the apportioned amount of public funding to them becomes a central theme in the finance of public higher education (YÖK Report, 2007). Therefore, the estimation results obtained throughout this dissertation would offer significant insights for further policy-making decisions steered by both administrative bodies of HEIs and the Council of Higher Education of Turkey.

III. ORGANIZATION OF THE DISSERTATION

This dissertation is consisted of eight chapters including this introduction chapter and the conclusion. The following two chapters (Chapter II and III) refer to the literature review of this research, whilst the former one corresponds to the theoretical motivation of this research; the latter is the summary of policy-orientated inspiration. Chapter IV clarifies the methodological aspect of the research, which examines parametric and non-parametric approaches to the measurement of efficiency performance. Chapter V and VI apply those methods to the Turkish public higher education dataset employing SFA and DEA respectively. Chapter VII articulates the policy conclusions of the findings, and lastly Chapter VIII concludes. The subsequent paragraphs summarise these chapters in sequence.

Chapter II scrutinises the economic theory of bureaucracy that is put forward as the major source of inefficient allocation of resources in the public sector organizations, following a brief introduction to the theoretical framework of the efficiency of public sector. Besides, alongside with the earlier Weberian (1947) and Downsian (1965) interpretation of bureaucracy, alternative perspectives on bureaucracy including contemporary debate on the efficient role of politicians and bureaucrats in the policy-making is visited referring to the recent papers of Alesina and Tabellini (2007; 2008). Lastly, institutional framework for the provision of goods and services is introduced to the chapter to have a comparative understanding of the public sector organizations.

Chapter III points out the challenges and obstacles faced by public higher education institutions in the 21st century. Secondly, it examines the contemporary outlook of Turkish higher education regarding to administrative structure, finance and academic success. And eventually, the role of non-profit universities is discussed to pose the question whether they might be good substitutes for public universities in the areas where government is confronting difficulties to provide decent quality services with more efficient allocation mechanisms.

Chapter IV investigates the theoretical underpinnings of both parametric and non-parametric efficiency estimation techniques as well as throws some light on the strengths and weaknesses of these two analytical methods. Furthermore, previous empirical papers (which can be defined as milestones in their areas) for each technique are touched upon to give a general understanding about the application of parametric and non-parametric estimation methods on the higher education institutions.

Chapter V is formed as follows: section II discusses different forms of cost function comprising Cobb-Douglas and Translog cases as well as examine pros and cons of these models. Section III 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 IV. Section V 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 scrutinised in the concluding section VI.

Chapter VI deals with the interpretation of the results derived from DEA estimation. Policy-reflection and suggestion aspect of those results will be discussed in Chapter VII alongside with the results obtained from SFA (Chapter V). Besides, incorporation of environmental variables in DEA to account for the determinants of efficiency among HEIs paves the way for comprehending the probable factors behind inefficient usage of resources as well as conducting a methodological comparison between SFA and DEA.

Chapter VII investigates the policy implications of estimated technical and cost efficiencies of public HEIs in Turkey by the means of parametric and non-parametric techniques. Mean technical and cost efficiencies of 53 public HEIs in Turkey as well as the determinants of inefficiencies were examined and discussed from a policy-reflection perspective. So as to suggest consistent and reliable statements, the estimated results in SFA were checked with the conclusions provided by DEA. The overlapping points of the two methodologies were encouraged and put forward as trustworthy recommendations for decision-makers in the higher education sector either in universities or The Council of Higher Education. And finally, Chapter VIII that would also be counted as the "non-technical summary of this dissertation" concludes.

CHAPTER II: Efficiency of Public Sector Organizations

I. INTRODUCTION

Economic insights on the provision of public goods and services by public sector organizations have been instigated by the probing questions on the efficient allocation of resources within them concerning neo-classical assumptions on the theory of firm (Coase, 1937; Alchian and Demsetz, 1972). The rationale behind the unprecedented divergences from the neo-classical firm postulations on the basis of not-to-operate at the efficient production frontier has attracted attentions of researchers working not only on the private firms but also on the public sector. Accordingly, it is appropriate to reveal here that the theoretical motivation for this particular PhD research stems from the current literature on the economics and efficiency of public sector organizations, which then develops a distinct inquiry on public higher education institutions in Turkey leaning on the statements indicated at the course of this chapter.

This chapter investigates theoretical underpinnings of efficient allocation of resources within public sector organizations on the basis of a variety of arguments. Before examining the (in) efficient usage of resources in the public sector that is mostly based on the theory of bureaucracy, methodological and practical challenges to measure the efficiency performances of public intuitions are visited. Subsequently, institutional framework on the public provision of goods and services is scrutinised referring particularly to the discussion on incentive schemes and efficiency. In doing so, theoretical background of this PhD thesis is mapped out relying extensively on the theory of bureaucracy that is assumed as the primary source of inefficiencies in the public sector organizations.

The outline of Chapter II is as follows: section II explores the theoretical framework for the efficiency of public sector organizations, section III illuminates the efficiency of government output based on the theory of bureaucracy including earlier sociological and economic researches to the contemporary debates, section IV demonstrates the institutional foundations of the allocation of resources in the public sector referring chiefly to the incentive-efficiency dichotomy and section V concludes.

II. THEORETICAL FRAMEWORK FOR THE EFFICIENCY OF PUBLIC SECTOR ORGANIZATIONS

Efficiency analyses of public provision of goods and services have often been intellectually stimulated by competing views on the function and boundaries of state intervention into the economic sphere. Although provision of social services by governments became a significant phenomenon during the modern age especially after the establishment of nation states (Rosanvallon, 2000), discussions on the appropriate role of governments in the society are as old as Plato's *The Republic*. The accumulated literature on this particular theme can be mainly classified into two streams as Besley (2011) points out clearly below:

"(...) One emphasises government in the public interest. It outlines the range of activities that government can undertake to improve the lives of its citizens. Government provides underpinnings of the market system by establishing property rights and a means of adjudication through the courts. (...) The logic behind this has been developed at length and provides the modern theory of state from a welfare economic point of view.

At the other extreme are accounts of government seen mainly as a private interest. Government can be a focus for rent seeking in which the power to tax results in private, wasteful efforts to capture the state which then rewards the powerful at the expense of citizens at large (...)" (Besley, 2011: 1-2).

Even though efficiency of public provision of goods and services forms a relatively younger literature in the microeconomics, the economics of public sector organizations has already become a distinct branch namely Public Finance within the discipline of economics for many years. Besley's (2011) noteworthy taxonomy above would be extremely helpful to grasp the fundamentals of this particular sub-division of economics. Due to the fact that this research is carried out to investigate the efficiency of public sector organizations, this section will deal with the efficiency literature afterwards. So as to examine an extensive literature on the economics of public sector, Musgrave and Musgrave (1989) can be visited. As a final point before moving towards to the central arguments, albeit this research takes the efficiency analysis of public institutions into the centre of its analysis, it needs to be stated here that further objectives of public sector organizations such as fairness, equality, consumer protection, poverty reduction and creating employment opportunities (instead of providing employment benefits) are still valid and preserve their significance.

Increasing awareness among the decision makers in the governmental bodies in relation to the efficient allocation of resources within public sector organizations has encouraged and expanded academic inquiry for the last three decades in this particular field (Duncombe, Miner, and Ruggiero 1997). The motivation behind this growing sensitivity between government authorities is highly associated with the fact that inefficiencies may "suggest that public service resources could be better used elsewhere in the economy, or that more outputs could be generated within the public services without additional resources" as well as "undermine the public's support for tax funding of public services" (Smith and Street, 2005). Thus, researches attempting to measure the efficiencies of public sector organizations have been used as policy-reflection papers alongside with their academic contributions and insights even though they have not received sufficient attentions as put forward by Duncombe, Miner, and Ruggiero (1997).

The major concern of the studies on this area of research is "to measure the relative efficiency of different public organizations providing the same public service" (Pedraja-Chaparro et al., 2005). Pedraja-Chaparro et al. (2005) puts forward two different approaches for the measurement. In the former approach, a set of partial measures of performance is developed with the aim of understanding the behavior of the organization. On the other hand, the latter one aims to define a "general index" to reveal the efficiency of the organization. Therefore, the first method indicates local efficiency performances, whereas the second one sets forth global efficiency indicators. The most common and methodologically accepted efficiency indicators are mostly departing from the second cohort of indicators using a variety of approaches including parametric, semi-parametric and non-parametric models (Stone, 2002).

Measuring efficiency performances of public sector organizations is noticeably harder than their private counterparts as they "produce goods that are provided either free at the point of use or at a price that is not determined by market forces"(IFS Report, 2002) as well as the "non-tradable nature of goods and services" supplied by them (Pedraja-Chaparro et al., 2005). Accordingly, price mechanism in the public sector does not function well enough *vis a vis* the conventional market procedures that are expected to ensure and sustain the efficient allocation of resources. That is to say, "signaling" in the market mechanism is highly probable to be substituted by the discretionary actions of the players in the political arena that would cause inefficiencies as far as the production process is concerned.

In addition to the inherent problems of the public sector concerning political manipulation on the provision of welfare services, ill-defined nature of property rights within them lead actors in the public service to act in reluctant ways on the allocation of resources. And accordingly “the allocation of public resources is governed by a political process which usually does not follow the price mechanism” (Kang, 1997). The political and social constraints, in lieu of market based constraints, on the publicly provided goods and services result in inefficient allocation of resources as well. Besides, the lack of competition and the “monopolistic nature of public production” prevent the actors in the public sector organizations to be cautious about the efficient usage of resources compared to their competitors in the private sector (Pedraja-Chaparro et al., 2005).

Over and above the previous arguments on the nature of public sector outputs that would cause inefficiencies, the objective function of public sector organizations needs to be touched in this section as well. Unlike private companies, public organizations are assumed to take the “equity goals” into consideration as one of their fundamental functions in the modern societies corresponds to the redistribution of income (Tullock, 1997). Thus, while conducting efficiency analysis on publicly run institutions and proposing policy recommendations, one should be careful about the contradicting nature of the efficiency-equity dichotomy in the objective function of public institutions (Pedraja-Chaparro et al., 2005).

As indicated in the preceding paragraphs, outputs produced in the public sector organizations either in police, post office, health sector and courts is questioned concerning their performance in productivity and efficiency. Chong et al. (2012) claimed that the reasons behind the lower productivity and efficiency figures in public sector can be summed up as “inferior outputs, including human and physical capital, technology, and poor management”. Moreover, Lewis (2004) and Bloom and Van Reenen (2007) stated that the poor public sector management is mostly motivated by lack of incentives, supervision and monitoring. Consequently, the statements on poor management in the public sector encourage comprehensive investigation on bureaucracy that backbones the organizational structure in the public sector organizations.

The economic insights on the bureaucracy studies are mostly centred on the fundamental question investigating to what extent efficient or inefficient usage of resources are linked to the managerial performances of bureaucrats as well as are comprised predominantly of budget size (Downs, 1965; Niskanen, 1971), slack maximisation (Migue and Belanger, 1974) and expenditure choices (Williamson, 1964) models. Moreover, since Migue and Belanger (1974) extended Niskanen (1971)’s assumption of technical inefficiency in the public sector by incorporating allocative inefficiency into the model, the number of empirical researches measuring both technical and allocative efficiencies of public sector organizations have boosted apparently. That is to say, the aforementioned papers on the economic theory of bureaucracy had paved the way for the current empirical researches to conduct efficiency analysis on public sector organizations.

Following the erstwhile theoretical approaches to the efficiency of public sector influenced mostly by the theory of bureaucracy, empirical papers first started with Hayes and Chang (1990), Davis and Hayes (1993) and Grosskopf and Hayes (1993) employing parametric techniques as well as Chalos and Cherian (1995) and Duncombe, Miner and Ruggiero (1997) that opt for conducting non-parametric methods. And currently, these studies become a distinct area of research (Stone, 2002; Pedraja-Chaparro et al., 2005). To these researches, efficiency of public sector institutions is highly contingent upon certain institutional and environmental factors that vary between organizations (Kang, 1997), which apparently encourages to examine the determinants of possible inefficiencies in the Turkish public higher education by taking the earlier literature into consideration.

III. ECONOMIC THEORIES OF BUREAUCRACY and EFFICIENCY OF GOVERNMENT OUTPUT

Public sector employees, who are also called as bureaucrats, form the backbone of the major part of public sector analyses particularly when the allocation of resources in the public sector organizations is questioned. Hence, the efficient or inefficient allocation of resources to provide public services has often been examined on the basis of budget choices made by bureaucrats (McNutt, 2002:124). This section critically summarises the fundamental insights and discussions on the bureaucracy starting from Weberian (1947) analysis and Niskanen's (1971) theory of bureaucracy to public choice interpretation of it and ending up with current debates on the relationship between politicians and bureaucrats. Besides, some of the propositions are extracted to interrogate the relevant theoretical statements on the theory of bureaucracy with the empirical conclusions of this dissertation.

Earlier Research on Bureaucracy

The preliminary researches on the bureaucracy that were mainly intensified around sociological paradigms are inspired from Weber's (1947) seminal work centred essentially on German example. In his piece, Weber's first and foremost aim was to put forward certain set of ideal characteristics for each and every bureaucratic mechanism including profit-maximising firms (McNutt, 2002:124). Moreover, he was also trying to create the most appropriate way of management in organizations to assure that a staff can enhance her technical competence as well as apply it to the certain practical cases. Weber's (1947) ideals for a well-functioning bureaucracy can be enumerated as "hierarchy, unity of command, specialization of labour, employment and promotion based on merit, full-time employment, decisions based on impersonal rules, the importance of documentation and a separation between the bureaucrats' work-life and private life". These aforementioned characteristics still influence modern conception of bureaucracy and stimulated the formation of vast literature in this particular area of research (Aucoin, 1995: 157).

Following the early sociological analysis of bureaucracy introduced by Max Weber, economic insights on bureaucracy initially commenced with the works of Tullock (1965), Downs (1965) and Niskanen (1971). All three authors were in search of figuring out the modes of "relations between people within an organisation in receipt of a recurrent block of funds" (McNutt, 2002:124). And eventually, their theoretical conclusions had formed the mainstream understanding in microeconomic research for many years. In this sub-section, Downs' approach to bureaucracy is stated briefly below; Niskanen and Tullock will be discussed in the subsequent sub-sections respectively.

Downs' (1965) fundamental assumption for bureaucrats is that they are solely motivated by their own self-interests like any other agent in the society. Hence, rather than specifying public interests, they prefer to maximise their utilities when they are performing in the bureau. Furthermore, to Downs, an organization can be defined as bureau if a) it is sufficiently large b) a majority of the employment consists of full-time workers c) hiring, promotion and retention base upon some sort of assessment d) the significant share of "its output is not directly or indirectly evaluated in any markets to the organization" (Downs, 1965). And subsequently, he indicates that the "non-market orientation" for bureaucratic outputs prevents an "objective monetary measure of profitability", which results in larger bureau sizes alongside with reluctance towards efficient usage of resources. As a final point, it needs to be stated here that Downs' preliminary analysis was rather influential on the further bureaucracy analysis particularly on Niskanen's theory of bureaucracy.

Three Models of Utility-Maximising Bureaucracy

Utility-maximising notion for managerial structures including bureaucracy has widely been used in the economics literature concentrating particularly on three different models: a) Budget Maximisation b) Slack Maximisation c) Expense Preference. The following paragraphs articulate these models separately.

Budget Maximisation

Niskanen (1971) coined the budget-maximising model for bureaucracy stating that bureaucrats are willing to increase the level of production until it reaches the largest amount of budget. The basic reason behind this attitude is that "bureaucrats do not have property rights to the fiscal residuum of the bureau" which corresponds to the difference between social costs and benefits incurred in the provision of services (Kang, 1997). That is to say, bureaucrats prefer producing the goods and services above their social optimum to utilise the remaining portion with an eye to enhance their position within the institution they work in (Downs, 1965; Niskanen, 1971).

Niskanen (1971) developed a demand function for output of bureau that is shown below on the basis of the assumption that demand and cost functions are linear.

$$MR = a - 2bQ \qquad (2.1)$$

where MR is the marginal revenue of the bureau and Q represents the amount of output provided by bureau. Hence, the total revenue becomes:

$$TR = aQ - 2bQ^2 \qquad (2.2)$$

and the total cost and marginal cost are narrated as:

$$TC = cQ + dQ^2, MC = c + 2dQ \quad (2.3)$$

The profit-maximising output of the bureau can be shown based upon conventional microeconomics analysis where MR=MC:

$$Q_O = a - c \; / \; 2(b - d) \quad (2.4)$$

Niskanen's (1971) hypothesis claims that bureaucrat does not choose the point where profit is being maximised as in (2.4) but her own budget is being maximised shown below in (2.5) as long as bureaucrat's budget line permits that output level[2]:

$$Q_N = a - c \; /(b - d) \quad (2.5)$$

The budget-maximising model developed by Niskanen received a fundamental criticism from Migue and Belanger (1974) on its very assumption that public sector operates technically efficient but may not be allocatively efficient. They criticised this assumption and relax it with the statement that public sector may both be technically and allocatively inefficient and eventually established a slack-maximising model that will be scrutinised subsequently.

Slack Maximisation

Migue and Belanger (1974) expanded the economic theory of bureaucracy by disproving the Niskanen's (1971) ironic approach stating that bureaucrats' only motivation is to increase the amount of budget they have and if this is right "then, no expenses other than those contributing to productivity are incurred since these would compete with output" (Kang, 1997). In contrary to the Niskanen's conclusions, they argue that bureaucrats will opt for the point on the budget line where marginal rate of substitution among the output of bureau and other expenses is equal to the slope of the budget line

[2] For further discussions, see Niskanen (1968, 1971) and Kang (1997)

(Migue and Belanger, 1974). Therefore, the relative prices of output and other expenses become the significant subject of analysis in lieu of maximum amount of attainable output on the budget line.

The argument between Migue and Belanger (1974) and Niskanen's (1971) models of bureaucracy is examined by Wyckoff (1990) leaning on four separate empirical predictions on the basis of "utility-based model of bureaucratic choice". The author argues, "slack-maximizing and budget-maximizing bureaucracies are similar in their response to changes in cost and in their generation of 'flypaper effects', but they differ in their responses to matching and lump-sum grants". In relation to the efficient usage of resources, budget maximization causes technical inefficiency as it leads over provision and cost efficiency; slack maximization creates allocative inefficiency, due to under-provision, and cost inefficiency (Duncombe, Miner, and Ruggiero 1997).

Expense Preference

In addition to the budget and slack-maximising models, Williamson (1964) initiated expense preference model to explain why bureaucrats are inclined to produce above the expected minimum cost level, which results in cost inefficiencies in the public sector organizations. Kang (1997) argues that Williamson (1964) meant in the expense preference model, "Managers do not have a neutral attitude toward all classes of expenses. Instead some types of have positive values attached to them". Thus, so as to "enhance individual and collective objectives of managers", certain types of expenses such as staff are incurred in higher amounts even though they do not have any impact on productivity and efficiency in the organization (Kang, 1997). In other words, if this is the case, cost function of a given public institution is expected to be highly correlated with labour expenses as well as staff characteristics (which causes higher labour expenses) would have an impact on the efficiency performances.

Following the arguments put forward in Williamson's (1964) paper, De Alessi (1969) reveals an inter-temporal dynamic of bureaucrat's expenditure preferences that leads the current amount of expenditures to rise above the optimum. Unlike private companies, De Alessi (1969) argues, government favours using lower discount rates, which result in overinvestment in the public sector organizations due to the overestimation of the benefits yielded from current investments. And accordingly, managers in the government institutions have an incentive to increase the amount of present investments rather than waiting for prospective ones (Kang, 1997).

Public Choice Theory and Bureaucracy

Tullock (1965) has the pioneering work on the public choice model of bureaucracy that had an obvious impact on the Niskanen's (1971) budget-maximising assumption of bureaucrats. Prior to the Tullock's economic analysis of bureaucracy, the sociological theories were manifesting themselves in this subject inspiring from Weber's model (1947) that was reluctant to the economic behaviours of bureaucrats. According to the public choice thinkers, actors in the political sphere comprised of voters, politicians and bureaucrats perform their acts concerning conventional free market procedure, which is also known as *catallaxy*. Therefore, as far as public choice theory is concerned, bureaucrats are expected to maximise their utility levels either exploiting the monetary gains or enjoying higher status in the organization (Tullock and Buchanan, 1965).

Tullock's (1965) particular hypothesis is centred on the growth of bureaucracy and output of bureaus from a dynamic or inter-temporal perspective. In his research, he concluded, "through time, bureaucracy grows in size and did not remain at initial size" (McNutt, 2003:143). He proposed a growth function of the budget for a given bureau depending on time as follows:

$$B_{t+1} = B_t \exp(r^t) \quad (2.6)$$

where B_{t+1} represents the budget size at time period (t+1), B_t refers to the budget size at time period t. Additionally, r corresponds to the magnitude of growth in the bureaucracy. Hence, as the time passes, the budget size is expected to grow referring to the fact that relatively older public institutions would experience higher inefficiencies as compared to their younger equivalents. This model also indicates that bureaucrats are desperately keen to increase the total amount of budget allocated to their bureaus as this increases their discretionary power over certain expenses that are more preferable to them (Williamson, 1964).

In the following discussions within public choice theory, Brennan and Buchanan (1980) as well as Mueller (1989) take one step further by incorporating tax base analysis into the budgetary preferences of bureaus. To these researchers, "if a citizen expected bureaucrats to maximise their budgets, they would constrain their ability" by imposing a limit on the tax base through certain legislative attempts (McNutt, 2002:145,146). Therefore, the extent of budget size is not merely contingent upon the preferences of bureaucrats but also citizenry constraints concerning the level of taxation are highly influential determinants of budget size in public sector organizations (Brennan and Buchanan, 1980; Mueller, 1989).

Alternative Perspectives on Bureaucracy

Over and above the models developed to illustrate the economic underpinnings of the theory of bureaucracy that became a mainstream reference point for the current literature, some theoretical alternatives will be shown in this sub-section so as to extend and expand the reasoned discussions on the (in) efficient allocation of resources within public sector.

Dunleavy's Model of Bureau Shaping

Unlike the previous papers on the bureaucracy, Dunleavy (1991) assumes that the main motivation for bureaucrats is not pecuniary gains (although they have significance) but non-pecuniary ones including "status and prestige" and the "intrinsic value of the work involved" (McNutt, 2002:150). To clarify this, he argues that: "There is always a pecuniary parameter in bureaucrats concerns (...). But this is unlikely to be a constraint which is surmounted relatively easily and thereafter is not very influential positively or negatively in structuring individual behaviour especially when officials are making policy decisions" (Dunleavy, 1991:201). Hence, bureaucrats are expected to maximise their utilities through exploiting full-control to shape their bureaus rather than maximising the sizes of their budgets.

To Dunleavy, bureaus are shaped by a number of policy-decisions consisting of major internal reorganisations to promote policy work over routine activities, transformations of internal work practices, redefinition of relations with external partners to enhance policy contacts, competition with other bureau to protect the scope of interesting work, load shedding, hiving off and contracting out functions which are seen as undesirable (Dunleavy, 1991:203-204). The main conclusion derived from Dunleavy's bureau-shaping model can be summed up in two propositions: "Firstly, budget maximising will be more likely in bureaus where the core budget makes up most or all of the program budget, i.e. in delivery, regulatory, taxing, trading and servicing bureaus. And secondly, other types of self-interested behaviour by senior bureaucrats will influence the activities of bureaus" (Dollery and Hamburger, 1995).

Bureaus with Monopolistic Power

This sub-section is devised to reveal the arguments claiming that bureaucrats benefit from the monopolistic power of their bureaus in providing the public goods to the citizens.

McNutt (2003) treats the bureau to act as a private monopolistic firm that chooses to provide the given public good at 'MC=MR' in lieu of the social optimum point at 'MC=AR'. So as to exploit monopolistic profits, bureaucrats are supposed to prefer operating at the former point on the basis of "monopoly bureau output" model.

As illustrated in the Figure-2.1, instead of producing at the socially optimum level where MC curve intersects to demand curve (represents AR curve as well) as proposed by Niskanen (1971), McNutt (2003) claims that monopolistic bureau is inclined to supply the public goods and services at point C in which higher prices are charged alongside with lower amount of provision. Moreover, relying on his conjecture, monopolistic bureau is expected to experience lower MC levels, which is not in tune with the conventional analyses on bureaucracy.

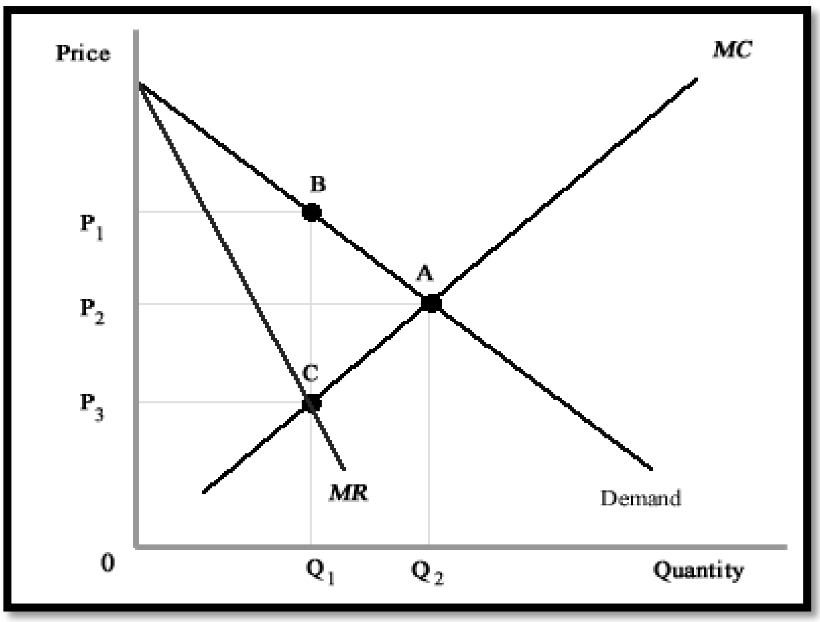


Figure-2.1

Bureaucrats and Politicians

The abovementioned arguments on the theory of bureaucracy were lacking of the relationship between bureaucrats and politicians who both choose and implement policies

(Alesina and Tabellini, 2007). Even though the link between these two significant players in the policy-making attracted the attentions of researchers many years ago, first economic insight belongs to Rogoff (1985) who particularly focuses on the decision-making process for monetary policy. In the related paper (1985), he claims that non-elected central banker with independent and inflation-averse characteristics would enhance social welfare.

Departing from preceding literature on the bureaucracy-politics relationship based upon principle-agent models (Maskin and Tirole, 2001; Schultz, 2003; Besley and Ghatak, 2005), Alesina and Tabellini (2007) states that "bureaucrats are preferable to politicians in technical tasks for which ability is more important than effort, or if there is large uncertainty about whether the policymaker possesses the required abilities to fulfil his task". Moreover, they conclude that the policies encompass "highly technical tasks" need to be handed over to the high-skilled public employees particularly in monetary policy, regulatory policies and public debt management. In addition to the aforementioned statements, Alesina and Tabellini (2008) extend their arguments in their following paper with certain propositions. They reveal the fact that bureaucrats are anticipated to perform better than politicians if "the criteria for good performance can be easily described ex ante, and are stable over time (...), the policy consequences touch narrowly defined interest groups and good performance can be easily formulated and assessed in terms of efficiency".

IV. INSTITUTIONAL PERSPECTIVE ON THE EFFICIENCY OF PUBLIC PROVISION OF SERVICES

Institutional framework for the public provision of goods and services starts with a generic question: "To what extent other forms of institutions may either be for-profit and not-for-profit, are capable of providing public goods and services in lieu of public sector organizations?" (Weisbrod, 1988). And accordingly, this particular question stimulates both empirical and theoretical researches so as to comprehend the possible failures/weaknesses as well as strengths of public provision of goods and services concerning particularly the efficient allocation of resources. The application of heterogeneous demands of consumers (Weisbrod, 1998) and the incentive schemes (Dixit, 2002; Burgess and Ratto, 2003;Ben-Ner, 2006) are frequently visited references in the papers working on the institutional analysis of provision of public goods and services, which have significant insights on the efficiency literature of public sector organization.

It is obvious that not only consumers but also suppliers have preferences and priorities among institutional forms including private, public and non-profit sector in relation to the provision of public services. Weisbrod (1988) argues that as long as the regulation of non-profit organizations (NPOs) is easier than regulation of outputs/production process/distribution of output carried out by public institutions in production of collective goods, than NPOs become more attractive to provide that particular type of public service provision. Moreover, heterogonous demands among the collective goods cause an institutional bifurcation between non-profit and public sector. That is to say, whilst public sector is more preferable in the markets where consumers have homogenous demand, heterogeneous demands of society in particular sectors necessitates non-profit sector to meet the needs of this sort of consumer choice (Weisbrod: 1988).

The chief argument on the inefficient usage of resources within public sector is interrelated with the trade-off between incentive schemes and efficiency performances of public sector organizations. In the mainstream microeconomics literature, public organizations are seen as inefficient entities as there is a lack of appropriate incentive scheme within them. To Burgess and Ratto (2003) "explicit incentive contracts in the form of performance-related pay have always been more common in the private sector than in the public sector, but the issue of incentivising the public sector is relatively recent", hence the incentive-orientated policies are encouraged to be put into action to overcome this structural obstacle for the efficient allocation of resources. From a different perspective, Dixit (2002) argues that sharing a set of "idealistic or ethical purpose" incentivises public sector employees, and subsequently motivates efficiency performances in a better way. The reference papers indicated above enumerate a number of points that impact on the incentive structure in the public sector organizations either in a good or bad way:

a. Multiple Principals (Both)
b. Multiple Tasks (Dixit)
c. Measurement and Monitoring Problems (Burgess and Ratto)
d. Lack of Competition (Dixit)
e. Teams in production and rewards (Burgess and Ratto)
f. Intrinsic motivation (Burgess and Ratto) & Motivated agents (Dixit)
g. Consequences (Dixit)

On the other hand, Ben-Ner (2006) argues that both non-profit and public sector organizations face more obstacles for operating in the efficient levels than for-profit counterparts. That is to say, if these organizations were to produce identical goods in the same circumstances, for-profit firms would be quite advantageous to be more productive than their rivals in the public and NP sector. After stating this, he points out that several contingencies like 'size of communities, educational attainment of consumers, and extent of social capital' do influence the comparative degree of efficiency in public and non-profit organizations. On the contrary, Borzaga and Bacchiega (2003) assert that NPOs would perform well in the provision of personal and collective goods that are not provided by for-profit and public organizations efficiently due to two main reasons: firstly, these services usually entail market and contractual failures, and secondly, 'a certain degree of redistribution from financiers to consumers' might be needed for production to start.

In the current literature, one of the components of the comparison between NPOs and public sector organizations is contingent upon the cost efficiency of service provisions. This notion stresses the reality that means of income redistribution *per se* encompass both production and distribution costs. That is to say, if a certain institution is devised to perform redistribution, that institution will include administrative/bureaucratic costs to be able to keep up its operations. Arthur Okun (1975) clarifies this argument with "Leaky-Bucket" experiment as follows: "However, the program (for income redistribution) has an unsolved technological problem: the money must be carried from the rich to poor in a leaky bucket. Some of it will simply disappear in transit, so the poor will not receive all the money that is taken from the rich". Hence, an organization with more complicated administrative structure and bureaucracy is expected to be more inefficient than its less bureaucratic counterpart. Advocates of NPOs to supply welfare/public services are mostly triggered off this cost efficient structure of NPOs (Robinson, 1997; Hulme and Edwards, 1997). Estelle James (1990) proposed that thanks to less bureaucracy, lower staff salaries and reliance on volunteers, NPOs could offer more efficient service delivery than their public sector counterparts through reducing the costs in a dramatic way. However, one needs to keep in mind that these arguments are not elucidating the ambiguity on quality levels of cost-reduced products and/or services.

V. CONCLUSION

After introducing the theoretical framework on the efficiency of public sector, this chapter examines the economic theory of bureaucracy that is seen as the major source of inefficient allocation of resources in the public sector organizations. Besides, alongside with the earlier Weberian (1947) and Downsian (1965) interpretation of bureaucracy, alternative perspectives on bureaucracy including contemporary debate on the efficient role of politicians and bureaucrats in the policy-making is visited referring to the recent papers of Alesina and Tabellini (2007; 2008). Lastly, institutional framework for the provision of goods and services is presented to have a comparative understanding of public sector organizations *vis a vis* their non-profit and private counterparts.

While ending this chapter, the implications of economic theories of bureaucracy on the higher education management in Turkey will be mapped out below on the basis of abovementioned arguments. The comprehensive analysis will follow those analyses in the upcoming chapter that focuses entirely on public higher education in Turkey. The relevant numerical figures on the spending schemes are shown in the Chapter V and VI where the estimation analyses are carried out.

Niskanen's first and foremost assumption on the structure of public institutions implies that bureaucrats prefer budget-maximising spending scheme rather than profit-maximising one, which departs from Downs' argument on self-interested bureaucrat. Thus, a chosen public institution is expected to experience higher spending levels then their non-profit and/or for-profit counterparts. The Turkish case on higher education spending where public universities have larger budget allocations than non-profit ones is in tandem with the conventional analysis on budget choices of bureaucratic institutions.

Following the budget maximising behaviour of bureaucrats put forward by Niskanen, Williamson's expense preference model is highly relevant with the Turkish public higher education due to the fact that relatively higher amount of spending is allocated to labour expenses than capital and goods and services expenditures. This budget allocation choice is made by administrative bodies of public universities to be able to get a control over to the organization thanks to recruiting more staff. Therefore, the notion of *catallaxy* is in function for the Turkish public higher education, as in the other free market orientated cases, which suggests that heads of schools, deans and Vice-Chancellors (VCs) maximise their budget shares as well as the extent of their power over to the institution instead of social welfare.

In addition to the expense preferences of managers in Turkish public universities, their appetite towards gaining more control over to the organization seems to be associated with the Dunleavy's bureau-shaping model in which top-level managers prioritise preserving their prestigious position within the organization in addition to the monetary gains. The VCs in the Turkish public HEIs are extremely powerful actors who have the full authority on the staff appointments, budget allocation among the schools and departments as well as the usage of university's facilities. Besides, according to the state protocol practices, VCs have the 8^{th} highest position in the provinces just after the high-ranking judges. Hence, losing this position would also mean being deprived of the social and political status, which allows VCs to exercise power over to the organizational bodies in the university.

Throughout the last 10 years, after 2001 banking crisis in Turkey, Turkish public universities face an upward slope in the allotted budget schemes proving Tullock's inter-temporal budget analysis in the public sector organizations, which is indicated in (2.6) above. The increasing level of spending in the Turkish higher education stimulated a dramatic increase in the number of public HEIs (investment on new buildings and campuses) by the beginning of 2005 reminding the De Alessi's statements on lower discount rates and overinvestment in the public sector organizations.

As indicated earlier, recent discussions are intensified on the efficient allocation of power between politicians and bureaucrats as far as the policy-making is concerned, stated by Alesina and Tabellini. For the Turkish higher education case, politicians' influence over to the HEIs through appointing the VCs and allocating the budget schemes is rather obvious. Although higher education management needs technical skills such as being well informed on cutting-edge research and teaching facilities, political parties have usually preferred to manipulate universities concerning their own political interests, which accordingly prevented to develop long-term plans.

The last but not least implication is coming from 'incentive-efficiency dichotomy' claiming that public institutions are less efficient than non-profit and for-profit ones owing to the fact that employees in the public sector organizations face less incentives than their counterparts in the non-profit and for-profit organizations. Therefore, public HEIs are expected to experience lower efficiency values than non-profit HEIs; which is supposed to be true for the Turkish higher education as well. So as to verify this statement, an empirical research needs to be conducted using both public and non-profit universities' data. However, lack of numerical figures on the non-profit universities does not allow researchers to make that sort of analysis currently.

CHAPTER III: Public Higher Education in Turkey

I. INTRODUCTION

The beginning of 21^{st} century led public higher education (PHE hereafter) to undergo a "state of crisis" in which share of state appropriations transferred to higher education has reduced by almost one-third throughout the last decade (Ehrenberg, 2006). This dramatic shrinkage in funding initially had an impact on faculty salaries that became higher in private universities; accordingly high quality academics are inclined not to work in public universities. Consequently, research and teaching quality -that are highly contingent upon faculty's qualification- in public universities have been surpassed by their non-profit and private counterparts (Ehrenberg, 2003).

This change in the global scale motivated national and regional entities particularly European countries to readjust their positions in an appropriate way. For instance, Sorbonne and Bologna Declarations (1998, 1999 respectively) as well as the Lisbon Strategy declared in 2000 (Mester, 2009) had a tremendous impact on policy-making of higher education in terms of standardization of quality of education across EU member and candidate states. Therefore, governments have supported new initiatives that have capabilities to provide cutting-edge research and education facilities to the lecturers and students. Turkey -as a candidate country to join EU- is one of the leading countries to rejuvenate its higher education system through both opening up new public universities and encouraging non-profit entrepreneurs to establish universities. Eventually, nearly 60 NP universities are operating in Turkish Higher Education alongside with 100 public universities contemporarily.

Higher education sector in Turkey is merely consisted of public and non-profit institutions as well as supervised by The Council of Higher Education (Yükseköğretim Kurulu, YÖK hereafter) that is an autonomous governmental organization. This council appoints deans and rectors of the universities even non-profit ones evoking statist and patriarchal type of administration in higher education. Moreover, whereas public universities are financed by governmental budget assigned by Ministry of Education annually, tuition fees and donations are the chief resources in non-profit universities. The higher education report released in 2006 by YÖK paved the way for the further policy-making decisions in the Turkish higher education. Accordingly, this chapter -that is mostly influenced by the latest YÖK reports on Turkish higher education and the economics of higher education literature- constitutes the policy-orientated aspect of this PhD research.

In this chapter, after examining public higher education system and the challenges that it is facing currently, the role of public universities in the provision of higher education is discussed relying on Turkish case. Moreover, non-profit universities that became a current trend in Turkish higher education are examined concerning their contributions to teaching and research. The outline of the chapter is as follows: Section II reviews literature on economic dimension of higher education including cost-sharing notions, Section III sheds light on the discussions around the challenges and obstacles for public universities in 21st century; Section IV describes Turkish public higher education in connection with a brief historical background, Section V puts forward NP universities as the current trend in the higher education of Turkey and finally Section VI concludes.

II. ECONOMICS OF PUBLIC PROVISION OF HIGHER EDUCATION

Economic crisis -motivated mainly by oil crisis- occurred in 1973 symbolises a vital point for the economic history of higher education. As soon as the drastic consequences of

World War II were eliminated, financial structure of countries had gone through a “boom” period that had positive impact on university education until 1973 crisis. After that date, enrolment rates and government appropriations to universities had declined dramatically particularly in the US. To Shumar (1997), “the crisis mentality” ended up with commodification of education through which students were treated as customers. Besides, this new environment tailored opportunities to private entrepreneurs to take part in higher education industry into which they transferred their business interests.

Although Shumar’s (1997) commodification arguments on higher education cannot be underestimated, fiscal problems of countries -that are mostly induced by government debts- in the contemporary age cannot be ruled out either. According to the OECD statistics, EU27 countries spend their 1.13% of their GDP on higher education institutions (Eurostat, 2012). Moreover, as Clotfelter et al. (1991) indicated clearly, in United States, expenditures on higher education increased in a considerable way between 1920s and 1980s from 0.7% to 2.6%. This remarkable change in expenditures urged policy-makers to be more cautious about the efficient allocation of resources within PHE and consequently to seek alternative mechanisms for the provision of higher education with entrepreneurial and market-orientated strategies. Therefore, the commodification process cannot be solely deduced to ideological shift (i.e. from socialism to neo-liberalism), but diversification of risks in the age of economic and in particular fiscal downturn must be taken into account seriously.

Relying on public economics literature, governmental support to higher education can be economically justified on the basis of public goods and positive externality notions that have similar reflections. These notions basically stimulate governmental intervention to the markets where third parties are influenced during the market exchange process apart from demanders and suppliers referring to the concept of “Pigouvian subsidy” (1920). For higher education case, not only two parties –students and university administration- in the market exchange are getting benefits from it, but also community living around the university becomes well off. Therefore, total benefit of university education exceeds private benefit due to addition of social benefit. Eventually, governmental support is needed to clear the market at the new equilibrium point as depicted in Figure-3.1 below.

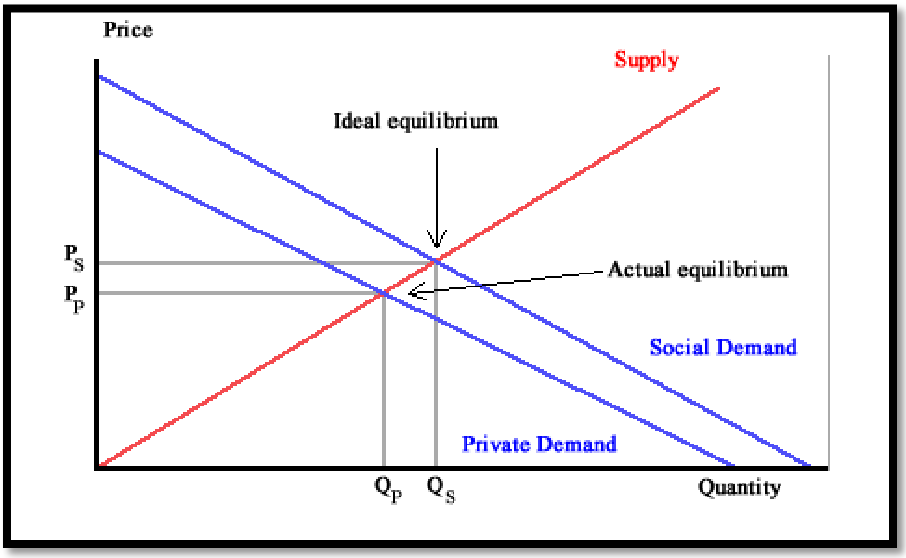


Figure-3.1

The possible failure of government intervention to this sector concerning efficient market paradigm is facing difficulty to set the appropriate tuition level that covers program costs as well as the amount of increase in tuition over time (Dill, 1997). To overcome this "economic calculation problem" of governmental institutions (Mises, 1990), deregulation of higher education and allowing non-governmental actors to get involved in this sector has been proposed by economists along with international organizations such as World Bank, UNESCO and OECD. Thanks to the participation of new players in this market, upward social mobility especially in the developing countries will be ensured via changing the current structure of education from elite to mass-orientated system in a more efficient way as clearly supported by World Bank under the strategy of "investing for all" and OECD's "equity" schemes (OECD, 2005; World Bank, 2011)

The fully marketization of higher education to alleviate governmental deficiencies and work out funding problem might not be a proper policy-making due to volatile structure of financial markets which would have a dreadful impact on reel markets including higher education sector. Thus, some argues that there is a precise need to repositioning of governments to sustain a balance between competition and regulation (Bloed, 2010). Bloed (2010) summarises the issue of funding and government intervention in higher education within the framework of autonomy and regulation dichotomy in four questions:

1. Who is responsible for paying higher education?
2. In what ways public funding is allocated to higher education?
3. What sort of incentives will be created thanks to the allocative mechanism?
4. How much autonomy universities will exercise over to the financial and human resources?

The first question put forward by Bloed (2010) forms the backbone of economics of higher education as well as has an apparent connection with "cost-sharing theory". This aforementioned approach is in favour of distributing the cost burden of higher education among the stakeholders comprised of individual students, families and government (Johnstone, 2004). To Johnstone (2004), sharing the cost in higher education became a necessity for this age of austerity in which governments are confronting "nearly intractable shortage of available public (taxpayer-based) revenue" and "growing competition from other, oftentimes more politically compelling, public needs such as elementary and secondary education, public health, housing, public infrastructure, welfare and the social and economic 'safety net', and internal and external security." Hence, encouraging enthusiastic entrepreneurs to establish universities is situated at the top of policy-making agenda in higher education across the world. Moreover, allocation of funds to the public higher education institutions with the appropriate incentive scheme receives greater attention than before, which encourages the researcher of this thesis to conduct an efficiency analysis on the Turkish PHE case.

III. CHALLENGES FOR PUBLIC HIGHER EDUCATION IN 21ST CENTURY

In this section of the paper, challenges being confronted by public institutions to provide higher education particularly for the 21^{st} century will be examined primarily relying on sustainable and stable funding crisis. By the beginning of new millennium, public higher education (PHE) seems to be in a “state of crisis” in which share of state appropriations transferred to higher education has reduced by almost one-third throughout the last decades (Ehrenberg, 2006). This dramatic shrinkage in funding initially had an impact on faculty salaries that became higher in private universities; accordingly high quality academics are inclined not to work in public universities (Ehrenberg, 2003). Consequently, research and teaching quality -that are highly contingent upon faculty’s qualification- in public universities have been surpassed by their non-profit and private counterparts.

The fundamental argument proposed to elucidate funding cuts in higher education is government’s preferences in spending on a plethora of sectors that have relative weights in the eyes of policy makers. As indicated by Rizzo (2006) in a panel data analysis for US state spending preferences, “Public higher education has been crowded out by increasing demands for state support of K12 education as a result of court-mandated equalization programs, but more important because of the great deal of discretion legislatures have over higher education spending" (Rizzo, 2006). For governments, the magnitude of positive externalities in primary and secondary education is exceedingly higher than the 4-year university education; hence these particular fields of education are seen to be more attractive for financial support.

Even though share of public funds in higher education has declined in recent years, they're still forming the significant share of funding schemes particularly in EU countries as illustrated in CHINC project's final report (Lepori et al., 2007). To this report, the trends in higher education spending among sample countries including UK, Spain, Switzerland, Norway, Germany, Italy, Netherlands and Czech Republic can be summed up under the four points:

1. Government appropriations are dominant resources in higher education funding corresponding to two-thirds in all countries except UK (37% in UK).
2. Tuition fees are significant resources only in Italy, UK and Spain.
3. The aggregate share of grants & contracts are differing from one country to another ranging from 10% to 20%.
4. Over the period 1995-2003, there is a slight decrease in governmental support to universities and no apparent change in the level of tuition fees.

This spending trend in EU members was drastically affected by the financial crisis occurred in 2008 which is out of the aforementioned project above. The salient example can be pointed out as UK where the current coalition government introduced a new funding scheme and tuition level to reduce the share of higher education expenditures in budget relying on Browne's findings and recommendations (Browne, 2010). Whereas the average Home/EU fee for an undergraduate degree was £3300 before the newly introduced scheme that preserves the previous student loan opportunities, it is now ranging from

£7500 to £9000 concerning the quality of the education university provides. This particular case reveals the point that to be able to alleviate the dire consequences of fiscal depression and have stable funding mechanism, new actors with more efficient resources allocation structures should get involved in higher education either establishing first-hand universities or invigorating current ones by means of partnership.

The scale of cutbacks in PHE in US is greater and more ubiquitous than EU as well as exacerbated by enrolment and inflation rates (Blose et al., 2006). As Rizzo (2006) indicated evidently, even if the amount of money used up to higher education raised $30 billion to $60 billion between 1974 and 2000, cost-covering capability diminished from 78% to 43%. Mainly for that reason, in lieu of full-time lecturers, adjuncts (part-time instructors) are opted by public institutions for the teaching positions that are 80% less expensive than full-time faculty (Bettinger et al., 2006). The simultaneous effect of increased use of adjuncts in public universities and high-quality faculty's leave from them -as mentioned earlier- have adversely affected the reputation of public universities and motivate students to prefer private universities. However, the impact of this decision onto the efficiency performances of HEIs still preserves its ambiguity that needs to be illuminated in this research.

Another challenge faced by PHE particularly in vocational education is lack of compatibility of traditional education skills with the requirements of labour market (De Alva, 2000). The gap between necessary skills for employment and provided education accounts for a significant proportion of unemployment among university graduates and results in dissatisfaction by employers. The findings of 1998 poll called "Transforming Post-Secondary Education for the Twenty-First Century" (De Alva, 2000) conducted with 50 state governors revealed four points that seemed to be the most important expectations from post-secondary education:

1. Students should be encouraged to go on lifelong learning
2. Allowing students to access educational facilities at any time, and use technological instruments for applied work
3. Stimulating collaboration between post-secondary institutions and private sector
4. Integrating job experiences into academic programs

Consequently, both society and policy-makers need to “bring adequate attention to the fact that PHE is increasingly in jeopardy because of instability and disinvestment on the part of most state governments” (King, 2006). So as to overcome abovementioned obstacles in PHE via ruling out ideological obsession, there is a precise need to enhance effective cooperation among public, private and third sector institutions in higher education. To prompt these current and prospective stakeholders, it is inevitable to have a “serious public policy discussion, setting out the public, as well as private, benefits of having a highly educated workforce, and deciding what fraction of the costs of education should be borne by the recipients of that education and what fraction should be borne by the public at large for the benefits they, too, receive” (Wiley, 2006).

IV. CONTEMPORARY OUTLOOK OF HIGHER EDUCATION IN TURKEY

Higher education sector in Turkey is fundamentally consisted of public and non-profit institutions as well as supervised by The Council of Higher Education (Yükseköğretim Kurulu, YÖK hereafter) that is an autonomous governmental organization. This council appoints deans and rectors of the universities even non-profit ones evoking statist and patriarchal type of administration in higher education. Moreover, whereas public universities are financed by governmental budget assigned by Ministry of Education annually, tuition fees and donations are the chief resources in non-profit universities. This section will examine Turkish higher education sector mostly motivated by YÖK's report released in 2006 regarding three points a) administrative and academic structure b) finance c) academic success including publications, patents and citations.

Administrative and Academic Structure

With respect to the previous legal framework put into action in 1981, five different institutions were running in Turkish higher education comprising universities, academies, 2-year vocational schools and conservatories, 3-year education institutions belonging to Ministry of Education and distance learning named as YAYKUR. In the following years, vocational schools, conservatories and 3-year educational institutions were connected to university administrations with couple of official amendments. The momentous increase in number of universities occurred in 1992 where 21 new universities were integrated into the sector. Furthermore, in 2006 and 2007, government established 41 public universities mostly in less developed cities as a part of regional development policy. This trend is shown in Figure-3.2 below. The chief motivation behind the increase in the number of public HEIs in Turkey can be articulated as "the governmental aspiration for provision of mass education" (Onder and Onder, 2011).

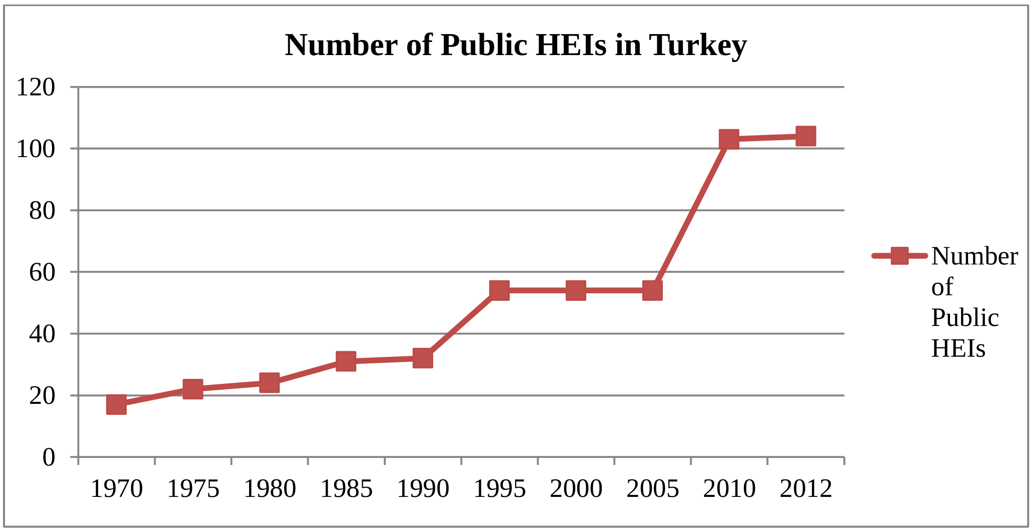


Figure-3.2

YÖK is the main administrative institution to manage universities in Turkey. With variations among public and non-profit universities, the universities' administrative bodies -deans and rectors in particular- are appointed within the YÖK's regulative procedures. However, the heads of board of directors in non-profit universities seize more managerial power than appointed rectors. The other supervisory organization in Turkish higher education is Interuniversity Council of Turkey (Üniversiteler Arası Kurul, ÜAK hereafter) that has a responsibility to coordinate universities in terms of academic well being as well as award associate professorships to the candidates with an oral examination. The candidates must fulfil certain requirements such as publishing papers in SSCI journals at least one in domestic journal.

The aforementioned supervisory entities bears the crucial question in minds is that to what extent Turkish universities are autonomous in decision-making process. Due to the fact that autonomy is the driving force behind innovation and keeping pace with cutting-edge academic enhancement, universities should have more autonomous administrative bodies than any other institution. Current OECD statistics (2005) concerning the level of autonomy in universities do not have optimistic signs for Turkey. Whereas Turkey's score is nearly 1.5 that is one of the lowest, Denmark had 6, Norway 5, Austria 4.5 and South Korea 2.5. These scores stipulate less influence from supervisory institutions (YÖK and ÜAK) as well as more emphasis on university-based decision-making.

Finance

Financing higher education in Turkey has been an essential policy issue for governments owing to centrally planned budget scheme in which public universities' individual budgets are determined and allocated. The constitutional reference identifying higher education as a form of public service is founding the legal backbone of governmental organizations to support universities financially. Whilst the public universities are mostly sustained by "public finance", non-profit universities have "private finance" mechanism mostly consisting of tuition fees and private donations. This private financing scheme in non-profit universities procures more autonomous administration, which results in academic freedom and research-orientated innovation. On the other hand, allocations from central budget for public universities can be enumerated as the key factor behind lower levels of autonomy in decision-making process.

The current financial structure of public HEIs in Turkey are clearly revealed in the Figure-3.3 with the most-updated data. To this figure, share of central government's appropriations decreases by 20%, whereas the share of universities' own revolving funding is increased by 50% between 1995 and 2005. However, there is not any evident change on the share of student contributions in the total higher education budget. As far as the cost-sharing notions in the finance of higher education is concerned, Turkish universities are showing an optimistic sign concerning the burden on the public finance, albeit central government is financing almost 60% of the whole higher education budget.

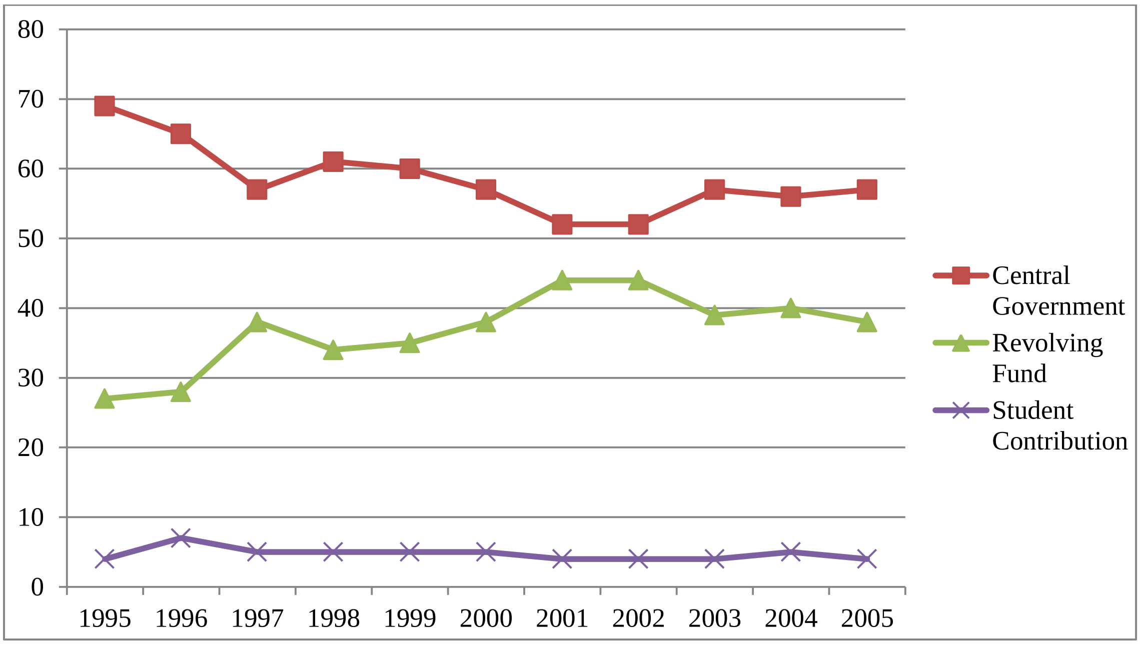


Figure-3.3

At the beginning of 1990s, the share of budget financing in public universities' revenues was 80% that has shown a descending tendency to nearly 50% recently. This reduction indicates optimistic signs in terms of alleviating the burden on public finance that is in favour of increasing the share of self-financing resources in universities. The previously mentioned YÖK report -published in 2006- relying on 2005 statistics was pointing out the shares of revenue items in public universities. To this report, 57% of revenue is being formed by universities' own budgets whereas the share of working funds is 38%. Moreover, 4% of it comes from students' contributions and the rest of it –which is nearly 1%- is other type of resources. To be able to examine the overall outlook of the share higher education financing in the total national economic activity, Figure-3.4 that illustrates the share of YÖK's budget in GNP would be a good reference point.

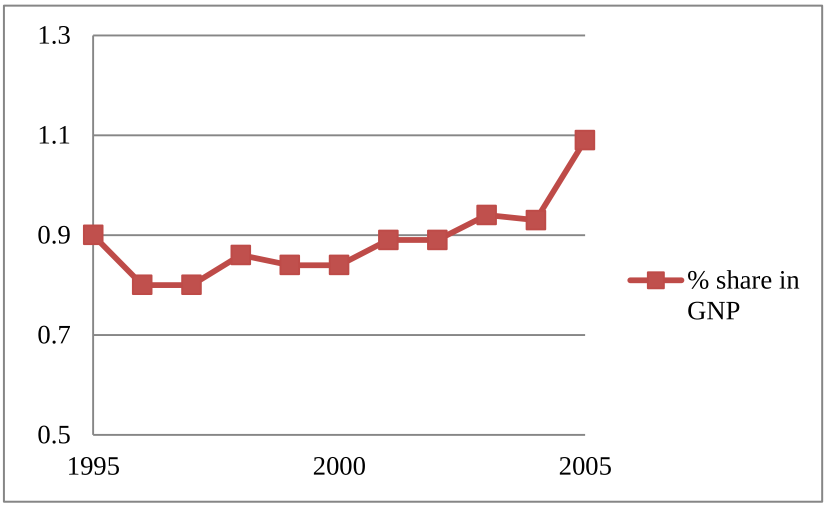


Figure-3.4 (YÖK, 2006)

Academic Success and Research

To the recent university rankings survey conducted by University Ranking by Academic Performance (URAP, 2011), three Turkish universities (Hacettepe, İstanbul and Ankara) succeeded to be in the top 500 universities list, and did other 17 universities in the top 1000 list. The salient characteristic of top three universities is to have well-established academic and administrative structure. For instance, İstanbul University was founded in 1846 as the first "secular" higher education institution during the period of Ottoman Empire. Accordingly, Ankara and Hacettepe universities can be identified as the earliest academic institutions established at the course of foundation of modern Turkish Republic.

In terms of the academic success of HEIs, research productivity of academics that is mostly consisted of number of publications and research grants has gained a significant role in revealing the academic quality of higher education institutions (HEIs) during recent years. University ranking measures including URAP, are taking the research productivities of academic staff into account alongside with certain quality indicators. Therefore, it is apt to demonstrate here that extent to which public HEIs in Turkey is growing concerning their research outputs. Figure-3.5 below represents the 5-year trend in research funding given by TÜBİTAK (Scientific and Technological Research Council of Turkey). According to these records, public HEIs in Turkey do not have a consistent development in research outputs as far as the amount of research grants awarded by TÜBİTAK is concerned.

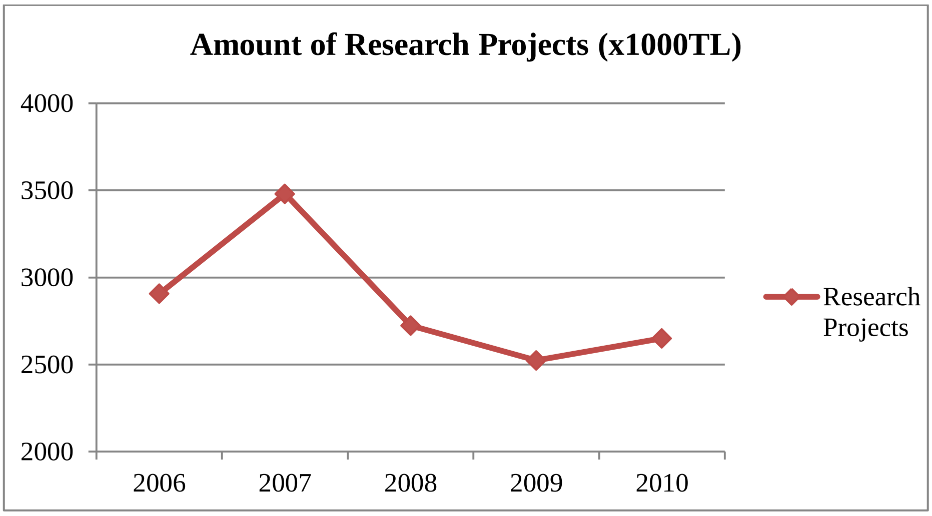


Figure-3.5

Even though economics of higher education in the developed countries has been enriched thanks to the papers published particularly throughout the previous decade (Ehrenberg et al., 2006), the number of researches on the higher education sector in the developing countries is highly scarce. Following to the restructuring of finance schemes in HEIs and application of cost-sharing theories in the higher education policy making among developed countries including UK and United States, the number of papers that are specifically focused on research productivities of academic staff is considerably growing as well (Gonzalez-Brambila and Veloso, 2007; Nguyen, 2009). However, there is not any sign of improvement for developing countries in which Turkey does not become an exception. Therefore, there is a precise need to conduct comprehensive research on the Turkish higher education examining particularly the research performance aspect of the universities in Turkey.

Last but not least, the URAP survey's results reveal the fact that even though newly emerging non-profit universities have had remarkable achievements in certain research areas, their overall academic performance is not sufficient to compete with their public counterparts currently as shown in Table-3.1. The best university among them –Bilkent University- became 11th in the rankings table. Besides, the top 10 universities are still public ones with relatively higher scores then non-profit universities. On the other hand, non-profit universities' appearances in the table within this relatively short time compared to the public universities indicate optimistic signs for the future of Turkish higher education as soon as this competition brings quality into the teaching and research.

RANKING	UNIVERSITY	Type of the University	SCORE
1	HACETTEPE ÜNİVERSİTESİ	PUBLIC	692.59
2	ORTA DOĞU TEKNİK ÜNİVERSİTESİ	PUBLIC	689.40
3	İSTANBUL ÜNİVERSİTESİ	PUBLIC	677.59
4	ANKARA ÜNİVERSİTESİ	PUBLIC	673.77
5	GAZİ ÜNİVERSİTESİ	PUBLIC	619.59
6	EGE ÜNİVERSİTESİ	PUBLIC	619.35
7	GEBZE YÜKSEK TEKNOLOJİ ENSTİTÜSÜ	PUBLIC	606.15
8	İSTANBUL TEKNİK ÜNİVERSİTESİ	PUBLIC	604.75
9	ATATÜRK ÜNİVERSİTESİ	PUBLIC	567.98
10	ERCİYES ÜNİVERSİTESİ	PUBLIC	565.45
11	BİLKENT ÜNİVERSİTESİ	NON-PROFIT	560.88
12	İZMİR YÜKSEK TEKNOLOJİ ENSTİTÜSÜ	PUBLIC	554.04
13	BOĞAZİÇİ ÜNİVERSİTESİ	PUBLIC	552.64
14	SABANCI ÜNİVERSİTESİ	NON-PRFOIT	551.66
15	DOKUZ EYLÜL ÜNİVERSİTESİ	PUBLIC	541.39
16	ONDOKUZ MAYIS ÜNİVERSİTESİ	PUBLIC	534.48
17	ÇUKUROVA ÜNİVERSİTESİ	PUBLIC	529.28
18	AKDENİZ ÜNİVERSİTESİ	PUBLIC	528.79
19	FIRAT ÜNİVERSİTESİ	PUBLIC	528.03
20	BAŞKENT ÜNİVERSİTESİ	NON-PRFOIT	524.60

Table-3.1 (URAP, 2011)

V. NON-PROFIT UNIVERSITIES IN TURKISH HIGHER EDUCATION

As a concluding section of this chapter, the current phenomenon in Turkish higher education –which is non-profit universities-, is touched upon due to their growing significance concerning both their numbers and teaching & research quality. The empirical findings of this research are expected to shed some light on the further policy-making to encourage non-profit entrepreneurs opening up universities in the areas where their public counterparts are struggling in terms of resource allocation. Besides, as soon as the cost structure of public HEIs is mapped out, non-profit universities would benefit from this for their prospective resource allocation decisions.

In Turkey, first and foremost requirement for opening up a university by entrepreneurs is not-for-profit motive (Turkish Constitution: Code No.130); hence there is not any for-profit university in Turkish higher education sector. Whereas the first foundation university was launched in 1984, numbers of non-profit universities and their student attendance have dramatically increased during the last decade as shown in Figure-3.6 and 3.7 respectively (YÖK, 2007). The report released in 2007 by The Council of Higher Education underscores the significance of non-profit universities "which started to shoulder the burden carried by public counterparts via providing high quality education to their students."

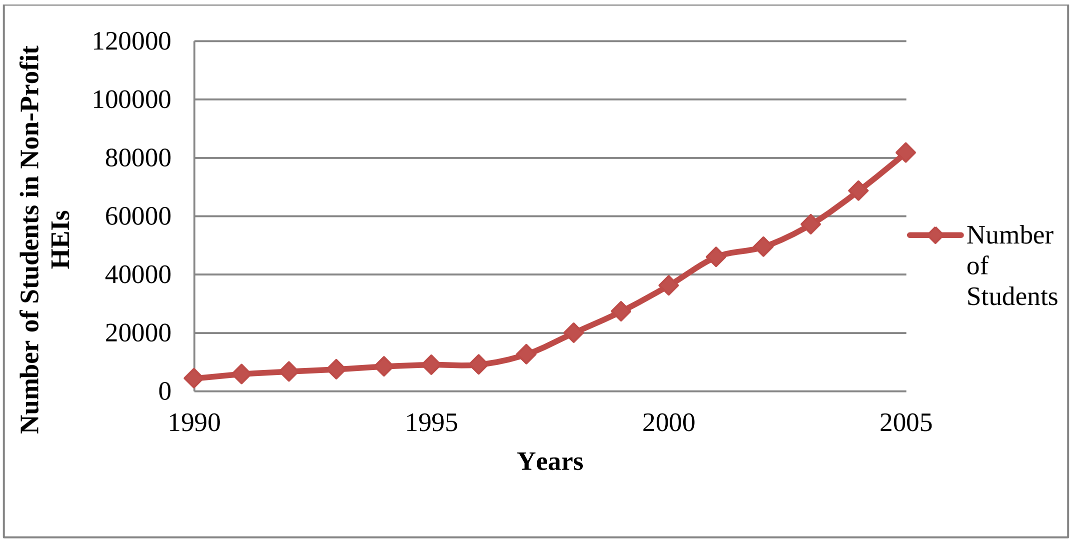


Figure-3.6 (YÖK, 2007)

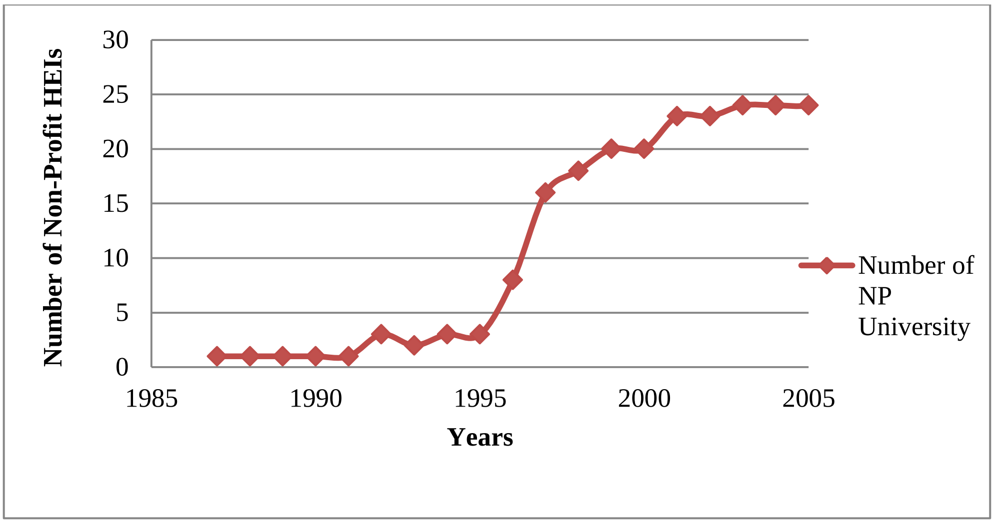


Figure-3.7 (YÖK, 2007)

This YÖK report mentioned above is explaining emergence of non-profit universities as a supply-side respond to the growing demand in higher education. Due to lack of sufficient provision by government, consumers lead entrepreneurs particularly non-profit ones to take part in market and address their needs as clearly pointed out in the previous chapter. Accordingly, demand-side pressure had a tremendous impact on Turkish higher education market and triggered the foundation of new universities predominantly at the midst of 1990s. The positive reaction came from suppliers resulted in a mutual relationship with consumers and nurtured this noteworthy boost in non-profit university sector.

Non-profit universities have three main financial resources comprising of foundation's own initial capital, tuition fees and state appropriations. The lion share of these resources belongs to tuition fees paid by enrolled students that are varying from one university to another. Government's financial support to the non-profit universities is forming a relatively small proportion of whole budget as well as has certain set of criteria for universities to be eligible for these benefits. Increasing the number of students granted with scholarship and training new teaching staffs can be enumerated as principal requirements for financial assistance by government. Table-3.2 is showing a sample of the share of government support to the non-profit universities' whole budgets relying on figures compiled by YÖK in 2005. As indicated in the table, highest share corresponds to 3.6% that means that non-profit universities' self-financing mechanism alleviates the burden carried out by public finance resources.

UNIVERSITY	**Percentage of State Appropriations to the Budget (%)**
BİLKENT ÜNİVERSİTESİ	1.6
SABANCI ÜNİVERSİTESİ	0.8
BAŞKENT ÜNİVERSİTESİ	2.7
KOÇ ÜNİVERSİTESİ	1.3
KÜLTÜR ÜNİVERSİTESİ	2.6
ÇANKAYA ÜNİVERSİTESİ	3.6
IŞIK ÜNİVERSİTESİ	2.4
HALİÇ ÜNİVERSİTESİ	2.7
ÇAĞ ÜNİVERSİTESİ	1.8
UFUK ÜNİVERSİTESİ	0.9

Table-3.2 (YÖK, 2007)

Last but not least point that must be stressed here is academic performance of NP universities in particular their research outputs. So as to expose the tremendous improvement in research among these universities, Table-3.3 is incorporated to the paper. To this table, within the last five years period between 2006 and 2010, NP universities almost doubled their number of publications appeared in SCI, SSCI and AHCI.

UNIVERSITY	**Number of Publications**	**Number of Publications**

	(2010)	(2006)
BAŞKENT ÜNİVERSİTESİ	392	357
BİLKENT ÜNİVERSİTESİ	383	244
YEDİTEPE ÜNİVERSİTESİ	230	105
KOÇ ÜNİVERSİTESİ	200	140
FATİH ÜNİVERSİTESİ	188	74
SABANCI ÜNİVERSİTESİ	164	103
TOBB ÜNİVERSİTESİ	115	40
ÇANKAYA ÜNİVERSİTESİ	103	59
ATILIM ÜNİVERSİTESİ	94	52
İZMİR EKONOMİ ÜNİVERSİTESİ	87	31
BAHÇEŞEHİR ÜNİVERSİTESİ	69	12
DOĞUŞ ÜNİVERSİTESİ	68	42
İSTANBUL BİLİM ÜNİVERSİTESİ	49	0
UFUK ÜNİVERSİTESİ	46	8
MALTEPE ÜNİVERSİTESİ	39	11
KÜLTÜR ÜNİVERSİTESİ	36	12
KADİR HAS ÜNİVERSİTESİ	33	15
IŞIK ÜNİVERSİTESİ	30	38
OKAN ÜNİVERSİTESİ	28	0
YAŞAR ÜNİVERSİTESİ	28	6
BEYKENT ÜNİVERSİTESİ	23	0
TOTAL	2405	1349

Table-3.3 (URAC, 2011 and YÖK, 2007)

Even though their academic achievements are not satisfactory to compete with their public rivals (as indicated in Table-3.1), NP universities have shown stable growth rates in research activities during the previous academic years. Eventually, one can argue that concerning these figures in academic performance, they would change the sequence in university rankings table very soon.

VI. CONCLUSION

Economic crisis -motivated mainly by oil crisis- occurred in 1973 symbolises a vital point for the economic history of higher education. As soon as the drastic consequences of World War II were eliminated, financial structure of countries had gone through "boom" period that had positive impact on university education until 1973 crisis. After that date, enrolment rates and government appropriations to universities had declined dramatically particularly in US. To Shumar (1997), "the crisis mentality" ended up with commodification of education through which students were treated as customers. Besides, this new environment tailored opportunities to private entrepreneurs to take part in higher education industry into which they transferred their business interests.

Currently, Turkish government's policies to increase provisions in higher education sector through establishing new universities pose vital questions as far as the efficient allocation of resources is concerned. The growing awareness in the efficient usage of funds allocated to the HEIs is mainly motivated by the fact that the share of social welfare expenditures has been increasing dramatically for the last 15 years. For instance, education expenditures in GNP have risen nearly 60% within the time period of 1996-2006 (Turkish General Directorate of Public Accounts, 2007). Consequently, government authorities encourage additional care on the performance indicators so as to reconsider the future allotments to the individual institutions.

The policy related conclusions of this PhD thesis stem exclusively from the aforementioned arguments revealed throughout this chapter. Universities with relatively older ages, larger sizes and less-qualified faculty are compared and contrasted with the universities having opposite characteristics concerning their efficiency performances. Moreover, global cost structure for the Turkish PHE as well as the individual efficiency scores are put forward to tailor opportunities for the further policy decisions not only for the public universities but also for the non-profit ones.

In conclusion, this chapter points out the challenges and obstacles faced by public higher education institutions in 21st century. Secondly, it examines the contemporary outlook of Turkish higher education regarding to administrative structure, finance and academic success. And eventually, the role of non-profit universities is discussed to pose the question whether they might be good substitutes for public universities in the areas where government is confronting difficulties to provide decent quality services.

CHAPTER IV: Estimation Methodology of Economic Efficiency

I. Introduction

In microeconomic theory, the objective of firms is identified as producing maximum output using given inputs with minimum cost. In other words, it can be defined as utilising minimum amount of one input within a given output and other input levels. This microeconomic notion stipulates or presumes that firms –within the framework of free market rules- should allocate input and output efficiently with the aim of obtaining maximum profit and/or minimum cost. Up to now, productive efficiency of a firm has been calculated by means of measuring the distance to a particular frontier such as the revenue frontier, profit frontier, cost frontier and production frontier.

Revenue frontier efficiency models measure the distance between each organization's actual revenue and maximum attainable revenue; profit frontier models figure out the distance between firms' actual profit levels and maximum attainable profit; cost frontier deals with the gap between actual cost and minimum achievable cost level, and finally production frontier gauges the distance between actual amount of output of the organizations and the highest level of feasible output (Kumbhakar and Lovell, 2000:57). Whereas revenue frontier model requires output prices information for the analysis, cost frontier entails input prices. And the profit frontier needs to incorporate both output and input prices; production frontier does not demand any information about prices.

This chapter investigates estimation methodology of economic efficiency on the basis of both mathematical programming and econometric techniques. Section II defines and illustrates the concept of efficiency regarding microeconomic framework. Section III examines Data Envelopment Analysis (DEA) that is the major linear programming model in efficiency analysis. Section IV deals with econometric techniques in particular Stochastic Frontier Analysis (SFA) that is the mostly used model among parametric techniques. Section V compares the merits and weaknesses of these aforementioned methodologies and concludes.

II. Definition of Efficiency

In market economies in which markets exercise power on the behaviours of firms and individuals, they are expected to achieve the theoretical maximum either in production and/or consumption. The failure of firms to produce at the "best-practicing" frontier that can be called as production inefficiency has been elaborated by researchers (Hicks: 1935, Debreu: 1951, Farrell: 1957, Leibenstein: 1966) on the basis of different approaches. Hicks (1935) argued that monopolistic firms do not feel any market restraint on them to become fully efficient as enjoying benefits of monopoly. In a similar vein, Debreu (1951) and Farrell (1957) proposed that lack of market power on managers in certain cases might cause inefficiencies among the firms.

The most controversial argument in explaining the inefficiencies of firms is Leibenstein's X-inefficiency approach that contradicts with neo-classical microeconomics theory. To Leibenstein (1966), the failure of firms to produce on the efficient frontier is by and large motivated by following set of reasons including inadequate motivation, incomplete contracts, asymmetric information, agency problems and attendant monitoring difficulties which are lumped together and form X-inefficiency. Stigler (1976) objected to this approach and put forward that all sources of inefficiency according to Leibenstein

(1966) can be shown as the evidence for incomplete production model in which whole set of relevant variables are failed to be incorporated (Fried et al: 2008, 9).

The pioneering work of Koopmans (1951) provided the earliest formal definition of technical efficiency as: “A producer is technically efficient if, and only if, it is impossible to produce more of any output without producing less of some other output or using more of some input.” Subsequently, Debreu (1951) and Farrell (1957) developed a slightly different definition of technical efficiency by ruling out the slack units: “one minus the maximum equiproportionate (radial) reduction in all inputs that is feasible with given technology and output” (Fried et al: 2008, 20).

To be able to examine those aforementioned means of measurement, it might be appropriate to introduce some certain notations and formulations:

$$Level\ Set: L(y) = \{x: (y,x)\ is\ producible\} \tag{4.1}$$

the production function is derived from input isoquant function to produce y

$$I(y) = \{x: x \in L(y), \lambda x \notin L(y)\ if\ \lambda < 1\} \tag{4.2}$$

and the efficient input subset is defined as:

$$ES(y) = \{x: x \in L(y), x' \notin L(y), x' < x\} \tag{4.3}$$

eventually interrelation between these three subsets can be represented as:

$$ES(y) \subseteq I(y) \subseteq L(y) \tag{4.4}$$

and depicted in Figure-4.1:

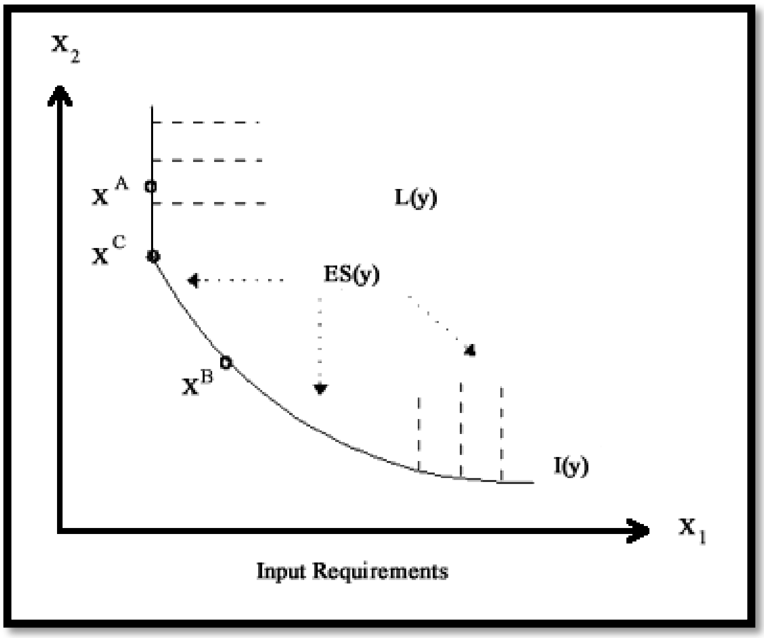


Figure-4.1

The Debreu-Farrell input-oriented technical efficiency can be formulated relying on the production function:

$$TE_{DF}\ y,x\ = \min\ \{\ \square : \square x \in L(y)\}$$

(4.5)

Shephard's (1953) input distance function is another apparatus that has been used to figure out the technical efficiency of firms from a relatively different perspective. Shephard formulated the distance function (based on input measurements) as indicated below:

$$D_S\ y,x\ = \max\ \{\lambda : \frac{1}{\lambda}\ x \in L(y)\} \qquad (4.6)$$

It is obvious that, Debreu-Farrell radial contradiction process of inputs is the inverse iteration of Shephard's input distance function. Therefore, (4.5) and (4.6) can be related to each other as:

$$TE_{DF}(y,x) = \frac{1}{D_S(y,x)} \qquad (4.7)$$

To Debreu-Farrell, the first and foremost requirement of being technically efficient is to be situated exactly on the isoquant curve I (y). However, Koopmans stipulates the “absence of coordinatewise improvements” which means “a simultaneous membership in both efficient subsets (Fried et al: 2008, 25).” For instance, while the point X^A on Figure-4.1 is technically efficient according to the Debreu-Farrell definition, Koopmans spots this point -which is outside the efficient subset- as inefficient due to slack usage of X_2. As a consequence, it is convenient to state, “Debreu-Farrell technical efficiency is necessary, but not sufficient for Koopmans technical efficiency” (Kang: 1997, 63).

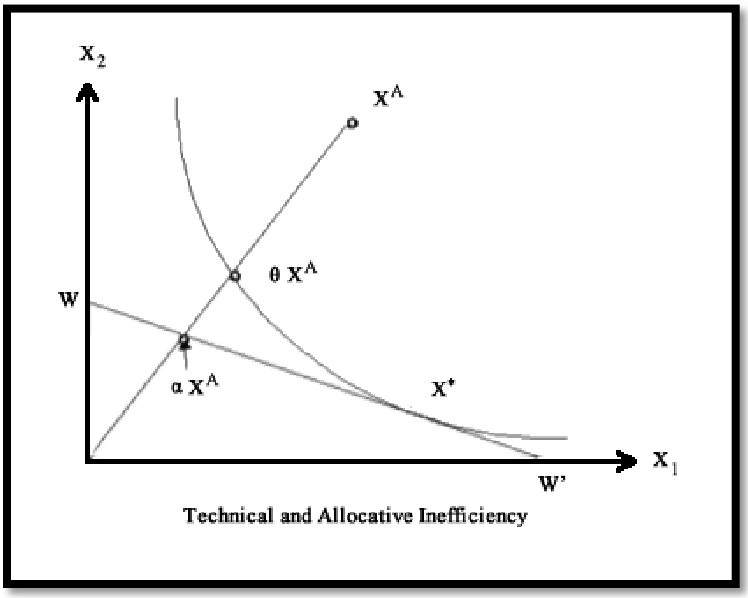


Figure-4.2

In efficiency analysis, Farrell (1957) puts forward two components as fundamentals of efficiency comprising of technical (TE) and allocative (AE). Whilst the former one arises when outputs fall short from ideal production given input level, the latter is the result of inappropriate input choices concerning certain input prices and output level. As indicated in Figure-4.2, producer utilises two inputs (X_1 and X_2) in order to produce a specific output. At the input bundle of X^A, this producer has the capability to decrease the amount of inputs all the points in "level set" back to isoquant curve until reaching to the point θX^A. That is to say, the input choices at X^A can be radially contradicted with the "absence of coordinatewise improvements" up to the point θX^A. Therefore, relying on both Koopmans and Debreu-Farrell definitions, technical efficiency of this firm at the point X^A is calculated as:

$$TE = \frac{O\ \theta X^A}{OX^A} \tag{4.8}$$

where X^Adenotes the observed input levels and θX^A represents the combination of technically efficient amounts of inputs.

To have an economically efficient production set, TE is not sufficient alone. The input combination should be selected appropriately on the basis of their prices. The best-practicing mixture of inputs concerning the prices is the intersection point of isoquant and isocost curves where technically feasible production units are produced at the lowest cost. According to the Figure-4.2, allocative efficiency at $X^A$is:

$$AE = \frac{O\ \alpha X^A}{O\theta X^A} \tag{4.9}$$

where θX^A represents the combination of technically efficient amounts of inputs, αX^A refers to the mixture of inputs that has the lowest cost given this output and technology.

In order to convert production efficiency to cost efficiency (particularly for the multiple output cases), assume that producer faces input prices $w = \{w_1, w_2 \ldots w_n\}$ and aims to minimise costs. For this case, cost frontier can be narrated as:

$$c\ \ y, w\ \ = \min_x \{\, w^T x : D_s(y, x) \geq 1\} \tag{4.10}$$

if the inputs are freely disposable and the level sets L(y) are convex and closed, the cost frontier above is the dual function of input distance function proposed by Shephard (1953). Therefore:

$$D_s(\mathrm{y},\mathrm{x}) = \min_{\mathrm{w}} \{ \mathrm{w}^{\mathrm{T}}\mathrm{x} : c \quad y, w \quad \geq 1\} \tag{4.11}$$

cost efficiency can be calculated as the ratio of minimum cost to actual cost:

$$CE\ (\mathrm{y},\mathrm{x},\mathrm{w}) = c \quad y, w \quad \mathrm{w}^{\mathrm{T}}\mathrm{x} \tag{4.12}$$

regarding to the points shown in Figure-2, cost efficiency at $X^A$is:

$$CE = \frac{O\ \alpha X^A}{OX^A} \tag{4.13}$$

As being easily inferred from Figure-2, cost-efficiency has two components that are allocative and technical efficiency. Whereas $\frac{O\ \theta X^A}{OX^A}$ corresponds to the technical side of it, $\frac{O\ \alpha X^A}{O\theta X^A}$ is indicating the allocative component. The product of them gives the value of cost efficiency.

$$CE = \frac{O\ \theta X^A}{OX^A} x \frac{O\ \alpha X^A}{O\theta X^A} = \frac{O\ \alpha X^A}{OX^A} \tag{4.14}$$

So as to measure the efficiency levels of firms, two separate methods have been developed by researchers under the rubric of mathematical programming approach and the econometric approach. Charnes, Cooper, and Rhodes (1978) originated mathematical programming approach that is also known as Data Envelopment Analysis (DEA). In DEA, multiple outputs and inputs are reduced into a single output-input form in which efficiency measure is yielded after necessary calculations are completed with linear programming.

Although DEA is frequently used in efficiency analysis its non-stochastic nature prevents researchers to attain comprehensive and sustainable results in many cases. Therefore, econometric approach or stochastic frontier analysis became preferable owing to its ability to distinguish the impact of variation in technical efficiency from external stochastic error on the firm's output. In the following sections, data envelopment and stochastic frontier analysis will be examined subsequently.

III. Data Envelopment Analysis (DEA)

One of the mainstream methods of efficiency analysis is called as DEA that does not presume any functional form for production. It basically "involves the use of linear programming methods to construct a non-parametric piece-wise surface (or frontier) over the data" (Coelli et al, 2005:162). Therefore, efficiency of each decision-making unit (DMU hereafter) that might be a bank, hospital, university and so forth is calculated regarding to the "best practising" producer. In other words, DEA is based upon a comparative analysis of observed producers to their counterparts (Greene, 2007). The comprehensive literature of this methodology can be reached in Charnes, Cooper and Rhodes (1978), Banker, Charnes and Cooper (1984), Thanassoulis and Dyson (1992), Seiford and Thrall (1990), Thanassoulis (2001) and Cooper, Seiford and Tone (2007).

Data Envelopment Analysis was first coined by Charnes, Cooper and Rhodes (1978) that had an input-oriented model with constant return to scale (CRS). This method that is currently known as basic DEA was an extension of "Farrell's measure to multiple - input multiple - output situations and operationalized it using mathematical programming" (Emrouznejad, 2000: 17). In subsequent researches, Färe, Grosskopf and Logan (1983) and Banker, Charnes and Cooper (1984), variable returns to scale (VRS) models were developed and introduced to the DEA literature. Furthermore, to capture the statistical error and separate it from efficiency term, two-sided deviation was brought in by Varian (1985) and besides "chance-constrained" efficiency analysis was integrated (Land et al., 1993) to the DEA models. And eventually, this efficiency estimation methodology is being used in the wide range of areas including management, operations research and economics.

Theoretical Framework

So as to illustrate basic DEA model mathematically, let's assume that each decision-making units (DMUs) use m inputs for the production of n outputs in a given technology level. X_{ij} denotes the amount of input *i* *(i=1,2,……,m)* produced by j^{th} DMU *(j=1,2,….,k)*, whereas Y_{sj} represents the quantity of output s *(s=1,2,…..,n)* produced by j^{th} DMU *(j=1,2,….,k)*. The variables u_r *(r=1,2…n)* and w_i *(i=1,2…m)* are weights of each output and input respectively. The technical efficiency of DMU_0 can be written as:

$$\text{Max} = \frac{\sum_{r=1}^{n} u_r Y_{r0}}{\sum_{i=1}^{m} w_i X_{i0}} \tag{4.15}$$

Subject to:

$$\frac{\sum_{r=1}^{n} u_r Y_{rj}}{\sum_{i=1}^{m} w_i X_{ij}} \leq 1 \qquad \text{for } j=1,2\ldots k \tag{4.16}$$

$$\boldsymbol{u_r} \text{ and } \boldsymbol{w_i} \geq 0 \quad (r=1,2,\ldots,n) \text{ and } (i=1,2,\ldots,m) \tag{4.17}$$

This mathematical representation can be clarified as finding the appropriate values for *u* and *w* that maximise efficiency level of the observed firm subject to all efficiency scores are less than or equal to 1. To avoid infinite solutions (Coelli et al., 2005:163) and obtain a linear programming model, Charnes-Cooper transformation can be used as following:

$$\text{Max} = \sum_{r=1}^{n} \mu_r Y_{r0} \tag{4.18}$$

subject to:

$$\sum_{i=1}^{m} w_i X_{i0} = 1, \tag{4.19}$$

$$\sum_{r=1}^{n} \mu_r Y_{rj} - \sum_{i=1}^{m} w_i X_{ij} \leq 0 , \tag{4.20}$$

$$\mu_r \text{ and } w_i \geq 0 \quad (r=1,2,.....,n) \text{ and } (i=1,2,.......,m) \tag{4.21}$$

Via using duality property of linear programming, equivalent form of this envelopment system can be illustrated as:

$$\text{Min } \Theta \tag{4.22}$$

subject to:

$$\sum_{j=1}^{k} \lambda_j X_{ij} \leq \Theta X_{i0} \qquad (i=1,2...m) \tag{4.23}$$

$$\sum_{j=1}^{k} \lambda_j Y_{rj} \geq Y_{r0} \qquad (r=1,2...n) \tag{4.24}$$

$$\lambda_j \geq 0 \quad \text{for } j=1,2\ldots k \tag{4.25}$$

where Θ is a scalar and λ is a k x1 vector of constants. The solution of this linear system will end up with finding Θs corresponding to the efficiency level of each DMU. Therefore Θ should be less than or equal to 1 as well as the firm with Θ=1 is technically efficient that means operating on the frontier concerning Farell's (1957) proposition.

In the previous section where Farell's (1957) and Koopman's (1951) definitions of efficiency were discussed, the magnitude of "coordinate wise improvements" was highlighted inspiring from Koopman's analysis. Therefore, there is a precise need to integrate slack variables into the linear programming model through which efficiency scores will be gauged concerning the slack usage of any input. The model becomes as follows:

$$\text{Min } \theta_0 - \varepsilon \left(\sum_{i=1}^{m} s_i^- + \sum_{r=1}^{n} s_r^+ \right) \quad (4.26)$$

subject to:

$$\sum_{j=1}^{k} \lambda_j X_{ij} + s_i^- = \theta X_{i0} \qquad (i=1,2,\ldots\ldots,m) \quad (4.27)$$

$$\sum_{j=1}^{k} \lambda_j Y_{rj} + s_r^+ = Y_{r0} \qquad (r=1,2,\ldots\ldots,n) \quad (4.28)$$

$$s_r^+, s_i^-, \lambda_j \geq 0 \qquad \text{for } j=1,2,\ldots,k \quad (4.29)$$

s_r^+ and s_i^- are constrained to become non-negative and transformed inequalities into equations. s_r^+ means that $Y_{r0} \leq \sum \lambda_j Y_{rj}$ must be satisfied by every single solution, whereas s_i^- denotes that $\sum \lambda_j X_{ij} \leq X_{i0}$ must be sustained for each input used by DMU_0.

As a result of all these linear programming iterations, efficiency level of the observed DMU - DMU_0 in this case- is equal to 100% if and only if:

i. $\theta_0 = 1$

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

If we turn back again the debate between Farell and Koopmans, proposition (i) is a necessary condition to Farell for efficiency; however Koopmans states that full efficiency necessitates both (i) and (ii).

Figure-4.3 illustrates DEA in a very generic representation that allows discussing Farell and Koopmans's efficiency approaches straightforwardly. To Farell, all the points on the isoquant curve can be named as efficient combinations of input-1 and input-2 such as point A, B, C and D. However, Koopmans reveals the fact that points on the isoquant curve with slack usage of inputs (like point F) cannot be shown as efficient combination of inputs. As far as the two propositions above are concerned, although point F ensures the former, it is not in line with the latter requirement that is indispensable for Koopmans efficiency.

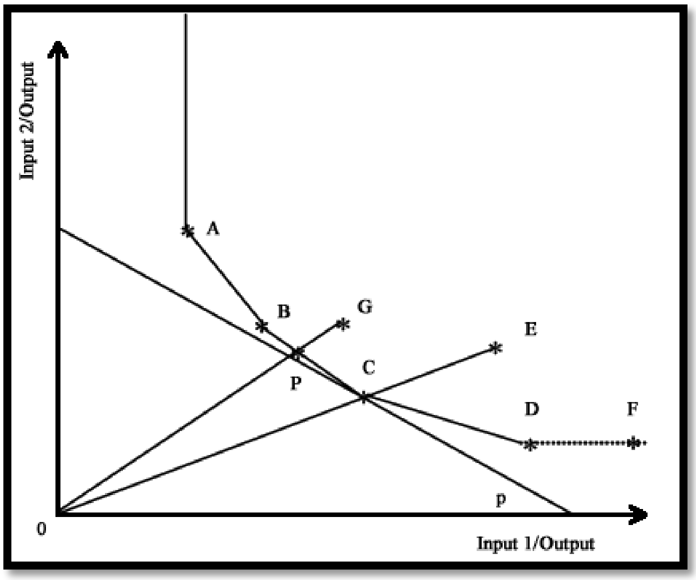


Figure-4.3

CRS vs. VRS Models

The analysis up to this point was assuming that DMUs are operating at constant return to scale (CRS) as put forward by Charnes, Cooper and Rhodes (1978) where *t* times increase in inputs will result in *t* times increase in output (i.e. t*Y = t*f {X}). On the other hand, in many sectors due to "imperfect competition, government regulations and constraints on finance" firms cannot be run at optimal scale (Coelli et al., 2005:172). Therefore, scale efficiency that has an impact on technical efficiency of a firm arises in these circumstances.

So as to capture the magnitude of "scale effect", Färe, Grosskopf and Logan (1983) and Banker, Charnes and Cooper (1984) developed a variable returns to scale (VRS) in which CRS assumption is relaxed. Figure-4.4 illustrates the divergence of VRS models from CRS ones in a quite generic way. For instance, the efficiency of point B is calculated as the ratio of O_1/O_2 regarding VRS frontier, whereas is equal to O_1/O_3 if CRS frontier is taken as the reference point. Eventually, it is apparent that VRS frontier takes the magnitude of scale efficiency into account while measuring the total efficiency.

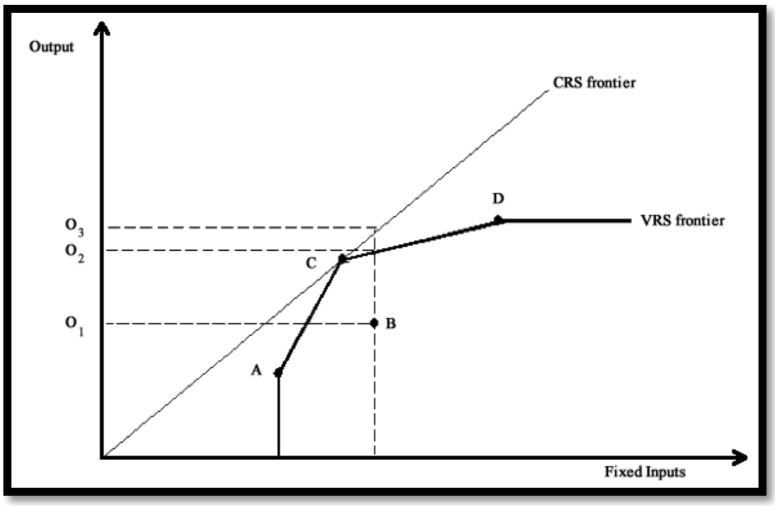


Figure-4.4

Linear programming model of VRS is quite similar to the CRS as indicated in (4.22), (4.23), (4.24) and (4.25). Only difference is addition of a convexity constraint to the system:

$$\sum_{j=1}^{k} \lambda_j = 1, \text{ for } j=1,2\ldots k \tag{4.30}$$

The mathematical relationship between VRS and CRS efficiency measurements can be illustrated as (Coelli et al., 2005:173):

$$TE_{CRS} = TE_{VRS}\ x \text{ SE, (SE denotes scale efficiency)} \tag{4.31}$$

which means that CRS technical efficiency of a firm can be decoupled into pure technical efficiency and scale efficiency (SE). Even though, an analytical association exists among CRS and VRS models, input and output efficiency scores are different in VRS unlike in CRS models (Emrouznejad, 2000: 25).

Input and Output Oriented Measurements

As mentioned earlier, the chief objective of a firm in market economies is either minimizing input or output maximization. Both in CRS and VRS models, input and output oriented measurements can be conducted pertaining to the preference of researcher. As Figure-4.5 demonstrates clearly, output-oriented frontier represents all combinations of outputs that are attainable by the production unit. Whilst the efficient frontier in input-oriented model refers to the minimum usage of inputs to produce given output level, efficient frontier in output-oriented model denotes maximum amount of outputs given input level.

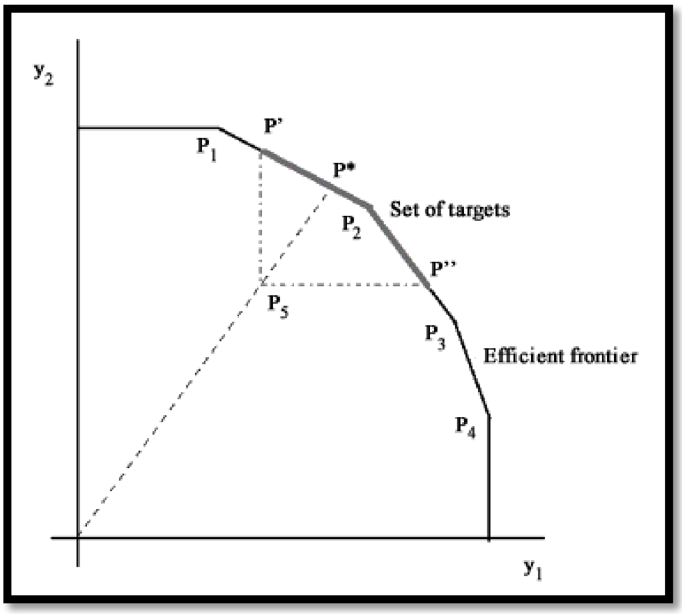


Figure-4.5

In the previous linear programming systems, input-oriented analysis was articulated relying on radially contraction of input vector without any change in output. In a similar vein, for output-oriented measurements, technical efficiency is calculated as a proportional increase in output level lacking any alteration in the amount of inputs. If this narrative is transliterated to mathematical lexicon as VRS:

$$\text{Max } \Phi \tag{4.32}$$

subject to:

$$\sum_{j=1}^{k} \lambda_j X_{ij} \leq X_{i0} \qquad (i=1,2\ldots m) \tag{4.33}$$

$$\sum_{j=1}^{k} \lambda_j Y_{rj} \geq \Phi Y_{r0} \qquad (r=1,2\ldots n) \tag{4.34}$$

$$\sum_{j=1}^{k} \lambda_j = 1, \text{ for } j=1,2\ldots k \tag{4.35}$$

$$\lambda_j \geq 0 \quad \text{for } j=1,2\ldots k \tag{4.36}$$

In this case, firms confronting higher Φs will have lower technical efficiency scores and the firm with Φ=1 can be identified as technically efficient in a given technological progress. Furthermore, due to the fact that input and output oriented DEA models are estimating same frontier, set of efficient firms will be the same, whilst there might be slight differences in the efficiency scores of inefficient firms.

Extensions in DEA

Allocative Efficiency

In DEA models, allocative efficiency of a DMU can be gauged alongside the technical efficiency scores by the means of cost minimisation or revenue/profit maximisation if price information about input set is available. Let's take VRS cost minimization case with input-orientated model as an example to demonstrate the measurement of allocative efficiency via using same linear system of (4.22), (4.23), (4.24) and (4.25):

$$\text{Min } p_i X_{i0}^* \tag{4.37}$$

subject to:

$$\sum_{j=1}^{k} \lambda_j X_{ij} + s_i^- = \theta X_{i0} \quad (i=1,2,\ldots\ldots,m) \tag{4.38}$$

$$\sum_{j=1}^{k} \lambda_j Y_{rj} + s_r^+ = Y_{r0} \quad (r=1,2,\ldots..,n) \tag{4.39}$$

$$s_r^+, s_i^-, \lambda_j \geq 0 \quad \text{for } j=1,2,\ldots.,k \tag{4.40}$$

$$\sum_{j=1}^{k} \lambda_j = 1, \text{ for } j=1,2\ldots k \tag{4.41}$$

where p_i represents price data about input set and X_{i1}^* is the cost minimising input quantities derived by linear programming. Eventually, cost efficiency (i.e. economic efficiency) of the firm is calculated as the minimum cost to observed cost:

$$CE= \frac{\sum_{i=1}^{m} p_i X_{i0}^*}{\sum_{i=1}^{m} p_i X_{i0}} \tag{4.42}$$

If the price information of output is available as well as "revenue maximisation is a more appropriate behavioural assumption" (Coelli et al., 2005:184), then programming model can be converted to revenue maximisation with VRS shown below:

$$\text{Max} \quad \sum_{i=1}^{n} q_i Y_{i0}^*$$

subject to

$$\sum_{j=1}^{k} \lambda_j X_{ij} \leq X_{i0}^{*} \qquad (i=1,2\ldots m) \qquad (4.43)$$

$$\sum_{j=1}^{k} \lambda_j Y_{rj} \geq Y_{r0} \qquad (r=1,2\ldots n) \qquad (4.44)$$

$$\lambda_j \geq 0 \quad \text{for } j=1,2\ldots k \qquad (4.45)$$

$$\sum_{j=1}^{k} \lambda_j = 1, \text{ for } j=1,2\ldots k \qquad (4.46)$$

where q_i refers to price information of corresponding output levels, Y_{i0}^{*} is the revenue maximisation amounts of output attained at the end of solution iterations. Then, revenue efficiency of the observed DMU is computed as the ratio of observed revenue to maximum revenue:

$$RE= \frac{\sum_{i=1}^{n} q_i Y_{i0}}{\sum_{i=1}^{n} q_i Y_{i0}^{*}} \qquad (4.47)$$

Lastly, if both price data of inputs and outputs is available, profit efficiency of the DMUs can be calculated via using DEA. Profit maximisation with VRS model is specified as:

$$\text{Max } \left(\sum_{i=1}^{n} q_i Y_{i0}^{*} - \sum_{i=1}^{m} p_i X_{i0}^{*} \right) \qquad (4.48)$$

subject to

$$\sum_{j=1}^{k} \lambda_j X_{ij} \leq X_{i0}^{*} \qquad (i=1,2\ldots m) \qquad (4.49)$$

$$\sum_{j=1}^{k} \lambda_j Y_{rj} \geq Y_{r0} \qquad (r=1,2\ldots n) \qquad (4.50)$$

$$\lambda_j \geq 0 \quad \text{for } j=1,2\ldots k \qquad (4.51)$$

$$\sum_{j=1}^{k} \lambda_j = 1, \text{ for } j=1,2\ldots k \quad (4.52)$$

Profit efficiency of the observed DMU can be computed as the ratio of observed profit to maximum attainable profit, however in this case efficiency values may be equal to 0 if observed profit is zero, and undefined if maximum profit is zero:

$$PE= \frac{\sum_{i=1}^{n} q_i Y_{i0} - \sum_{i=1}^{m} p_i X_{i0}}{\sum_{i=1}^{n} q_i Y_{i0}^{*} - \sum_{i=1}^{m} p_i X_{i0}^{*}}$$

Heterogeneity

Another point worth examining in DEA models is that how this mathematical programming system deals with "environmental factors" that cause inefficiencies out of firm's control (Coelli et al., 2005:190). In these cases, efficiency of the DMU could be influenced by external effects which are not controlled or directed by decision makers inside the firms and accordingly efficiency scores can be miscalculated due to these effects. Couple of methods with some weaknesses have been named to cope with this obstacle up to now.

First method (Banker and Morey, 1986) proposes comparing the efficiency of firm A with the firms in the sample which have the value for environmental factor (which can be ordered from worst to best) less than or equal to firm A. The second method developed by Charnes, Cooper and and Rhodes (1981) puts forward that 1) dividing the sample into two sub-samples and solution by DEA 2) project all observed points on the frontier 3) solving a single DEA system and check whether there is any difference in the mean efficiencies of two sub-samples. Third one suggests the inclusion of environmental variables directly into the linear system by integrating the expression following where Z indicates environmental variable:

$$\sum_{j=1}^{k} \lambda_j Z_j \leq Z_1 \quad (4.53)$$

The last one encourages researchers to conduct two-stage method in which solving the system by DEA in a traditional way forms the former leg and regressing efficiency scores onto the environmental factors forms the latter one. Although all these four methods have deficient aspects, they give a decent insight to separate the effects of external factors from efficiency scores within the DEA method.

Additional Methods

Even though flexibility in DEA is praised frequently in the literature, its structure may cause troubles if assigned weights to the input/output sets show unrealistic properties (Coelli et al., 2005:199). For this reason, researchers can construct more realistic models to "improve the discrimination of models" through *weight restrictions* (WR) on output and/or input bundles (Podinovski, 2001). Lower and upper bounds are specified for weights of input and output sets and then incorporated to the linear programming system:

$$\boldsymbol{\mu_L} \leq \mu \leq \boldsymbol{\mu_U} \text{ (restrictions on output)}, \ w_L \leq w \leq w_U \text{(restrictions on input)} \quad (4.54)$$

The main problem in WR models is the possibility of ending up with an inappropriate boundary which is solely contingent upon researchers' own value judgments.

Another concept in additional methods is super efficiency. This method relaxes the linear programming system not to use observed DMU as its own peer which results in efficiency scores with greater than 1. For instance, regarding to this chapter's representation, X_{i1} and Y_{r1} are dropped from the left hand-side of the input (4.23) and output (4.24) inequalities correspondingly to eliminate peer effect of DMU_1. Thanks to this omission, the analyst is able to compare efficient firms (with Θ=1) operating just at the frontier with its efficient counterparts, however no changes could be observed for inefficient firms.

Last additional method in DEA is bootstrapping which provides statistical properties to DEA estimations (Coelli et al., 2005:202). This method fundamentally produces a number of random samples that have same sample sizes from initial data set (Sena, 2003). The chief advantage of this "re-sampling technique" is to allow constructing confidence intervals and thus conducting hypothesis testing on estimated efficiency scores. As Coelli et al. (2005) articulates clearly, this re-sampling should not be confused with random noise motivated from measurement or specification error in stochastic analysis. In addition to the bootstrapping procedures of efficiency estimation in linear programming, Fethi and Weyman-Jones (2006) can be visited for the in-depth analysis of stochastic DEA models.

Previous Empirical Studies

Since the first paper published by Charnes, Cooper and Rhodes (1978), DEA has been applied to a wide range of sectors compromising health care, education and banking. Particularly, due to their significance in public services provision, hospitals and higher education institutions (HEIs) have extremely attracted attentions of researchers to conduct efficiency analysis by the means of DEA. In the following sentences, papers in the higher education sector are shown and discussed, for a detailed review of literature; bibliography of this paper can be glanced at.

The pioneering works on this particular area of research may be enumerated as follows: Johnes and Johnes (1995), Coelli (1996) and Madden, Savage, and Kemp (1997). The first one applies a basic DEA model to the 36 UK university economics departments for the 1989 academic year. The second paper deals with 36 Australian universities using a Variable Returns to Scale (VRS) model through which both technical and scale efficiencies of universities were computed. And the third paper investigates 24 Australian university economics departments between 1987 and 1991. All these three papers form the fundamentals of the literature in higher education efficiency analysis and encouraged further researches, even though they put forward inadequate insights on the efficiencies of HEIs in broad-spectrum. Moreover, the main concern of these aforementioned papers is to address the reliability of DEA to become an appropriate performance indicator for HEIs as clearly put forward by Johnes and Johnes (1995): “We conclude that DEA has a positive contribution to make in the development of meaningful indicators of university performance”. Accordingly, subsequent researches on the efficiency analysis of HEIs have been built upon the theoretical as well as methodological framework put forward by Johnes and Johnes (1995), Coelli (1996) and Madden, Savage, and Kemp (1997).

After the first stream of papers, the most comprehensive work which still preserves its significance in the literature –due to its inquiry on the determinants of inefficiency- is Macmillan and Datta’s piece (1998) written on 45 Canadian universities for the 1992-1993 academic year. They estimated efficiencies of universities concerning different input/output sets to check the robustness of efficiency values and ended up with the fact that overall efficiency among Canadian universities is nearly 94% which would be “upwardly biased due to modest number of observations” as the authors argue. In addition to the efficiency estimates, they conducted two-stage DEA analysis to reveal the determinants of inefficiency in Canadian higher education sector. They regressed inefficiency values (1 minus efficiency scores) onto the certain variables that are expected to motivate inefficiency and concluded that larger full-time equivalent enrolments reduce inefficiency in Canadian universities. Even though two-stage methodology includes econometric problems – as indicated in the methodology chapter- Macmillan and Datta’s attempt to understand the factors behind the inefficiencies stimulated straightforward thinking on this particular question in efficiency performance of HEIs.

Abbott and Doucouliagos's work (2003) covers 36 Australian universities for the academic year of 1995. They find that Australian universities are operating very close to the technically efficient frontier for the different mixture of input and output measurement sets. However, efficiency results suggest, "There is still room for improvement in several universities". In addition to the conventional efficiency estimation for HEIs, this paper states a number of recommendations for further researches: i) Non-parametric techniques can be applied to panel data for inter-temporal analysis ii) Disaggregated data is needed to conduct comparisons between faculties among different universities iii) International comparisons are necessary for universities as they are currently competing in the global arena (Abbott and Doucouliagos, 2003).

Johnes (2006) extended her previous works with updated data and more comprehensive analysis including robustness checks for the efficiency results. She applied DEA with bootstrapping methods to the universities in England for the academic year 2000-2001. The findings of the paper reveal that English universities are operating efficiently in overall ranging from 94% to 96% as to various types of models considered in the paper. Moreover, as a consequence of bootstrapping procedures –which is the distinctive attribute of this paper as it is the first research develops bootstrapping method- that are followed up to construct 95% confidence intervals for efficiency scores of the DMUs pointed out that there is a significant difference between best- and worst-performing English universities. Hence, "while DEA cannot reliably be used to discriminate between the middle-performing HEIs in terms of their level of efficiency, it can discriminate between the worst- and best performing HEIs".

Casu and Thanassoulis (2006) focus on UK universities' central administrative services (CAS) based on 1999/2000 academic year. Their initial findings claim that 17 institutions out of 108 are found cost-efficient. Besides UK universities have mean inefficiency scores of 27% on providing CAS. In relation to the scale efficiency estimations, the result corresponds to the fact that although universities have different sizes, there is not an indication of scale inefficiency 'with the exception of a few institutions'. Another significant analysis coming out of this particular paper is that new universities are paired with new universities whilst old universities are paired with the old ones as far as the peer analysis is concerned.

In recent years, DEA is commonly and widely applied to measure efficiency performance of the HEIs for different datasets with more enhanced methodological papers. Flegg et al. (2004) computed efficiency values of 45 British universities with multi-period DEA through which the influence of public funding and student/staff ratios on the variations in efficiencies among the chosen universities is figured out. Worthington and Lee (2008) focuses on inter-temporal analysis of efficiency scores among 35 Australian universities by way of employing Malmquist index. The results of the paper "indicate that annual productivity growth averaged 3.3% across all universities, with a range from -1.8% to 13.0%, and was largely attributable to technological progress". Ying Chu NG and Sung-ko LI (2009) applied DEA to the Chinese universities, Maria Katharakia and George Katharakis (2010) preferred 20 Greek public universities for assessing their efficiencies.

The history of efficiency analysis on Turkish HEIs goes back to very recent years; first paper appeared in the first half of the last decade. In the related paper, Kutlar (2004) measures technical efficiencies of the faculties in Cumhuriyet University –which is one of the public HEIs in Turkey- and comes up with the conclusion that whereas Faculties of Medicine, Administrative Sciences, Education and Engineering have higher efficiency values, Theology, Arts and Fine Sciences faculties confront relatively lower efficiency scores. Furthermore, results indicate that less-efficient faculties have shown evident improvements during five years. Following Kutlar's paper (2004), Baysal et al (2005) calculate efficiency performances of 50 public HEIs relying on 2004 statistics and set forth an individual budget projection for universities in 2005. According to this research, overall technical efficiency among these 50 universities is almost 92%, whilst the worst performing university is 62% efficient. In relation to the budget projection, this paper argues that the difference between amount of estimated budget and budget allocated by government is significant. Whereas 22 out of 50 universities are assigned higher proportion from the government, 28 of them experience lower public funding in substantial amounts fluctuating from 42 % to 79%.

Babacan et al (2007) extends Kutlar's earlier work (2004) so as to compare the efficiency performance of Cumhuriyet University (CU) with the rest of the public universities. Throughout five years, CU is performing relatively less inefficient then its counterparts, although it exploits increasing returns to scale both in input and output oriented technologies. Ozden's paper (2008) is the first research that applies DEA onto the Turkish non-profit universities. To the paper's analysis, non-profit universities have differing efficiency values ranging from 52% to 100%. Moreover, the overall efficiency of non-profit universities in Turkey is calculated as 92%. In addition to the technical efficiency analysis of public universities carried out in previous papers, Kutlar and Babacan's work (2008) gauges the scale efficiencies of them to check whether there are any gains from economies of scale. The findings reveal the fact that the number of technically efficient universities had decreased considerably from 33 to 17 in five years. On the other hand, the number of universities experiencing 'increasing returns to scale' (IRS) had risen from 8 to 17 during the same period. The aforementioned papers in the earlier sentences sparked the light on the efficiency analysis of HEIs in Turkey; and accordingly formed the empirical fundamentals of this PhD research.

IV. Stochastic Frontier Analysis (SFA)

As Greene (1997b) figured out, in general, frontier production function can be described as “an extension of the familiar regression model based on the microeconomic premise that a production function represents some sort of ideal, the maximum output attainable given a set of inputs.” In recent researches, to measure the efficiency level of a firm/organization, distance between estimated production frontier and observed one is computed. Prior to current analysis, different approaches have been developed for efficiency measurement in an econometric way by researchers (Farrell: 1957, Aigner and Chu: 1968).

The initial framework on parametric frontier analysis commenced with Farell’s (1957) cross-sectional model where goal-programming techniques were used to estimate production function. Parametric frontier is specified as:

$$Y_i = f\ X_i, \beta\ .TE_i \qquad (4.55)$$

where i=(1,2,3,…,I) represents the corresponding produces, Y is the level of output, X refers to a vector of N inputs, $f\ .$ is the production frontier depending on inputs and technology parameters (β) to be estimated. The last term TE_i is the technical efficiency of the i^{th} firm calculated as the ratio of observed output over maximum feasible output:

$$TE_i = \frac{Y_i}{f\ X_i, \beta} \qquad (4.56)$$

Aigner and Chu (1968) reformulated frontier function above with log-linear Cobb-Douglas production function that was still reflecting the behaviours of deterministic frontiers:

$$lny_i = \beta_0 + \beta_n lnX_n - u_i \qquad (4.57)$$

Even though frontier functions became parameterised with these extensions, technology parameters are not estimated in any statistical sense, rather they are calculated via using mathematical programming techniques. Therefore, to be able to “capture the effects of exogenous shocks beyond the control of analysed units”, alternative econometric approaches were put forward during the subsequent researches in this particular area of research (Murillo and Zamorano: 2004).

In two independent papers by Aigner et al. (1977) and Meeusen and van den Broeck (1977) stochastic frontier function for Cobb-Douglas case was specified as following:

$$lny_i = \beta_0 + \quad {}_{n=1}^{N} \beta_n lnX_{ni} + \varepsilon_i \qquad (4.58)$$

Where lny_i represents the logarithm of observed output, X_{ni} *is* the vector of given inputs and β_n is a vector of unknown parameters. Accordingly ε_i is specified as:

$$\varepsilon_i = v_i - u_i, \quad u_i \geq 0 \qquad (4.59)$$

First error component v_i *is* independently and identically distributed as $v_i \sim N(0, \sigma_v^2)$ and captures the effects of statistical noise such as random effects of measurement error and external shocks out of firm’s control, while u_i is independently and identically half-normal distributed $u_i \sim N^+ (0, \sigma_u^2)$ and intended to capture technical inefficiency which can be measured as the deficiency in output away from the maximum possible output given by the stochastic production frontier:

$$lny_{i=}f\ \ x_i, \beta\ \ + v_i \tag{4.60}$$

The property that $u_i \geq 0$ ensures all the observed outputs should lie below or on the stochastic frontier. Any deviation from the aforementioned frontier will be treated as the result of factors controlled by firm that named as technical and economic inefficiency (Aigner et al., 1977). Eventually, technical efficiency (economic efficiency will be discussed in the next section) of the ith firm can be depicted as:

$$TE_i = \frac{y_i}{\exp(f\ \ x_i,\beta\ \ +v_i)} = \frac{\exp(f\ \ x_i,\beta\ \ +v_i - u_i)}{\exp(f\ \ x_i,\beta\ \ +v_i)} = \exp(-u_i) \tag{4.61}$$

First and foremost motivation behind efficiency analysis is to estimate maximum feasible frontier and accordingly measure the efficiency scores of each and every DMU relative to that frontier. This estimation process was initially originated with different versions of Ordinary Least Squares (OLS) as shown in Figure-4.6 through which average-practising frontier was estimated and shifted up by (i) the maximum amount of residuals (Corrected OLS) coined by Gabrielsen (1975) or (ii) the mean of the residuals (Modified OLS) used by Richmond (1974). Apparently, the main drawback of these estimation procedures is taking the efficiency performance of the average producer as a benchmark (instead of best-practising one) and calculating other observed units' efficiency concerning that point.

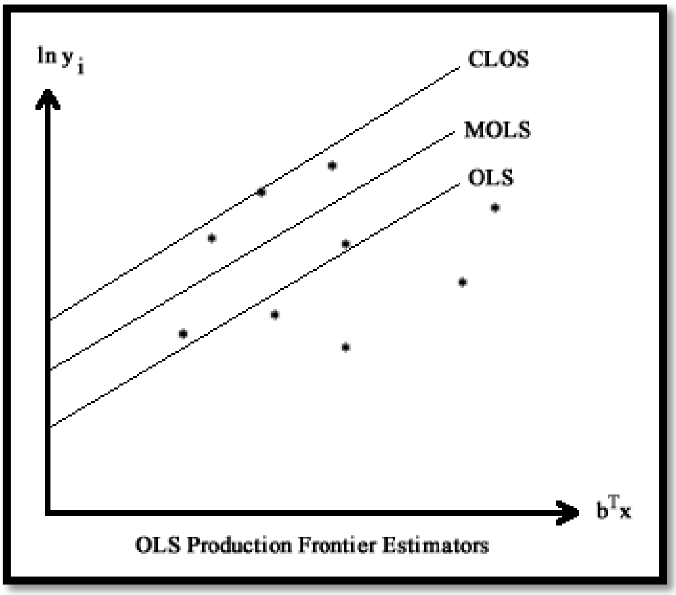


Figure-4.6

In lieu of using OLS, Greene (1980a) preferred Maximum Likelihood Estimation (MLE) to estimate technology parameters as well as residuals that were eventually decomposed into statistical noise and inefficiency term by Jondrow et al (1982). The parameters of this regression (βs) are being estimated by log-likelihood function in which $\sigma^2 = \sigma_v^2+\sigma_u^2$ and $\lambda^2= \sigma_u^2 / \sigma_v^2 \geq 0$. λ corresponds to a value presenting the magnitude of the inefficiency term's impact on the error term. For instance, If λ=0, this means whole deviation from the stochastic frontier is motivated by noise term and there is not any sort of technical inefficiency. The log-likelihood function of the stochastic frontier is written as:

$$\ln L(y|\beta,\sigma,\lambda) = -\frac{I}{2}\ln\left(\frac{\pi\sigma^2}{2}\right) + \sum_{i=1}^{I}\ln\Phi\left(-\frac{\varepsilon_i\lambda}{\sigma}\right) - \frac{1}{2\sigma^2}\sum_{i=1}^{I}\varepsilon_i^{2} \qquad (4.62)$$

Where y and ε_i are corresponding same representations in (4.58), Φ (x) is the cumulative density function (cdf) of the standard normal distribution. To estimate βs, "iterative optimisation procedure" is undertaken until the values maximising the function are obtained (Coelli et al., 2005:246).

Before coming to a conclusion in this introduction section to the stochastic frontier models, misspecification in frontier functions and its repercussions in estimating technology parameters will be clarified on the basis of, mean efficiency scores and efficiency rankings of DMUs. Although, misspecification problem has not received sufficient attention in the literature, some of the researches (Guermat and Hadri, 1999; Meesters, 2010)[3] have visibly shown that it would have a number of adverse effects particularly in ranking the efficiency scores of DMUs. The findings of these papers that both used Monte Carlo simulation experiment reveal that technology parameters do not differ if the model is misspecified. However, Meesters (2010) argues that the coefficient of constant term may vary significantly from one state to another, thus interpretation of it might be misleading in the sense that "large coefficient of the constant in the efficiency term is found, this does not automatically mean that many producers are inefficient." To be able to alleviate the serious influences of misspecification, researchers are advised to employ manifold specifications with different forms of frontier functions (Guermat and Hadri, 1999).

Estimating Inefficiency Term

It is obvious that the very goal of efficiency estimation procedures is not solely about figuring out technology parameters but to gauge efficiency performances of each individual unit. So as to estimate them, residuals (ε) obtained from MLE must be decomposed into their components. As indicated previously, Jondrow et al. (1982) developed a method (known as JLMS) which is an indirect estimation of inefficiency term (u_i) dependent on $\varepsilon_i = v_i - u_i$:

$$\mathrm{E}\ u_i \mid \varepsilon_i = \frac{\sigma\lambda}{1+\lambda^2} \quad \frac{\phi\,(\varepsilon_i\lambda/\sigma)}{\Phi(\varepsilon_i\lambda/\sigma)} + \frac{\varepsilon_i\lambda}{\sigma} \tag{4.63}$$

ϕ and Φ denote standard normal density and cumulative density function, respectively. The JLMS technique includes two different distribution assumptions for $u_i s$ consisting of

[3] For a detailed discussion, aforementioned papers can be visited.

normal-truncated normal and normal-exponential in separate analysis. The former terms in the distribution types correspond to the distribution of v_is, whilst latter terms are indicating the distribution of $u_i s$. In the case of normal-truncated normal model where the conditional distribution of u_i on ε_i is $N(\mu_*, \sigma_*^2)$ truncated at zero:

$$\mathrm{E}\ u_i \mid \varepsilon_i = \mu_* + \sigma_* \frac{\phi\ (-\mu_*/\sigma_*)}{1-\Phi(-\mu_*/\sigma_*)}, -\frac{\mu_*}{\sigma_*} = \frac{\varepsilon\lambda}{\sigma} \tag{4.64}$$

The normal-exponential model in which the conditional distribution of u_i on ε_i is assumed as exponential with density function $f\ (u)$ = exp $(-u\ \ \sigma_u)/\sigma_u$ and have a conditional distribution $N\,(-\sigma_v A, \sigma_v^2)$:

$$\mathrm{E}\ u_i \mid \varepsilon_i = \sigma_v\ \frac{\phi\ (\mathrm{A})}{1-\Phi\ \mathrm{A}} - \mathrm{A}\ ,\ \mathrm{A}=\frac{\varepsilon}{\sigma_v}+\frac{\sigma_v}{\sigma_u} \tag{4.65}$$

Thanks to JLMS technique, error term is separated into its components that are statistical noise and inefficiency term that is the main notion under examination for this particular research field.

In the estimation of inefficiency term, the major concern of researchers is to decide on the appropriate distribution function of it. Up till now, Aigner et al. (1977) proposed half-normal, Stevenson (1980) used truncated normal, Greene (1980) preferred to use gamma, and finally Beckers and Hammond (1987) extended exponential distribution function for inefficiency component of error term. Although, to opt for the best-fitted distribution is overwhelmingly difficult, prior theoretical insights of researchers do shape this decision making process. Coelli et al. (2005) underlines the notion of parsimony that is in favour of choosing the less complicated one ceteris paribus. Therefore, half-normal and exponential distributions are the best candidates that have simpler structures than other aforesaid options (Coelli et al., 2005: 252).

Stochastic Cost Frontier Approach

After examining the concept of stochastic frontier analysis, in this section stochastic cost frontier approach (SCFA) that will be employed during this PhD research, will be scrutinized specifically. SCFA paves the way for researchers who are dealing with economic efficiency analysis in which both technical and allocative efficiency of the given firms can be worked out.

SCFA 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 cost production (Greene, 1997b). In a similar vein, frontier production function illustrated above can be converted to frontier cost function which will be articulated below via changing the sign of inefficiency error component consisting of both technical and allocative inefficiency (Kumbkahar and Lovell: 2000). Decomposition of the inefficiency term into the technical and allocative components is the central theme of 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, the function is specified as:

$$\ln C_i = \ln C(p_i, q_i; \theta) + v_i + u_i \quad (4.66)$$

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 has the same distribution in (4.59) and reflecting the statistical noise. Cost efficiency can be illustrated as:

$$CE_i = \frac{C(p_i, q_i; \theta).\exp(u_i)}{C_i} \quad (4.67)$$

Where CE_i reflects the ratio of the minimum possible cost, given inefficiency u_i , to actual total cost. If $C_i = C(p_i, q_i; \theta).\exp(u_i)$, 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 $0 < CE_i \leq 1$.

The fundamental framework behind SCFA is illustrated above. However, an extensive analysis including panel data models, decomposition of inefficiency into its components, and using other cost functions like Translog needs to be stated. Instead of doing those analysis here, Chapter V where SCFA will be applied to a specific case (Higher Education in Turkey) will comprise them with the results obtained from cost function regression.

Extensions in SFA

Recent studies in SFA extended the volume of analysis via integrating observed/unobserved heterogeneity, panel data models and Bayesian inferences to the literature. Each of these extensions will be identified and examined in the following sections separately.

Heterogeneity

Heterogeneity among the organizations is often classified as observed and unobserved heterogeneity. The former conception refers to the cases where variations can be reflected in measured variables, whereas the latter term which is usually assumed time-invariant comes into the function as effects (Greene, 2007). Major concern for researchers to figure out heterogeneity is the likelihood of treating this given variation as inefficiency that is actually not. To account for observable heterogeneity in efficiency analysis, variable z is identified and incorporated to the non-stochastic part of frontier function that has similar distribution properties for v_i and u_i (4.66):

$$lny_i = f(x_i, \beta) + Z_i\gamma + v_i - u_i \tag{4.68}$$

Couple of models have been developed in order to explore the relationship between exogenous (environmental) factors (*Z*s) and inefficiencies as well as separating them from each other. The earliest paper conducted this analysis is the study of Pitt and Lee (1981) whom used two-stage approach. In the initial stage, they estimated conventional frontier function without taking any environmental variables into consideration, and secondly, the projected efficiencies are regressed onto *Z*s. The chief problem arises here is that exclusion of environmental variables in the first stage leads to biased estimators both for parameters of non-stochastic part of function and inefficiency terms as indicated by Caudill et al. (1995) and Wang and Schmidt (2002). To achieve the same target from a different technique, Kumbhakar et al. (1991) allowed Z terms to influence u_i directly by assuming the distribution of it as $N^+(Z_i\gamma, \sigma_u^2)$.

Orea and Kumbhakar (2004) came up with another method (one-stage approach) to deal with heterogeneity named as "latent class stochastic frontier model" (LCSFM) that is the combination of latent class structure and SFA. This method -applied to Spanish banking sector- basically segregates the whole dataset to the number of classes which is usually determined by Akaike Information Criterion (AIC) or Schwarz Criterion (BIC) and estimates a unique frontier for each class in the sample. Consequently, predicting biased estimators in "one sample case" due to heterogeneity can be avoided owing to this class segregation methodology.

Panel Data (Fixed Effects and Random Effects Models)

The stochastic frontier function in previous studies was lack of "time effect" which is indispensible for panel data models. Preferring panel data in lieu of cross-section offers a number of advantages due to its data enriched structure. Coelli et al. (2005:275) enumerates three of these as following:

- Some of the distributional assumptions to differentiate statistical noise and inefficiency terms is relaxed
- To obtain more consistent estimators of inefficiencies
- Examining the change in inefficiencies over time (which might be a good indication of technological progress)

To incorporate time effect into the stochastic frontier in (4.58), "t" will be added as a subscript alongside with i:

$$lny_{it} = f(x_{it}, \beta) + \varepsilon_{it},\ \varepsilon_{it} = v_{it} - u_{it} \tag{4.69}$$

The main matter of discussion for this modelling in panel data analysis is whether to treat inefficiency term as time variant or invariant. Time-invariant inefficiency model imposes $u_{it}= u_i$ and is estimated either by fixed effects or random effects approach. On the other hand, time-variant inefficiency supposes that firms learn from their experiences to enhance efficiency levels incrementally that can be formulated as $u_{it}= f(t)\, u_i$ (Coelli et al., 2005:278). Two diverse functional forms for capturing time effect have been generated: first one is by Kumbhakar (1990) $f(t) = [1 + \exp(\alpha t + \beta t^2)]^{-1}$ and the second belongs to Battese and Coelli (1992) $f(t) = exp[\mathfrak{h} (t - T)]$ where ɧ, α and β are unknown parameters to be estimated.

Last point that should be touched upon in this section is heterogeneity in panel data estimation of efficiency terms that was elucidated in Greene's (2005) seminal work. In this paper, Greene (2005) discusses pros and cons of fixed effects and random effects models as well as propose his own methodology called as "true fixed effects" and "true random effects" models. The fixed effects model illustrated below treats $\boldsymbol{\alpha_i}$ as firm-specific inefficiency, thus any heterogeneity among firms is omitted:

$$y_{it} = \alpha_i + \beta\, x_{it} + v_{it} \tag{4.70}$$

To overcome this problem, true fixed effects is brought into:

$$y_{it} = \alpha_i + \beta\, x_{it} + v_{it} + u_{it} \tag{4.71}$$

In random effects model where firm-specific inefficiency is assumed as constant over time, the frontier function is narrated as:

$$y_{it} = \alpha_i + \beta\, x_{it} + v_{it} + u_{it} \tag{4.72}$$

Due to the shortcomings of this model indicated by Greene (2005), he specified a comprehensive frontier production function to separate firm-specific effects denoted by w_i from inefficiency terms and called it true random effects:

$$y_{it} = \alpha_i + \beta\, x_{it} + w_i + v_{it} + u_{it} \quad (4.73)$$

Some may think that there are three disturbance terms in the regression (w_i, v_{it}, u_{it}), but indeed not because the real model has two disturbances:

$$y_{it} = \alpha_i + \beta\, x_{it} + w_i + \varepsilon_{it} \quad (4.74)$$

Empirical Works on Higher Education

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 has 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. This section reviews 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 in this paper. After taking required analytical steps, researchers come up with the conclusion that British universities are suffering with 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 which are compatible with Johnes (1997).

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 & 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 the paper, Mensah & 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 & 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.

V. Comparison of DEA and SFA and Concluding Remarks

Whereas the superiority of SFA over to the DEA is revealed as a) including statistical noise into the frontier b) allowing statistical tests on the estimates, DEA is seen advantageous at times due to the fact that it does not require any specific functional form for production function and distributional form for inefficiency terms. For that reason, trade-off between misspecification bias (in SFA) and measurement error (in DEA) determines the preference of researchers conducting efficiency analysis. To alleviate the repercussions motivated from this trade-off, statistical properties are trying to be integrated to the deterministic approaches, even as recent applications using diverse collection of functional forms prevents stochastic methods to be over-parameterised (Fried et al., 2008).

The first paper comparing SFA and DEA relying on a sample data was Gong and Sickles (1991). The result put forward by them was claiming that "Our results indicate that for simple underlying technologies the relative performance of the stochastic frontier models vis-a-vis DEA relies on the choice of functional forms”. In addition to that, severity of misspecification error accompanied by “degree of correlatedness of inefficiency with regressors” makes DEA more appealing (Gong and Sickles, 1991). In this particular case, the loser of the trade-off between misspecification and measurement errors is named as the former one. In another two separate papers, Bauer et al. (1998) and Cummins and Zi (1998) using dataset of US banks and life insurance companies, they explored a weak but positive rank correlation between point estimators of econometric and mathematical programming techniques (Fried et al., 2008)

The other point that gives idea about the robustness and appropriateness of these two methodologies is the value of “λ” corresponding to σ_u σ_v. If λ gets closer to +∞, this means all variation from frontier is being motivated from inefficiency that is the chief argument of deterministic frontiers. In a similar vein, in the cases where λ is close to 0, stochastic analysis is worth opting for (Greene, 2007).

As a result of all these aforementioned arguments, it is extremely obvious that choosing one method to another will always have a certain amount of opportunity cost (Erkoc, 2012). Therefore it’d be better to finish this chapter with Sena’s (2003) arguments:

“It is really impossible to suggest one approach to the other, as they both have positive and negative features; in a sense, they could be used jointly as they provide complementary information. At any rate, it is clear that the frontier approach offers an interesting set of tools to measure efficiency and total factor productivity (TFP) and so contribute to decision-making within both private and public organisations”

This chapter investigates the theoretical underpinnings of both parametric and non-parametric efficiency estimation techniques as well as sheds some light on the strengths and weaknesses of these two analytical methods. In the following two chapters a specific dataset is worked out by employing SFA and DEA respectively. As indicated earlier, this joint application would offer significant insights for the further methodological discussions around the robustness of parametric and non-parametric methods.

But before moving ahead, it is necessary to reveal the reasons behind the variable variation between SFA and DEA efficiency estimation models:

1. Number of publications and the amount of research grants are highly correlated with each other, which caused one of them to be dropped due to the fact that stochastic frontier models specify a cost function whereas DEA models do not.
2. Goods and Services expenditures are added to the DEA models, which made the iteration steps of the likelihood function in SFA noisy and accordingly halted it.
3. The related literature in SFA and DEA is followed at the expense of full-fledged overlap in the variable set among them.
4. However, comparison and contrast is carried out on the basis of overlapping SFA and DEA models particularly for the consistent empirical and policy implication arguments.

CHAPTER V: Efficiency Analysis of Public Higher Education Institutions in Turkey: Application of Stochastic Frontier Analysis (SFA)

I. 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; Dagbashyan, 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 chapter 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 chapter is as follows: II discusses different forms of cost function comprising Cobb-Douglas and Translog cases as well as examine pros and cons of these models. Section III 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 IV. Section V 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 scrutinised in the concluding section VI.

II. COST FUNCTION OF HIGHER EDUCATION INSTIUTIONS

So as to estimate the efficiencies of a variety of organisations including HEIs, researchers have used different types of frontiers including production, cost, revenue and profit. Even though each and every of these frontiers have noteworthy strengths and advantages as indicated in the previous chapter (methodology chapter), one of them is opted for by the author due to several reasons such as properties of dataset, estimation technique and her own value judgements. In this chapter, cost frontier is employed owing to certain rationales:

1. The dataset for HEIs in Turkey does not allow the researcher to estimate revenue and/or profit frontier as it does not contain any information about the prices of outputs,
2. Multi-production (or multi-output) in HEIs leads the researcher to give up production frontier, as it is used “single-output” cases for frontier analysis,
3. Since one of the main concerns of this research is to map out the cost structure of HEIs in Turkey, estimating cost frontier becomes more valuable than any other alternatives concerning policy-implications.

As already touched upon in the preceding chapter, cost function of multiproduct organisations and frontier estimation of it will not be discussed here. Instead, primary insights on HEIs’ cost function will constitute the main arguments in this section.

The empirical inquiry on cost structures of HEIs as multiproduct organisations has boosted since the beginning of 1990s particularly stemming from two main sources. The first one is the work of Cohn, Rhine & Santos (1989) that used nearly 2000 American HEIs. Another source is Groot, McMahon and Volkwein (1991) that preferred concentrating on a relatively homogenous set consisting of 147 research universities. This stream of discussions went on with the papers of Dundar and Lewis (1995), and Koshal and Koshal (1999). Subsequently, frontier estimation methods have burgeoned and been applied to cost functions of universities (Johnes, 1996). Besides, technical and cost efficiencies of these institutions were computed using both non-parametric and parametric approaches.

While departing from traditional multiproduct cost functions which formulates total cost as a function of level of output, input prices and some exogenous factors, cost function of HEIs can be described as follows:

$$C = c(y, w, z, \beta, \gamma, \delta) \tag{5.1}$$

where C represents total cost, y is the vector of outputs, w corresponds to the vector of input prices and z is denoting the vector of exogenous factors; β,γ and δ are the regression parameters to be estimated.

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 & 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.

III. SELECTION OF VARIABLES

After discussing functional form of the cost function for HEIs, components of it will be illuminated. Relying on traditional cost frontier analysis, outputs, input prices and environmental variables will be the main locus point for this section concerning higher education case. For detailed information, Table-5.1 could be visited.

Selection of Outputs

Even though the obstacle of selecting appropriate output matrix is not unique for higher education, universities' role in a variety of activities including teaching, research, community services and business sector makes researchers to be more cautious during the decision-making process. Besides, lack of data (or detailed data) in this particular sector precludes researchers to illustrate the perfect picture of HEIs properly.

In higher education literature, while authors (Robst, 2001; Izadi et al., 2002; McMillan and Chan, 2006; Daghbashyan, 2011) highlight the difficulties of selection process concerning the impossibility to measure the genuine impact of HEIs in society, they usually prefer:

i) Number of full-time undergraduate and postgraduate (both master's and PhD degrees, but some uses PhD degrees as a separate indicator) students as the teaching output

ii) Number of publications/patents per academic staff and research funding as the research output.

The chief shortcoming of these indicators is that they do not represent the quality of education and research performance of HEIs. For instance, a paper published in one of the top journals might be seen much more significant than a student graduated from department of finance or vice versa. So as to overcome this, some put forward to construct weighted average matrix for whole output set via assigning certain values to each output variable, "however specifying the weights a priori based on value judgements could be erroneous" (Daghbashyan, 2011). Therefore, previous studies assumed equal weights for every output indicator due to the fact that the cost of weight-oriented function would exceed the benefit of it.

In this research, as following the preceding literature, three output categories are specified:

1. Number of Full-time Undergraduate Students = Total number of undergraduate students whom are officially registered to the university administration within the full-time equivalent academic year
2. Number of Full-time Postgraduate Students = Total number of undergraduate students whom are officially registered to the university administration within the full-time equivalent academic year
3. Research Grants = Correspond to the amount of funding in a year basis that is given by The Scientific and Technological Research Council of Turkey (TÜBİTAK) to the HEIs on project-based applications

Selection of Inputs

Selection of input prices has attracted relatively less attention of researchers than output selection as it is commonly argued that input bundle should include the prices of each and every factors of production such as labour, capital and raw materials. However for this case, lack of corresponding data in those factors becomes a prominent obstacle for the researchers. In the previous studies, total amount of labour, capital and material expenditures have been used as proxies for input prices after making necessary scaling amendments, particularly taking average prices (Coelli et al., 2005). For instance, in some of the studies, average staff cost is used to reflect the price of labour (as indicated in Table-5.1).

In this research, the dataset for Turkish HEIs allows to take:

i) Total labour expenditures per academic staff as the price of labour

ii) Total capital expenditures per size of the university (summation of number of undergraduate and postgraduate students) as the price of capital.

Table-5.1: Literature review on inputs and outputs commonly used

Author(s)	Sample	Outputs	Input(s)
Robst (2001)	440 HEIs in South Carolina	Number of Undergraduate Students Number of Postgraduate Students Research Expenditures	Compensation (State's Financial Support)
Izadi (2002)	99 UK Universities	Number of Undergraduate Students (Arts and Science) Number of Postgraduate Students Research Revenues	No Input Information
Stevens (2001)	English and Welsh Universities	Number of Undergraduate Students (Arts and Science) Number of Postgraduate Students Research Revenues	Average Staff Cost
Mensah & Werner (2003)	131 Private HEIs in United States	Number of Undergraduate Students Number of Postgraduate Students Research Revenues	No Input Information
Johnes & Johnes (2009)	121 British Universities	Number of Undergraduate Students (Science and Non-Science) Number of Postgraduate Students Research Revenues	No Input Information
Daghbashyan (2011)	30 Swedish HEIs	Number of Undergraduate Students (Medicine, Humanity and Technical) Number of Postgraduate Students Research Expenditures	Average Annual Salary

Environmental Variables for HEIs

In addition to the discussions around the selection of outputs and input prices mentioned above, some environmental variables -embodying HEI-based characteristics- that would motive either cost function and inefficiency scores will be examined throughout this section.

The exogenous variables that will be used throughout this research are as follows:

i) Age of the university: Number of years passed since the establishment of the university regarding to the date of formal acceptance by Ministry of Education,

ii) Size of the university: The number of total students comprising both undergraduate and postgraduate students will be used as a proxy variable for university size (Daghbashyan, 2011).

iii) Load per academic staff: It is the ratio of full time student to all academic staff,

iv) % Of full-time staff: It is the ratio of full-time academic staff to all academic staff,

v) % Of professors among academic staff: It is the ratio of professors to all academic staff,

vi) % Of foreign students: It is the share of students with foreign background,

vii) Dummy variable for having medical school.

It is obvious that variables that would have impacts on either cost frontier or inefficiency values are not limited to the aforementioned ones. Age and experience of the academic staff, cognitive qualities of students and a number of macroeconomic indicators for the cities in which universities are located can definitely be included into the model.

Nevertheless, current dataset does not comprise the information about those variables since statistical institutions in Turkey do not collect and publish them.

As indicated above, HEI-based characteristics are incorporated to the frontier function for not only their influence over total cost but also inefficiency values. Thanks to the incorporation of certain environmental factors, some hypotheses in relation to the influence of those factors onto the cost functions of universities as well as their efficiency performances will be investigated. These hypotheses can be enumerated as follows:

Hypothesis K1: Universities with younger age incur higher costs due to their lack of experience in academic and administrative skills.

Hypothesis K2: Universities with younger age incur lower costs due to their better capital structures and less bureaucracy. Besides, Tullock's (1965) inter-temporal budget expansion hypothesis argues that the older the institution gets the higher the inefficiencies do.

Hypothesis L: The size of universities motivates higher costs and would cause inefficiencies if they are experiencing diseconomies of scale particularly in teaching output (number of undergraduate and postgraduate students) as well as bureaucrats in higher education are inclined to expand their office and budget scheme as suggested by Downs (1965) and Niskanen (1971).

Hypothesis M: Load factor is evaluated as the possible source of economic efficiency even though it decreases total costs (Daghbashyan, 2011).

Hypothesis N: Universities with medical schools are expected to face greater amount of costs motivated from the structural features of this specific discipline. Having a separate research hospital renders high maintenance costs as well as laboratory-intensified teaching modules are much more costly than any social sciences departments where marginal costs are visibly lower.

Hypothesis O1: Universities with higher percentages of professors among academic staff experience fairly higher costs as the salary expenditures would be higher.

Hypothesis O2: Universities with higher percentages of professors among academic staff "might contribute to the more efficient operation having impact on the education output in terms of quantity and quality" Daghbashyan (2011) argues.

Hypothesis P: Higher the percentages of full-time academic staff higher the salary expenditures that will eventually increase the total cost.

Hypothesis Q: The proportion of foreign students within total number of students increases teaching costs as they represent enhanced and diversified demand in higher education. Nonetheless its influence on efficiency is still open to discussion.

IV. 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 (YÖK) as well as the Almanac of Student Selection and Placement Centre (ÖSYM). 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 (TÜBİTAK) 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 5.2:

Table-5.2: Descriptive Statistics						
Variables	**Abbreviation**	**Obs**	**Mean**	**Std. Dev.**	**Min**	**Max**
Output						
Number of Undergraduate Students	UG	265	43262.79	148209.7	623	1581743
Number of Postgraduate Students	PG	265	2222.034	2556.401	76	12909
Amount of Granted Research Project*	RES	265	2856732	4613204	7600	4.76E+07
Input Prices						
Price of Labour*	LAB	265	44734.24	10632.56	1663.751	83045.56
Price of Capital*	CAP	265	1494.715	1723.414	12	14418
Total Cost						
Total Annual Expenditures*	TC	265	1.28E+08	8.48E+07	8055000	5.10E+08
University-based Characteristics						
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)						

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

$$ln\ TC = \beta_0 + \beta_1 lnUG + \beta_2 lnPG + \beta_3 lnRES + w_1 lnLAB + w_2 lnCAP + z_1 AGE + z_2 SIZE + z_3 LOAD + z_4 PROF + z_5 FTS + z_6 FORGN + z_7 MED + v + u \qquad (5.2)$$

The latter specification belongs to Translog cost function and is shown as follows:

$$ln \frac{TC}{CAP} = \beta_0 + \beta_1 lnUG + \beta_2 lnPG + \beta_3 lnRES + w_1 \ln \frac{LAB}{CAP} + \frac{1}{2}\beta_{11} (lnUG)^2 + \frac{1}{2}\beta_{22} (lnPG)^2 + \frac{1}{2}\beta_{33} (lnRES)^2 + \frac{1}{2} w_{11} \left(\ln \frac{LAB}{CAP}\right)^2 + \beta_{1L} lnUG \ln \frac{LAB}{CAP} + \beta_{2L} lnPG \ln \frac{LAB}{CAP} + \beta_{3L} lnRES \ln \frac{LAB}{CAP} + \beta_{12} lnUG \ln (PG) + \beta_{13} lnUG \ln (RES) + \beta_{23} lnPG \ln (RES) + z_1 AGE + z_2 SIZE + z_3 LOAD + z_4 PROF + z_5 FTS + z_6 FORGN + z_7 MED + v + u \qquad (5.3)$$

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 structure 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, are developed:

Model A1: Cobb-Douglas cost function, without environmental variables, normally distributed and time-varying inefficiency terms, and panel data

Model A2: Cobb-Douglas cost function, with environmental variables, normally distributed and time-varying 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 and time-varying inefficiency terms, and panel data

Model B2: Translog cost function, with environmental variables, normally distributed and time-varying 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.

V. 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.

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) as other estimation models confront considerable weaknesses to estimate frontiers as pointed out in the methodology chapter (Chapter IV). In addition to these six models (A1, A2, A3, B1, B2, and B3), results of supplementary frontier models developed to demonstrate the influence of distribution of inefficiency term and certain panel data treatments are added to Appendix A.

Cobb-Douglas Specification

The cost frontier estimates for Cobb-Douglas specification concerning three different models are shown below in Table-5.3:

Table-5.3: 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***	0.5458***
	(-0.0344)	(-0.00037)	(-0.021)
lnPG	0.2182***	0.0290***	0.0299***
	(-0.0175)	(-0.00016)	(-0.0102)
lnRES	0.1159***	0.0556***	0.0558***
	(-0.0149)	(-0.00012)	(-7.00E-04)
lnPLAB	0.3288***	0.4838***	0.4833***
	(-0.0406)	(-0.00027)	(-0.0149)
lnPCAP	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***	.1975*
		(-0.00035)	(-0.123)
FT		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)
LAMBDA	2.5361***	368.184***	3393.506***
	(-0.07407)	(-0.0009)	(-1691.77)
SIGMA (u)	0.4072***	0.2297***	0.22880***
	(-0.01661)	(-0.004)	(-0.0006)
ETA	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 in parentheses.

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 lambda 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 above have higher values than 0 for lambda 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-5.3 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 it is 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 exogenous variables. Table-5.3 reveals that each and every exogenous 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). The detailed results concerning the impact of environmental variables onto the total cost function with Cobb-Douglas specification are demonstrated in Table-5.4.

Table-5.4: Hypothesis Results for Environmental Variables

Hypothesis/Model	Model A2	Model A3
Hypothesis K1	Reject	Reject
Hypothesis K2	Accept	Accept
Hypothesis L	Accept	Accept
Hypothesis M	Accept	Accept
Hypothesis N	Accept	Accept
Hypothesis O1	Accept	Accept
Hypothesis P	Accept	Accept
Hypothesis Q	Accept	Accept

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 chapter.

The cost frontier estimates of Translog function pertaining to three different models are as follows (Table-5.5):

Table-5.5: Translog Cost-Frontier Results

Variables	Model B1	Model B2	Model B3
Constant	9.097305 (7.355)	-0.35439835 (0.5667)	-0.354398 (1.3788)
lnUG	-0.9550621 (1.0081)	0.1419931 (0.1083)	0.1419931 (0.2261)
lnPG	0.157686 (0.3396)	0.2876*** (0.0423)	0.2876278 (0.1784)
lnRES	-0.3330358 (0.5858)	0.2067*** (0.026)	0.206725* (1.10E-01)
ln(Pl/Pk)	1.463*** (0.4583)	2.1398*** (0.0459)	2.13988***
0.5 lnUGxlnUG	0.393*** (0.0584)	0.2945*** (0.0125)	0.29457*** (0.0381)
lnUGxlnPG	-.07205** (0.034)	-.0577*** (0.0048)	-.05775** (0.023)
lnUGxlnRES	-0.0289111 (0.0689)	-.0754*** (0.0042)	-.0754*** (0.0175)
0.5 lnPGxlnPG	0.050955 (0.0311)	-.0155*** (0.0057)	-0.0155 (0.0173)
lnPGxlnRES	0.013529 (0.0213)	0.0149*** (0.0033)	0.014945 (0.0108)
0.5 lnRESxlnRES	0.024719 (0.026)	0.0301*** (0.003)	0.031*** (0.0085)
0.5 ln(Pl/Pk)xln(Pl/Pk)	0.278*** (0.046)	0.1517*** (0.0051)	0.1521*** (0.0441)
lnUGxln(Pl/Pk)	-.3577*** (0.04108)	-.2548*** (0.0073)	-.2614*** (0.0394)
lnPGxln(Pl/Pk)	0.046443 (0.0367)	0.0523*** (0.0042)	0.0519* (0.028)
lnRESxln(Pl/Pk)	0.0848** (0.0369)	0.004532 (0.0032)	0.004429 (0.022)
AGE		0.0054*** (0.0009)	0.0052*** (0.0007)
SIZE		0.00001*** (2.00E-07)	0.000012*** (8.70E-07)
LOAD		-.02048*** (6.00E-04)	-.02051*** (1.30E-03)
PROF		0.00431235 (0.0617)	0.00421345 (0.208)

Table-5.5: Translog Cost Frontier Results (cont'd)

FT		0.0519*** (0.0143)	0.0521*** (0.0344)
FORGN		3.2903*** (0.8812)	3.3102*** (1.0668)
MED		0.0527 (0.1048)	0.025 (0.1052)
LAMBDA	2.4406*** (0.07096)	9.0280*** (0.0285)	9.0310*** (3.29802)
SIGMA (u)	0.3114*** (0.0069)	0.1994*** (0.002)	0.20068*** (0.00054)
ETA	0.01 (0.0236)	0.01 (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 in parentheses.

All three models have higher lambda 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. For the further conclusions, Table-5.6 could be visited.

Table-5.6: Hypothesis Results for Environmental Variables

Hypothesis/Model	Model B2	Model B3
Hypothesis K1	Reject	Reject
Hypothesis K2	Accept	Accept
Hypothesis L	Accept	Accept
Hypothesis M	Accept	Accept
Hypothesis N	Indeterminate	Accept
Hypothesis O1	Indeterminate	Indeterminate
Hypothesis P	Accept	Indeterminate
Hypothesis Q	Accept	Accept

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 Coelli’s (1992) time-varying efficiency estimation. The estimated eta concerning four different models has 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.

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[4] 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 scrutinize the likelihood of having all coefficients of environmental variables equal to zero.

Table-5.7 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

[4] For the further explanations about LR test, Appendix B can be visited.

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-5.8. 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. The results of abovementioned hypotheses are indicated below:

Table-5.7: Hypothesis Testing for Model Specification: Cobb-Douglas vs. Translog

Model	Null Hypothesis	Value of LR-Test	Prob> χ2	Decision (5% Level)
A1 vs. B1	H_0: All the coefficients of second-order terms are equal to zero β_{11}=β_{22}=β_{33}=w_{11}=β_{1L}=β_{2L}=β_{3L}=β_{12}=β_{13}=β_{23}=0	137.9374	0.0000	Reject H_0
A2 vs. B2	H_0: All the coefficients of second-order terms are equal to zero β_{11}=β_{22}=β_{33}=w_{11}=β_{1L}=β_{2L}=β_{3L}=β_{12}=β_{13}=β_{23}=0	94.2554	0.0000	Reject H_0
A3 vs. B3	H_0: All the coefficients of second-order terms are equal to zero β_{11}=β_{22}=β_{33}=w_{11}=β_{1L}=β_{2L}=β_{3L}=β_{12}=β_{13}=β_{23}=0	91.1611	0.0000	Reject H_0

Table-5.8: Hypothesis Testing for Model Specification: Incorporation of Environmental Variables

Model	Null Hypothesis	Value of LR-Test	Prob> χ2	Decision (5% Level)
A1 vs. A2	H_0: All the coefficients of environmental variables are equal to zero Z_1=Z_2=Z_3=Z_4=Z_5=Z_6=Z_7=0	.136	0.6834	Fail to Reject H_0
B1 vs. B2	H_0: All the coefficients of environmental variables are equal to zero Z_1=Z_2=Z_3=Z_4=Z_5=Z_6=Z_7=0	4521.3765	0.0000	Reject H_0

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)'s methodology –which is exclusively discussed in Chapter IV-, preferred to be conducted. All the models developed for this chapter either Cobb-Douglas and Translog have reliable lambda values, hence their estimations will be used not only for this section but also for further empirical and policy-making discussions. The descriptive statistics for the mean efficiency values are shown below in the Table-5.9. For the university-by-university efficiency scores, Appendix C[5] can be visited.

Table-5.9: Descriptive Statistics for Mean Efficiency Values

	Model A1	Model A2	Model A3	Model B1	Model B2	Model B3
Mean	0.691903	0.833028	0.711564	0.749832	0.856211	0.904001
Standard deviation	0.181688	0.103077	0.152195	0.168233	0.0956	0.0395
Minimum	0.12562	0.331731	0.53642	0.269967	0.450127	0.870437
Maximum	0.961819	0.989679	0.965577	0.96937	0.98558	0.990533

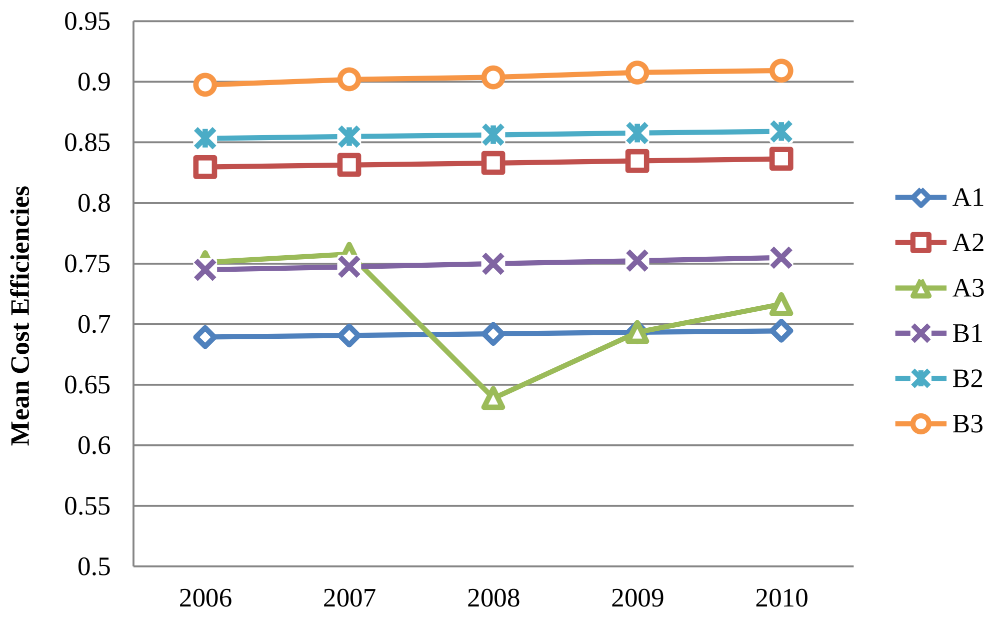
These initial statistics mentioned above have certain suggestions for HEIs in Turkey. Firstly, mean efficiency performances of Turkish public universities are fairly dispersed ranging from 70% to 90%. This would encourage a new set of policy-making decisions to lead inefficient universities to be aware 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

[5] The names of the HEIs are not revealed in the tables; instead they are coded by PU1, PU2, and PU3 so and so forth at the Appendix C section, as it may cause unintended consequences in the political levels.

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-5.5, 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-5.1 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-5.1: Average Cost Efficiencies over Time



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-5.10 is carried out for this comparison.

Table-5.10: Spearman Rank Correlations

	Model A1	Model A2	Model A3	Model B1	Model B2	Model B3
Model A1	1					
Model A2	.465628	1				
Model A3	.792720	.318720	1			
Model B1	.684789	.401335	.552452	1		
Model B2	.331513	.545335	.226778	.524377	1	
Model B3	.239149	.392292	.300739	.345083		1

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-5.10, 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 section.

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 & 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-5.2.

In addition to the formulation in (5.3), new specification is needed for the inefficiency term to be able to conduct one-step analysis narrated in (5.4). 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 regression model without intercept is taken into the analysis as the conventional neo-classical economics assumes that firms do not experience inefficient usage of resources as long as factors causing inefficiency are eliminated. 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:

$$u_i = Z_0 + Z_1AGE + Z_2SIZE + Z_3LOAD + Z_4PROF + Z_5FT + Z_6FORGN + Z_7MED + \alpha_i \quad (5.4)$$

The estimation results of the inefficiencies are pointed out in the Table-5.11:

Table-5.11: Regression Results for Determinants of Inefficiencies

Variables	Model B2 (Without Intercept)	Model B2
AGE	0.0054***	0.044586
	(0.0009)	(0.039)
SIZE	0.00001***	.797D-04*
	(0.0000002)	(.450D-04)
LOAD	-.02048***	-0.16852*
	(0.0006)	(0.098684)
PROF	0.00431235	4.045698
	(0.0617)	(12.60634)
FTS	0.0519***	0.277591
	(0.0143)	(1.381614)
FORGN	3.2903***	55.24667
	(0.8812)	(49.17822)
MED	0.0527	1.84628*
	(0.1048)	(0.964238)
CON	N/A	1.499941
		(2.63512)
SIGMA (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 in parentheses.

Both two models have significantly reliable lambda values as well as reasonable log-likelihood ratios. 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 (Downs, 1965; Niskanen, 1971) put forward in Chapter II 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 (1964).

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 Tullock's (1968) inter-temporal budget growth hypothesis. 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. However, as these estimates are not supported in the two models simultaneously, there is a precise need to perform robustness checks that will be exercised in the upcoming chapter concerning the results of Data Envelopment Analysis.

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.

VI. LIMITATIONS and CONCLUDING REMARKS

The methodological problems of SFA has already been enumerated and examined in the previous methodology chapter. Thus, 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 chapter.

The first limitation of this research is affected 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 (1995)'s 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.

In conclusion, stochastic cost frontier analysis does provide reliable estimates on cost frontier and inefficiencies of HEIs in Turkey. However, these results need to be exposed to robustness checks with Data Envelopment Analysis that is exercised in the upcoming chapter.

CHAPTER VI: Efficiency Analysis of Public Higher Education Institutions in Turkey: Application of Data Envelopment Analysis (DEA)

I. INTRODUCTION

As already indicated in the previous chapter, estimating technical and cost efficiencies of higher education institutions (HEIs) has become a central area of research in the literature of efficiency analysis particularly over the course of the last two decades. Unlike other for-profit entities that have been under scrutiny in terms of efficiency performance by researchers such as banking and airlines companies, not-for-profit motive among HEIs run either public or non-profit entrepreneurs has attracted attentions of researchers to test the fundamental arguments around incentive-efficiency dichotomy claiming that lack of profit motivation among non-profit and public organizations would lead them to operate less efficient then their for-profit counterparts (Ben-Ner, 2002). Eventually, a remarkable number of papers –whose results are discussed in the following section-, have accumulated on the efficiencies of HEIs that were applied to various country cases including Britain, Sweden, Canada, Australia, China and Greece (Katharakia and Katharakis, 2010; Daghbashyan, 2011).

So as to investigate efficiencies of HEIs, two mainstream methodologies are applied: Stochastic Frontier Analysis (SFA) and Data Envelopment Analysis (DEA). In the previous chapter, the former method that entails parametric steps to estimate efficiencies of HEIs was utilised, whilst the latter one will be the main focus of the analysis carried out in this chapter. That is to say, in this chapter, efficiencies of public HEIs in Turkey are estimated by employing non-parametric DEA technique. In doing so, the results obtained from parametric technique can be compared and contrasted with the results put forward by the non-parametric technique. Accordingly, policy recommendations coming out of these two distinct efficiency estimation methodologies are revealed in the following chapter.

This chapter is designed to address certain questions that have vital importance for the various aspects of public HEIs in Turkey regarding their efficiency performances. In other words, the analysis of this chapter sheds light on the extent to which public HEIs are using their resources in an efficient manner both individually and the sector as a whole within the framework of the non-parametric efficiency estimation technique. Those questions are:

1. What are the overall technical and cost efficiency levels of public HEIs in Turkey concerning different input/output specifications and production/cost frontier?
2. What are the individual efficiencies of public HEIs in Turkey?
3. To what extent efficiency scores are changing throughout 5-year time span?
4. What are the determinants of inefficiency among public HEIs? Do environmental factors matter for universities concerning efficiency performance?
5. What is/are the limitation(s) of this particular analysis? Are the results reliable for forthcoming academic and policy-based researches?

Chapter VI deals with the interpretation of the results derived from DEA estimation. Policy-reflection and suggestion aspect of those results will be discussed in Chapter VI alongside with the results obtained from SFA (Chapter V). Besides, incorporation of environmental variables in DEA to account for the determinants of efficiency among HEIs paves the way for comprehending the probable factors behind inefficient usage of resources as well as conducting a methodological comparison between SFA and DEA.

The organisation of the chapter is as follows: Section II defines and describes the output/input variables as well as environmental factors that are expected to influence efficiencies of HEIs. The following section –section III-, illustrates the dataset that is used for this analysis and also puts forward models comprising different input/output sets over and above the model of assumed technology. Section IV summarises the mean efficiency values for selected DEA models and examines them, whereas section V conducts robustness tests for the models. Section VI illuminates the potential driving forces behind inefficiencies by employing two-stage DEA method through which efficiency values are estimated in the first stage and Tobit regression model is carried out to reveal the association between certain environmental variables and efficiency scores in the second. Section VII states the limitations of this research and propose a set of statements for future researches and lastly Section VIII concludes.

II. SELECTION OF VARIABLES

The validity of efficiency analysis is vastly contingent upon the selection of appropriate output and input variables. Both production and cost frontiers –which is non-parametric in DEA-, are drawn regarding to the given output and input measures, hence efficiency of each decision-making unit is calculated as regards to the specified frontier. Therefore, if decision-making process to choose the output and input bundles builds on wrong judgments, researchers would end up with biased efficiency results. The following paragraphs will articulate the variables constituting the dataset of this chapter under three sections: output measures, input measures and environmental factors.

Output Measures

As mentioned earlier in the Chapter V, the ideal output bundle of universities should be consisting of various fields of activity including teaching, research, community service and cooperation with business sector due to the fact that services offered by HEIs are not appealing merely to students and academia. To reflect the contribution of universities into the society as a whole, there is a precise need to attain wide-ranging data from community services and the consequences of university-business sector cooperation. However, lack of sufficient data on related activities does not allow researchers to map out HEIs fully, thus efficiency estimation may not be performed properly. Within this scenario, efficiencies of universities that are good at providing community services as well as developing effectual relations with business sector would culminate in downwardly biased values. Furthermore, data on the quality of outputs must be incorporated to the models which is seen as the most challenging and deficient side of efficiency analysis since the measurement of quality variables contains considerable difficulties (Abbott and Doucouliagos, 2003).

While being aware of these weaknesses and limitations, certain output variables that are currently measurable will be used in this chapter. For HEIs in Turkey, the following variables will be taken into the analysis:

i) Number of Full-time Undergraduate Students (UG): This refers to total number of registered undergraduate students within one academic year. (Graduates are excluded)

ii) Number of Full-time Postgraduate Students (PG): This corresponds to total number of registered master's and doctoral students within one academic year. (Graduates are excluded)

iii) Number of Indexed Publications per Academic Staff (PUB): It denotes total number of publications appeared in SCI, SSCI and AHCI indexes per the number of academic staff

iv) Total Amount of Research Grants (RES): This measures total amount of funding that is given by The Scientific and Technological Research Council of Turkey (TÜBİTAK) to the HEIs on project-based applications.

Input Measures

Universities produce those outputs by employing certain set of inputs. In the literature of efficiency analysis of HEIs, for input variables, expenditures of universities that are divided into different factors such as labour, material, capital, library and total expenditures are used by researchers (Maria Katharakia and George Katharakis, 2010). In this chapter, similar variables will be situated into the DEA model as shown below:

i) Number of Academic Staff (FAC): It is the total number of faculty including full and part-time staff.

ii) Labour Expenditures (LAB): It represents total amount of expenditures allocated to the salary payments of academic and non-academic staff.

iii) Capital Expenditures (CAP): This represents the remaining amount of expenditures in the total expenditures when labour related as well as goods and services expenditures are subtracted.

iv) Goods and Services Expenditures (G&S): This measures the amount of money allocated to purchase certain goods and services needed to keep up daily operations.

v) Total Expenditures (TOTEXP): This accounts for the total amount of expenditures within a specific year.

Environmental Factors

In addition to the measures for outputs and inputs, environmental variables constituting individual characteristics of HEIs that would have an impact on either cost function or inefficiency scores will be put forward in this section. The hypotheses in relation to the probable effect of environmental factors over to the efficiency performances of HEIs are precisely akin to the hypotheses put forward in the previous chapter (Chapter V). Thanks to the two-stage DEA estimation methodology, the extent to which these university-based factors are exerting influence upon inefficiencies of HEIs will be illuminated.

The environmental variables that are used throughout the two-stage DEA, as revealed in the previous chapter, are as follows:

i) Age of the university (AGE): Number of years since the establishment of the university regarding to the procedures of Ministry of Education.

ii) Size of the university (SIZE): The number of total students comprising both undergraduate and postgraduate students will be used as a proxy.

iii) Load per academic staff (LOAD): It is the ratio of full time student to all academic staff.

iv) % of full-time staff (FTS): It is the ratio of full-time academic staff to all academic staff.

v) % of professors among academic staff (PROF): It is the ratio of professors to all academic staff.

vi) % of foreign students (FORGN): It is the share of students with foreign background.

vii) Dummy variable for having medical school (MED).

III. DATA and MODELS

In this section, dataset for the DEA is described concerning the input and output measures as well as the environmental factors that would influence the efficiency performances of the given HEIs in Turkey. Secondly, different DEA models are developed to improve the robustness of the results on the basis of CRS-VRS and production/cost frontier framework. Lastly, incorporation of environmental variables is briefly discussed so as to have a general methodological understanding on them beforehand.

Data Description

This research covers 53 public universities existing in Turkish Higher Education between 2005 and 2010 including five full academic years, corresponding to 265 observations. The data for inputs and outputs as well as university-based characteristics were collected from the website of The Council of Higher Education (YÖK), archives of Measurement, Selection and Placement Centre (ÖSYM) and the annual reports of Ministry of Education of Turkey. Moreover, the Scientific and Technological Research Council of Turkey (TÜBİTAK) releases report on the amount of research funds granted to the universities annually.

The sample of this research includes a variety of HEIs concerning their size, amount of expenditures and geography that are distinctly embodied in the relatively wide ranges for related variables. The variation among the given HEIs is summarised under the rubrics of institutional features as well as the staff and student characteristics. Table-6.1 summarises the dataset for the all variables whose explanations are indicated above.

Table-6.1: Descriptive Statistics					
Variable	**Mean**	**Std.Dev.**	**Minimum**	**Maximum**	**Obs**
Output					
UG	43262.8	148210	623	1.58E+06	265
PG	2222.03	2556.4	76	12909	265
PUB	0.231741	8.03E-02	1.93E-03	0.482192	265
RES*	2856.73	4613.2	7.6	47649.8	265
Input					
FAC	1510.21	1028.16	275	5437	265
LAB*	68121.7	51690.6	3744	297693	265
G&S*	22117.7	17283.4	2627	109375	265
CAP*	25017.5	10661.6	500	83533	265
Financial Output					
TOTEXP*	128236	84787.9	8055	509612	265
University-based Characteristics					
AGE	27.26415	13.78013	12	66	265
SIZE	45484.82	148317.2	1408	1584003	265
LOAD	28.66435	83.9492	1.22863	888.6197	265
PROF	0.115158	0.064291	0.028874	0.378363	265
FTS	0.856985	0.241984	0.071222	1	265
FORGN	0.009205	0.012179	0	0.066902	265
MED	0.679245	0.46765	0	1	265

Note: *Thousands of Turkish Liras (TLs)

Model Specification

The different specifications of DEA model are needed to perform robustness checks for the efficiency values assigned to the HEIs. In this chapter, each model will be consisted of different sets of outputs and inputs departing from the fact that "DEA analysis can be sensitive to the variables included" as well as to reflect the theoretical discussions on the selection of variables (outputs and inputs) in the efficiency analysis of higher education (Macmillan and Datta, 1998).

Developing different models entail two distinct efficiency estimation named as technical and cost efficiency. That is to say, whereas first four models measure technical efficiencies of HEIs with respect to the non-parametric production frontier, last two models compute cost efficiencies of HEIs regarding non-parametric cost frontier. And eventually, both constant returns to scale (CRS) and variable returns to scale (VRS) optimisation methods will be applied to the each specification. The illustration of these alternative models is shown below:

Table-6.2: Alternative DEA Models

Variable	Model 1	Model 2	Model 3	Model 4	Model 5*	Model 6*
Output						
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
Input						
FAC				X		
LAB	X	X	X	X		
G&S		X	X	X		
CAP	X	X	X	X		
Financial Output						
TOTEXP					X	X

Note: *Cost Specification, financial output is treated as the only input

Model 1 and Model 5 are the most parsimonious models as well as corresponding to the almost same variable set that was already used in the previous chapter through which Stochastic Frontier Analysis was carried out. Whereas Model 1 computes technical efficiencies, Model 5 reveals cost efficiencies of universities due to the fact that it uses cost specification model. Model 2 enriches the previous variable set of Model 1 with the inclusion of new input variable –which is goods and services expenditures-; Model 3 extends the specification through adding new output variable (publication per faculty). Model 4 uses all output and input sets available for this research to measure technical efficiencies of universities. And the last model (Model 6) is arranged to gauge cost efficiencies of universities with all existing output measures.

Incorporation of Environmental Factors

One of the vehemently debated topics in the recent literature of efficiency analysis is the incorporation of environmental factors that would be either under the control of decision-makers or consisted of unmanageable factors (Greene, 2004; Alvarez, Arias and Greene, 2005). Those environmental variables are expected to have impact on the computed efficiency scores of the DMUs, thus their influence should be included into the non-parametric efficiency estimation (Charnes, Cooper and Rhodes, 1981; Banker and Morey, 1986; Macmillan and Datta, 1998).

So as to amalgamate environmental factors, two different methodologies were developed. The first method is called as one-stage DEA model in which all environmental factors are treated as either non-discretionary inputs or outputs (Coelli et al., 2005:194). Second one is the two-stage method through which linear programming is carried out based on traditional inputs and outputs at its first stage and in the second stage the derived efficiency scores are regressed upon to the various environmental factors. Thanks to this method, the influence of university-based characteristics differing apparently from traditional input sets over to the efficiency performances of HEIs can be estimated by Tobit regression procedure. Moreover, policy-based implications for decision-makers both in universities and government could be extracted out of this analysis -which exposes the determinants of inefficiencies among HEIs so as to allocate resources more efficiently. For further explanations, Coelli et al. (2005) could be visited.

For this particular research, two-stage methodology will be chosen to investigate the potential impact of university-based features that cannot be deduced wholly to classical input variable set. That is to say, as Macmillan and Datta (1998) and Dagbashyan (2011) argue, the size and age of the university as well as student/staff based characteristics such as proportion of full-time staff alongside with the professors among faculty and percentage of students with foreign background are corresponding to the heterogeneity among the HEIs and diverge evidently from conventional inputs in higher education sector.

IV. INTERPRETATION OF RESULTS

This section focuses predominantly on the topics that are indicated below:

- Efficiency values of public HEIs in Turkey referring not only to the production frontier but also cost frontier are measured (technical and cost efficiencies),
- Confidence intervals are developed for their efficiency values through bootstrapping procedures,
- Total factor productivity indexes are estimated thanks to the Malmquist method both individually and the sector as a whole.

Efficiency Values (Technical and Cost Efficiency)

The summary statistics of technical and cost efficiencies of 53 public universities in Turkey with CRS frontier are shown in Table-6.3. The corresponding efficiency scores for each and every university will be indicated in the Appendix D[6]. Whereas the first 4 models are designed to measure technical efficiencies, the last two are measuring the cost efficiencies of universities with different output mixtures. Moreover, each model comprises both input and output orientations so as to detect possible variation coming out of the type of optimisation choice, even though orientation method does not have any impact on the ranking of HEIs in terms of their efficiency performances.

Table-6.3: Summary Statistics for Estimated Efficiencies (CRS)

Model/Estimated Efficiencies	Orientation	Mean	St.Dev.	Min	Max
Model 1	Input	0.2486	0.2209	0.0238	1
	Output	0.2916	0.2145	0.0345	1
Model 2	Input	0.3269	0.2276	0.0410	1
	Output	0.3401	0.2276	0.0412	1
Model 3	Input	0.3650	0.2195	0.0809	1
	Output	0.3949	0.2092	0.1235	1
Model 4	Input	0.4714	0.2147	0.1679	1
	Output	0.4734	0.2141	0.1680	1
Model 5	Input	0.2265	0.1905	0.0253	1
	Output	0.2623	0.1914	0.0357	1
Model 6	Input	0.2566	0.1873	0.0620	1
	Output	0.3111	0.1799	0.0973	1

In the first two models (Model 1 and 2) where output mixture does not include number of publications per faculty, the overall technical efficiencies of universities are computed as almost 30% ranging from 25% to 35% concerning different orientations (input/output). Even though there are universities that perform higher efficiency scores, nearly two-thirds of them have efficiency scores below than 50%. Furthermore, the dispersion of efficiency scores is quite significant and revealing the fact that worst practising DMUs are dramatically differing from best-practising ones. And it may seem to be a bit intriguing

[6] The names of the HEIs are not disclosed in the Appendix D due to the same concerns indicated in the previous chapter.

that inclusion of one more input variable (goods and services expenditures) has not had any adverse impact on efficiency scores in overall, rather it enhanced the weighted combination of input measures to produce given output set.

Completing output and input matrices via adding new variables leads to an increase in efficiency scores. In the Model 4 in which all output and input variables are utilised, the overall efficiency scores more or less doubled if they are compared with the values in Model 1. When one output variable (number of publication per faculty) is ruled out, average of efficiency values diminished from 47% to 36% in input-orientation and 47% to 39% in output-orientated measurement. Besides, the performance of worst practising university has increased by four times in model 3 and eight times in model 4.

In the last two models through which total expenditures are used as the sole input variable, cost efficiencies of universities are calculated. For the model 5, the mean cost efficiencies of universities are estimated as 22% and 26% in input and output orientations respectively. In the model 6 where publication per faculty is added to, efficiency scores have shown slightly higher values up to 30%. The difference between worst- and best-practising universities has widened in model 5 and model 6 if they are measured up to model 3 and 4, whilst it has not significantly changed if the comparison is performed with Model 1 and 2.

If the findings of CRS-DEA efficiency scores of this research are put side by side the previous literature on public HEIs in Turkey –even though it is considerably limited-, it could be argued that the results of these models are diverging notably from them concerning mean efficiency values and the performance of worst-practising HEIs. For instance, whereas overall technical efficiencies of public HEIs in Baysal et al’s paper (2005) are nearly 90%, the mean technical efficiency of public HEIs is 50% in the full model (Model 4). However, Kutlar and Babacan's (2008) paper revealed the fact that there is a downward tendency among public HEIs in Turkey concerning efficiency performances, which is in line with the findings of this chapter. Besides, whereas the efficiency values of public HEIs in Turkey are scattered within a pretty narrow-range in the previous literature (Baysal et al, 2005; Kutlar and Babacan, 2008), dispersion of HEIs pertaining to their efficiency values is remarkable in the research of this chapter which galvanise a subsequent inquiry on the determinants of this dispersion among the public HEIs in Turkey.

So as to relax technology assumption and have flexible frontier, efficiency scores are estimated with VRS in addition to the previous CRS optimisation. Previous theoretical literature on non-parametric efficiency analysis (Banker et al, 1984; Coelli et al, 1998) proposes the fact that while VRS increases efficiency values, CRS decreases them. Hence, overall efficiency scores for public HEIs in Turkey are expected to rise with VRS-DEA technology. The summary statistics of estimated efficiencies with VRS technology are indicated in Table-6.4.

Table-6.4: Summary Statistics for Estimated Efficiencies (VRS)

Model/Estimated Efficiencies	Orientation	Mean	St.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

The first and foremost interpretation from VRS analysis is that mean efficiencies for all given models have remarkably increased which is in line with the earlier theoretical literature. For instance, the overall technical and cost efficiencies of universities have risen up to 60% with output orientation in Model 4 and Model 6. Besides, overall efficiency scores with VRS optimisation have converged to the results put forward by the preceding research indicated above. In addition to that, the worst practising universities for different models have shown better efficiency performances and almost doubled in some cases. And eventually, the number of universities that have efficiency estimates lower than 50% has decreased in particular for the full and nearly-full models in terms of input and output mixtures.

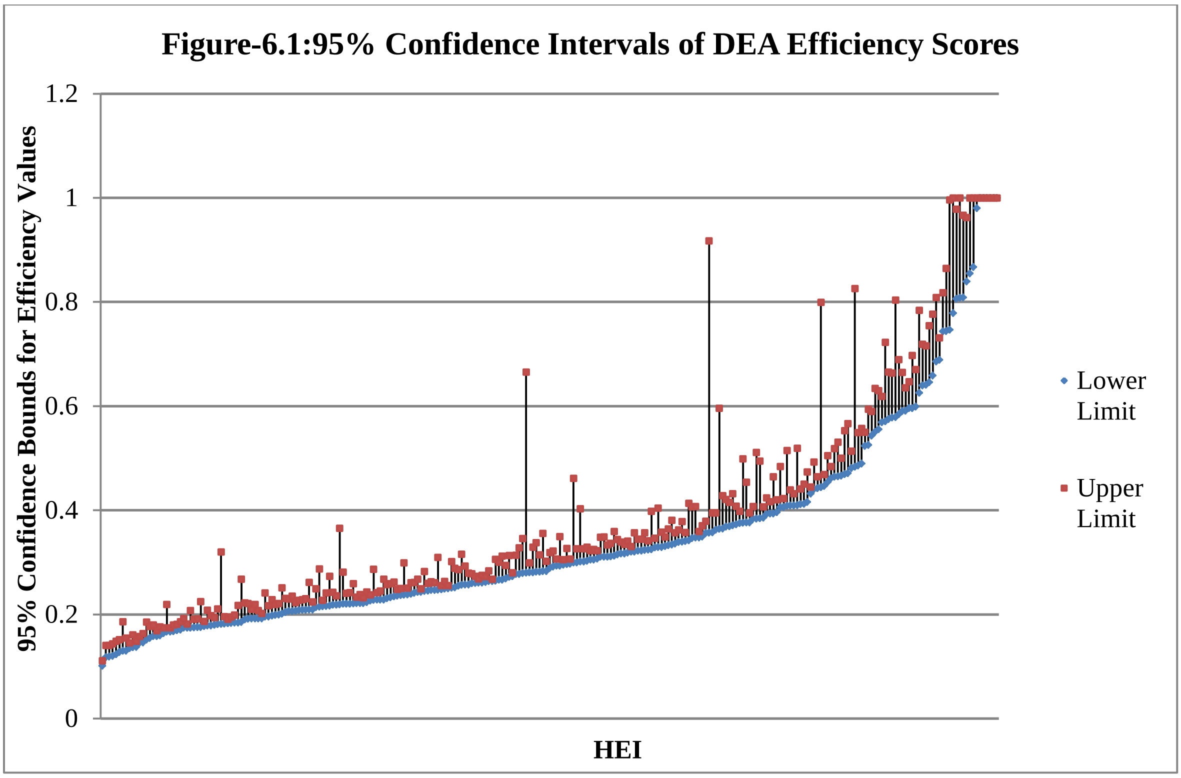
Even though next chapter performs a rigorous comparison between the results come out of DEA and SFA, an introduction to that comparison is set forth in the last paragraph of this section. Due to the fact that non-parametric approach (DEA) does not take external shocks that are totally differing from inefficiencies into the consideration, its efficiency estimation is expected to be lower than the estimated values by SFA. For this research, as in tune with the expectations, whereas overall efficiencies of public HEIs are gathered around 80% in parametric models, the highest mean efficiency among non-parametric models correspond to 60%.

Confidence Intervals and Bootstrapping

As discussed in the methodology chapter, non-parametric techniques have a fundamental shortcoming that is lack of statistical properties in their estimation procedures. DEA is not immune to this problem that makes its efficiency results less reliable. That is to say, “although DMUs may appear to vary widely in their efficiency (as denoted by the DEA efficiency score), the basic DEA technique provides no indication whether the difference between DMUs is statistically significant” (Johnes, 2006). To overcome this specific obstacle, bootstrapping method that constructs confidence intervals for efficiency values is introduced (Simar and Wilson, 1998) and becomes a widely used method in the DEA literature.

Thanks to this method, the distinction between the HEIs concerning efficiency performances is statistically tested. Moreover, the panel component of the dataset would tailor a vital opportunity to check whether “time effect” does have any statistical significance in efficiency values. Thus, if the analysis is reduced to cross-sectional data, then the impact of time will be ruled out. However, Malmquist index will backbone the central arguments when the discussion comes to inter-temporal analysis. In addition to the inter-temporal aspect of the bootstrapping procedure for Turkish public HEIs, segmentation for them can be carried out to reveal the differentiation among competing HEIs in terms of their sizes, age and location.

For this specific analysis, 95% confidence bounds are developed for efficiency values in Model 6 with 10 times replicated sample. The upper and lower limits for the each DMU are shown in Figure-6.1.



Although confidence bounds are not appropriate to reveal the distinction among the mid-performing universities, they clearly indicate that best-performing universities have significantly higher efficiencies than worst performing ones. As Figure-1 shows, the universities with 40% and lower efficiency scores are dramatically diverging from the universities with 60% and above. Efficiency values of the ones between those thresholds are not significantly different concerning bootstrapping statistical procedures. The apparent variation between best- and worst-performing universities would have indispensable policy-implication through peer analysis of worst performing universities.

Malmquist Index (Inter-Temporal Analysis*)*

The salient advantage of having panel data is the ability to check whether any improvements in efficiency values have taken place at the course of the observed time period. Malmquist Index (or Total Factor Productivity and MI hereafter) is the only method to conduct inter-temporal analysis in DEA literature. Caves et al. (1982) introduced this index in the productivity literature by departing from Shephard's (1970) distance function. The desirable property of MI is that it does not require any "behavioural assumptions such as cost minimisation or profit maximisation" which makes it viable for the cases where the objective of the DMU is unknown (Mohammadi and Ranaei, 2011). Furthermore, it should be noted here that if the value yielded by MI is less than 1, it signifies a decrease in total factor productivity (TFP), whilst the productivity increases if the MI is greater than 1; and accordingly it refers to a lack of change in TFP if the value is exactly equal to 1.

For this research, Malmquist values are computed as shown in Table-6.5 with respect to the cost efficiency values yielded in Model 6. Besides, time periods are assigned to the transition process between current year and the next one. That is to say, Period 1 refers to the move from 2005-2006 to 2006-2007 academic years. And subsequent periods are determined by the same method. Due to the fact that 2009-2010 does not have any following year, the analysis covers four time periods.

Table-6.5: Average Malmquist Results across HEIs, by period:

Average/Period	Period 1	Period 2	Period 3	Period 4
TFP	1.023	0.669	1.487	1.1156

Period 1 indicates a slight increase in TFP, whereas Period 3 and 4 denote relatively significant improvements. However, Period 2 signals an apparent deterioration in overall TFP among public HEIs in Turkey. Furthermore, even though there is not any systematic improvement in efficiencies among universities, during the last two years they have demonstrated progress in terms of efficiency. Figure-6.2 clearly reveals this inconsistent improvement through which efficiency performances of universities have witnessed ups and downs, thus motivates researchers to understand the driving forces behind this variation. During the following parts of this chapter –in particular determinants of inefficiency part-, the factors influencing efficiencies will be illuminated via focusing on a set of university-based variables.

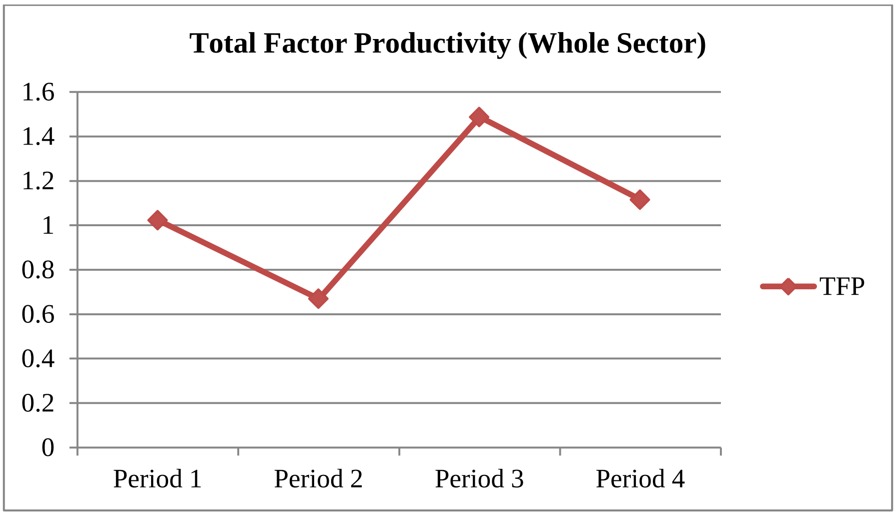


Figure-6.2

In addition to the overall analysis, Malmquist index also gives individual results that are indicated in Table-6.6. The university-by-university TFP scores contribute to the policy-reflection part of this PhD research especially for the administrative bodies of the universities as they are more or less representing the overall efficiency improvement or decline in the given period. Hence, university-based results are discerned to put forward consistent and accurate implications to the decision makers that will be discussed in the following chapter in detail.

The initial indication of Table-6.6 is that while the majority of universities demonstrate a pattern in line with the global results, there are universities that diverge from it. Secondly, individual MI for HEIs refers to the change in efficiency either might be increasing or declining. For instance, corresponding numbers to PU1 at the first row indicate that during Period 1 and 3, efficiency has increased by almost 1.38 and 1.18

respectively, whilst there are reductions in Period 2 and 4 by nearly 0.70 and 0.91 in that order. The remaining results can be interpreted in line with this previous analysis.

Table-6.6: Malmquist Index Results by Individual Universities

DMU	Period 1	Period 2	Period 3	Period 4	DMU	Period 1	Period 2	Period 3	Period 4
PU1	1.38098	0.708154	1.18929	0.916409	PU27	0.771978	0.685171	1.18634	1.20868
PU2	0.957281	0.58407	1.34797	1.08764	PU28	0.995265	0.349447	1.77622	1.01924
PU3	0.987611	0.677002	1.34576	0.921349	PU29	0.900853	0.3161	3.146	1.37669
PU4	1.30311	0.441314	1.07625	1.02979	PU30	0.685361	0.887294	1.2091	1.48393
PU5	1.39154	2.46391	0.373723	1.40376	PU31	1.05348	1.27246	1.04622	0.964879
PU6	1.26423	0.339769	1.44612	1.19452	PU32	0.82026	0.82462	1.17716	1.22425
PU7	0.595538	0.535399	2.47136	1.22568	PU33	1.15268	0.519999	1.72779	1.0974
PU8	0.953676	0.49873	1.41648	1.04954	PU34	2.6896	0.3437	0.883345	0.941566
PU9	0.993887	0.442703	1.69871	0.989868	PU35	2.10313	0.174288	1.72769	1.04207
PU10	0.903984	0.503421	1.87971	1.02153	PU36	0.796499	0.308653	2.48261	1.33378
PU11	0.827913	0.588547	1.6671	1.05762	PU37	0.839442	0.654124	1.2494	1.23009
PU12	0.755963	0.617664	1.34207	1.03793	PU38	0.842219	0.425136	2.24111	1.05006
PU13	1.00778	0.436397	1.79705	1.15296	PU39	0.901164	0.640464	1.44407	0.943159
PU14	0.860271	0.805699	1.05009	1.17953	PU40	1.13898	1.35154	1.22783	0.772658
PU15	0.864794	0.358846	1.95619	1.24201	PU41	1.2662	1.19841	0.853576	0.896704
PU16	0.912347	0.573937	1.62128	0.968558	PU42	0.979146	0.754437	1.35364	1.12585
PU17	0.928647	0.64166	1.28266	1.03383	PU43	0.67215	0.507545	1.23131	1.2958
PU18	1.03354	0.676564	1.56012	1.07812	PU44	0.902515	0.562559	1.56232	1.12126
PU19	0.793465	0.70887	1.41905	1.50227	PU45	0.968927	0.968128	0.931011	1.18893
PU20	0.848956	0.39654	2.17574	1.28037	PU46	0.953068	0.416114	2.13487	1.12331
PU21	0.829557	0.294387	2.245	1.54003	PU47	1.25872	0.367228	1.66162	1.04297
PU22	0.893291	1.4754	0.975428	1.10272	PU48	1.05827	0.580433	1.41844	1.25575
PU23	0.944684	1.18116	0.9048	0.959541	PU49	1.12706	0.491447	1.56849	1.08738
PU24	0.964004	0.752682	0.947179	1.01858	PU50	0.862109	0.676965	1.50688	1.12012
PU25	1.26872	0.616404	1.04764	1.0614	PU51	0.866859	0.360474	2.09139	1.00302
PU26	1.10563	1.16791	0.844629	1.10671	PU52	0.904528	0.427983	1.90448	0.950857
PU27	0.771978	0.685171	1.18634	1.20868	PU53	1.13466	0.905077	0.984927	1.06388

V. SPEARMAN RANK COMPARISON OF DEA MODELS

After examining efficiency results of HEIs regarding to different DEA optimisation procedures, this section is tailored to deal with comparison of aforementioned models relying largely upon Spearman rank correlation. Even though HEIs may get different efficiency scores for diverse models, Spearman rank correlation checks whether this divergence influences the rankings of HEIs concerning their efficiency performances. For this particular analysis, Spearman rank correlation values are calculated to expose the impact of following scenarios:

i) Introducing new input and/or input variables,

ii) Measuring the efficiencies by the means of non-parametric production or cost frontier,

iii) Choosing the optimisation method for technology that might be CRS or VRS.

Table-6.7 shows the rank correlations that were driven from CRS whereas Table-6.8 is the indication of rank correlations between the models assumed VRS frontier. The last table – which is Table-6.9- demonstrates the rank correlations between CRS and VRS cost frontier models. Besides, input-oriented efficiency rankings are employed to illustrate those relationships.

Table-6.7: Spearman Rank Correlation for CRS Models

	M1	M2	M3	M4	M5	M6
M1	1					
M2	0.960115	1				
M3	0.871233	0.911632	1			
M4	0.824439	0.817994	0.947712	1		
M5	0.973117	0.955667	0.869829	0.803156	1	
M6	0.862338	0.856157	0.938065	0.904141	0.892113	1

The initial statement coming out of Table-6.7 is that rankings of HEIs in different input and output sets are by and large same. That is to say, although overall efficiency scores for HEIs are slightly differing from each other in six models, higher correlation values signify that the rankings of HEIs are not altering notably. Therefore, it is arguably obvious that efficiency scores attained by CRS-DEA models have substantial insights both for researchers and decision-makers. The least correlation coefficient is between Model 4 and Model 5 but even that one's value corresponds to 0.8 that denotes strong correlation between these two models. Furthermore, the simplest model (Model 1) in terms of input/output mixture has the lowest correlation with the full model (Model 4), thus one can argue that adding new variables into the model has mattered to certain universities.

Table-6.8: Spearman Rank Correlation for VRS Models

	M1VRS	M2VRS	M3VRS	M4VRS	M5VRS	M6VRS
M1VRS	1					
M2VRS	0.896564	1				
M3VRS	0.869533	0.955112	1			
M4VRS	0.850428	0.880198	0.90661	1		
M5VRS	0.964431	0.911273	0.871489	0.853839	1	
M6VRS	0.941888	0.905349	0.903175	0.902046	0.96187	1

Like in Table-6.7, rank correlation coefficients among the models that employed VRS frontier are considerably close to each other in Table-6.8. It clearly figures out that as the models get nearer to the full model (Model 4), spearman rank correlation attains higher values. Whilst the coefficient is 0.85 between Model 4 and Model 1, it becomes 0.90 when the relationship between Model 4 and Model 3 is concerned. In addition to that, high correlation among the results derived from cost and production frontiers encourages policy-implication aspect of this research to emerge confidently.

Table-6.9: Spearman Rank Correlation for CRS and VRS Cost Models

	M5	M6	M5VRS	M6VRS
M5	1			
M6	0.892113	1		
M5VRS	0.925779	0.930118	1	
M6VRS	0.875851	0.961316	0.96187	1

Even though previous tables (Table-6.7 and Table-6.8) have put forward that efficiency results have robust properties, conducting comparison between CRS and VRS models would be much more appropriate to conclude the discussions on the robustness of those results belonging to the different models. To check this, cost efficiency rankings for different technology frontier are singled out to perform the test. As expectedly, rank correlations between CRS and VRS cost efficiency models have got markedly larger values ranging from 0.87 to 0.96. Accordingly, efficiency scores yielded from diverse output/input sets as well as preferred technology frontiers have significantly robust insights both for the following researches and policies.

VI. DETERMINANTS OF INEFFICIENCY

In addition to the estimation of efficiencies, recent literature in efficiency analysis persuades researchers to take step forward and accordingly interrogate potential factors influencing efficiency performances of decision-making units (DMUs). This statement is not different for efficiency analysis of higher education sector through which certain university-based features are put under spotlight. For this chapter, so as to illuminate the causes of inefficiencies among public HEIs in Turkey, a set of environmental variables indicated above will be employed via building upon previous studies.

As the efficiencies of HEIs driven from DEA procedure take values between 0 and 1, classical regression analysis would not be appropriate to be conducted. Thus, Tobit regression will be opted for examining determinants of inefficiency by treating data as i) pooled and ii) panel. Besides, since Tobit regression is designed to censor values lower than 0, inefficiency scores (1- efficiency scores) of HEIs will be taken as the dependent variable in lieu of efficiency scores. Therefore, the variable with (+) sign will indicate a negative relationship with efficiency and vice versa.

The next step is deciding which inefficiency values will be preferred as dependent variable. Previous part on the rank correlation of HEIs was stating that efficiency scores do resemble each other due to the fact that the lowest correlation coefficient among different models was 0.82.Hence, choosing any of the inefficiency scores will not be suffered from 'selection bias' in a dramatic way. And eventually, for this research, inefficiency scores yielded from Model 1 and Model 1VRS are selected as the main components of this Tobit regression analysis. The dependant variable in Model A is the inefficiency scores coming from Model 1VRS, whilst Model B takes the values from Model 1. Model C prefers the values from Model 1, when the most insignificant variable is dropped from the regression model. Table-6.10 reports the results for pooled data:

Table-6.10: Tobit Regression Results for Pool Data

Variables	Model A	Model B	Model C
AGE	-.39940D-04	-0.00041009	
	(-0.0015011)	(0.00154432)	
SIZE	-.17144D-05	-.149576D-05	-.17245D-05
	(.11908D-05)	(.12252D-05)	(.12171D-05)
LOAD	0.002826	0.003159	0.00320543
	(-0.002132)	(0.00219382)	(0.00218055)
PROF	-0.13865	-0.2731	-0.30751
	(0.39987)	(0.41148656)	(0.37327346)
FTS	0.09785*	0.12641**	0.1261902**
	(0.05941)	(0.0611377)	(0.06113406)
FORGN	2.00763	2.80765	2.743357
	(1.80883)	(1.86065793)	(1.83340526)
MED	0.06877*	0.0730076*	0.073668*
	(0.03811)	(0.03921196)	(0.03919456)
CON	0.49354***	0.52245***	0.51885***
	(0.07239)	(0.07449951)	(0.07229048)
SIGMA (u)	0.02279	0.02243458	0.02243621
	(0.0097603)	(0.00997657)	(0.0099773)
LOG-L	11.88612	7.8755	7.855646

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

2. Asymptotic standard errors in parentheses.

Table-6.10 reveals that the influence of AGE, SIZE and LOAD of the HEIs on their efficiency performance is ambiguous which is not in the interior of expectations. That is to say, although these factors would be the major components of production and/or cost function of HEIs, their correlations with inefficiency values are statistically vague. Furthermore, percentage of full-time academic staff among whole faculty (FTS) seems to be the leading variable concerning its correlation with inefficiency. The coefficient of FTS implies that as the share of full-time staff increases, inefficiency increases as well, or alternatively efficiency decreases. Another implication coming out from this table is that having medical school (MED) reduces efficiency by almost 0.07 which may encourage researchers to investigate efficiencies of medical schools as a separate research question. Lastly, the percentage of professors (PROF) and foreign students (FORGN) do not have any link with inefficiency scores of HEIs according to the aforementioned regression results.

And Table-6.11 demonstrates the regression results for panel data with random effects treatment:

Table-6.11: Tobit Regression Results for Panel Data			
Variables	Model A	Model B	Model C
AGE	-.39930D-04 (-0.00181718)	-0.00030839 (-0.00177478)	
SIZE	-.16144D-05 (.16329D-05)	-.169582D-05 (.17329D-05)	-.172415D-05 (.16559D-05)
LOAD	0.003026 (-0.00285428)	0.0031588 (-0.00296712)	0.00320723 (-0.00289554)
PROF	-0.13954558 (-0.5214565)	-0.27300681 (-0.52132894)	-0.3076005 (-0.450931990
FTS	0.09774264* (-0.05559317)	0.12638375** (-0.05765066)	0.12618928** (-0.05743758)
FORGN	2.00752574 (-2.40340857)	2.80685771) (-2.61961309)	2.7433569 (-2.49164345)
MED	0.06771132 (-0.04789048)	0.07392279) (-0.05037202)	0.07367102 (-0.0483697)
CON	0.49330*** (-0.06620654)	0.52244*** (-0.06441148)	0.51884*** (-0.06442898)
SIGMA (u)	0.02179933 (-0.02372067)	0.02243458 (-0.02398005)	0.02243621 (-0.02326832)
LOG-L	14.76703	7.875583	10.83485

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

2. Asymptotic standard errors in parentheses.

The Tobit regression results obtained from panel data analysis have not had any apparent impact on the coefficients of variables, excluding dummy variable for medical school (MED). MED became insignificant due to a slight increase in its standard deviation for the all three models. Besides, share of full-time academic staff (FTS) still preserves its significance on efficiency performance of HEIs for the panel data analysis. The rest of the variables including AGE, SIZE, LOAD, PROF, and FORGN are not counted as noteworthy factors pertaining to the results indicated in Table-6.11 that was the case for pooled data analysis.

VII. LIMITATIONS and CONCLUDING REMARKS

Although estimated efficiencies as well as the determinants of inefficiencies among public HEIs in Turkey have considerable implication both for researchers in this particular area and decision-makers in the higher education sector, they might be suffering from certain methodological, structural or computational shortcomings. In this section, those possible limitations will be illuminated and discussed. Besides, a number of insights and suggestions will be put forward for forthcoming academic and policy-based inquiries.

The first weakness is stemming from DEA's well-known methodological problem. As linear programming assumes deterministic frontier, statistical noises would be treated as inefficiencies. Therefore, HEIs might be assigned with lower efficiency values than they were previously done within stochastic frontier framework. So as to overcome this particular obstacle, number of bootstrapping procedures could be increased and confidence intervals for efficiency scores in DEA model can be compared and contrasted with the scores attained by stochastic frontier analysis (SFA).

Secondly, like any other efficiency and/or productivity measurement techniques, the linear programming suffers from a structural problem that is lack of appropriate quality assessment variable for output sets. For instance, a specific HEI may have lower numbers of teaching and research output than the others with almost same input prices and accordingly end up with higher inefficiency scores. However, its impact both on academia and society would be considerably greater owing to the quality of the production that motivates its efficiency performance to rise. Thus, incorporation of post-university status of students such as employability and annual earnings would alleviate the adverse effects of this problem for teaching side, whereas adding number of citations to the estimation process would be appropriate to achieve this for research side.

Thirdly, performing two-stage DEA method to estimate the determinants of inefficiency among HEIs in Turkey may comprise a computational problem. If the regression results indicate a correlation between certain environmental factors and inefficiency scores of HEIs, then the efficiency scores estimated at the first stage could have biased values. Hence, conducting one-stage DEA would have meaningful insights if their results are compared with the ones in two-stage DEA.

Last but not least, for the Tobit regression analysis to examine the dynamics behind inefficiency, variable set might not be sufficient to capture the influence of all factors on efficiency performance of HEIs like managerial skills due to lack of comprehensive dataset. For that reason, an extended dataset for public HEIs in Turkey would render opportunities to the potential researchers to map out the determinants of efficiencies for this particular sector.

Public HEIs that are directly financed by governmental bodies, account for the significant element of whole education expenditures in Turkey. On a year-to-year basis, Ministry of Education presents the expenditures of HEIs to the Turkish National Assembly and looks for sufficient amount of appropriations to them for pursuing their academic and social goals. This funding exercise that corresponds to almost 60% of HEIs' own budget (Erkoc, 2011), recently sparked an interest among academics and policy-makers to scrutinise the usage of resources allocated to the higher education sector. Accordingly, efficiency measurements particularly for HEIs have gained great importance to illuminate the efficiency performances of them.

The research carried out in this chapter is tailored to estimate technical and cost efficiencies of public HEIs in Turkey by the means of non-parametric technique called DEA. By doing so, overall efficiencies of HEIs as well as their individual scores are demonstrated on the basis of certain production and cost models motivated by different sets of input/output as well as the frontier technology (CRS and VRS).

The results of those models, firstly, have shown that public HEIs in Turkey are performing in unsatisfactory levels although some of them are doing fairly well. Besides, as the model closes to the full input/output set, both individual and overall efficiency scores are getting relatively higher values. Secondly, even though there is not any systemic increase during this five-year time span, efficiencies of public HEIs in Turkey have increased at the course of last two years. Thirdly, 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.

Consequently, even though those findings might be suffering from couple of methodological problems as indicated in Section VIII, they would be used as the departure points both for academic and policy-making interests.

CHAPTER VII: Critical Evaluation of Efficiency Results and Their Policy Implications

I. INTRODUCTION

Average efficiency scores for HEIs alongside with their individual scores have policy-making implications for higher education sector in Turkey particularly as the apportioned amount of public funding to them becomes a central topic in the finance of higher education decision-making (YÖK Report, 2007). Joint impact of increasing demand for university education as well as limited government funding allocated for HEIs are put forward as the main driving forces behind the recent growing curiosity on the allocation of resources in the Turkish higher education (Önder and Önder, 2010). Therefore, the estimation results obtained in the Chapter V and VI would offer noteworthy insights for further policy-making decisions conducted by both administrative bodies of HEIs and the Council of Higher Education of Turkey.

As already indicated in the previous chapters, although the number of researches on the economic efficiencies of HEIs has generated a remarkable volume of literature, studies investigating the efficiency aspect of Turkish universities are extremely scant. Accordingly, policy implications of the efficiency estimates for higher education in Turkey are mainly inspired from the earlier conclusions put forward by various researchers on different cases including United States, Sweden and England and so forth. However, Dundar and Lewis's (1999) as well as Önder and Önder's (2010) papers on the Turkish universities are visited to release consistent statements even though the findings of former piece are comparatively out-dated.

The estimation of economic efficiencies for Turkish public HEIs is performed by two different methodologies named as Stochastic Frontier Analysis (SFA) and Data Envelopment Analysis (DEA). Moreover, determinants of inefficiencies are estimated with these techniques by the econometric procedures introduced by them. Since these two methods might present differing results, policy recommendations for the given HEIs should be proposed and strongly supported if there is an agreement between them. However, in this particular research, parametric model is given slightly higher importance in policy conclusions, as its suggestions are closer to the previous empirical literature and theoretical considerations. Otherwise, suggested statements would cause conflicting policy conclusions and consequently this research will be deviated from its initial motivation.

The policy implications of the findings driven from SFA and DEA are indicated in the following order throughout this chapter: Section II reviews the mean cost efficiencies of HEIs concerning the location, age and size of HEIs in a time profile, Section III summarises both technical and cost efficiencies of HEIs as well as perform categorical analysis done in the previous section, Section IV deals with the scale economies and its relationship with the output choices of HEIs in the given five-year time span, Section V is devised to examine the impact of environmental factors on the efficiency performances of HEIs, Section VI presents the Spearman rank correlations for SFA and DEA models, and eventually Section VII concludes.

II. COST EFFICIENCIES BASED ON SFA

Preceding discussions (Robst, 2001; Dagbashyan, 2011) claiming the likely influence of university-based characteristics on individual efficiency scores of universities lead researchers to put more emphasis on those factors. Therefore, cost efficiency values of SFA yielded from Model B2 -which is shown to be the best-fitted model among others by the means of hypothesis testing- are segregated as regards to the location, size group and age of the HEI so as to infer introductory insights for the probable impact of the aforementioned factors over to the efficiency performances of HEIs. Over the course of the following sections, after revealing the mean efficiency scores of HEIs in a yearly basis, policy reflection of the segregated results will be indicated. Lastly, it should be noted here that the exact impact of university-based characteristics (if there is/are any) on efficiencies forms the governing idea of section VI of this chapter.

Average Cost Efficiency Scores for public HEIs in Turkey

Public HEIs in Turkey seem to be operating fairly efficient in overall, even though there are HEIs apparently underperforming whose efficiency scores are corresponding to the values less than 50% as indicated in the Table-7.1. Departing from the normality assumption, one can argue that economic efficiency scores of 95% of public HEIs in Turkey are nearly within the range of 66% to 93%. Accordingly, the number of public HEIs performing less efficient than 70% and more efficient than 95% is rather scarce. In addition to the previous statements, the most significant conclusion coming out of Table-7.1 is that mean efficiencies of the given HEIs have not changed throughout five-year time span, albeit individual scores are varying from one to another. Whereas, the worst performing HEI has the value of 0.45 in 2006, in 2010 the minimum efficiency score is equal to 0.47. Moreover, the performance of best-practising HEI has not shown any significant improvement during 5 years.

Table-7.1: Average Cost Efficiency Scores for Public HEIs in Turkey (Yearly Basis)

Year	Mean	St Dev.	Min	Max
2006	0.853320	0.098284	0.450127	0.98499
2007	0.854779	0.097306	0.455598	0.98514
2008	0.856224	0.096338	0.461015	0.98528
2009	0.857655	0.095380	0.466378	0.98543
2010	0.859071	0.094431	0.471688	0.98558
Overall	0.856211	0.09564	0.450127	0.98558

Average Cost Efficiency Scores by Location

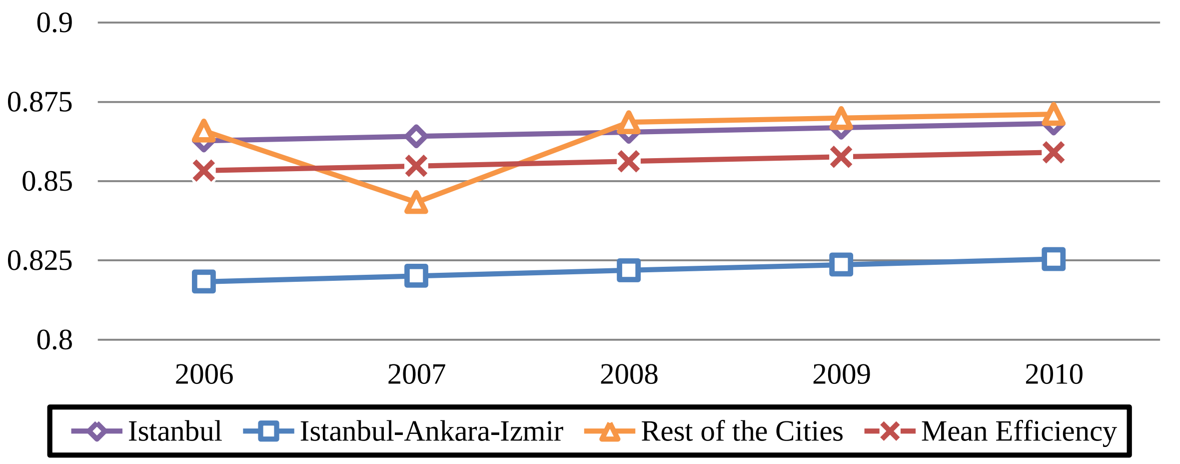
The first data segregation is performed considering the location of HEI to point out whether efficiency performances of universities in larger cities are differing noticeably from the ones located in relatively smaller cities. So as to illuminate this, three categories are developed: i) HEIs located in Istanbul ii) HEIs located in Istanbul, Ankara and Izmir iii) HEIs located in the rest of the cities. Istanbul is chosen as a separate category owing to the fact that one-sixth of the whole Turkish population lives in Istanbul as well as one-fifth of the GDP is generated within the Istanbul region according to the recent statistics (TÜIK: 2012). The second category comprises Ankara and Izmir that are enumerated as the 2nd and 3rd largest cities of Turkey. Lastly, third category is constituted to encompass all other cities dispersed to the different regions of Turkey.

The chief conclusion suggested by Table-7.2 is that HEIs located in Istanbul is performing marginally better than the mean efficiency revealing the fact that higher life standards and the demographic conditions do not have any evident association with efficiency performances of public HEIs in Turkey. Secondly, the noticeable mean efficiency gap between the first and second categories points that universities placed in Ankara and Izmir are conspicuously underperforming than their counterparts in Istanbul. Thirdly, universities opened up in the rest of the cities are operating slightly more efficient than overall efficiency level as well as equally efficient with the universities in Istanbul except the year 2007. Last but not least, average cost efficiencies of HEIs split into three different categories have not indicated any considerable increase in their efficiency performances throughout the given time span. The linear trend depicted in Figure-7.1 is the confirmation of this statement although universities situated in the rest of cities category experienced a sharp decline in 2007 whilst their competitors in Istanbul, Ankara and Izmir performed entirely in the opposite way.

Table-7.2: Average Cost Efficiency Scores for Public HEIs in Turkey (by Location)

Year	Istanbul	Istanbul-Ankara-Izmir	Rest of the Cities	Mean Efficiency
2006	0.862773	0.818283	0.865897	0.853320
2007	0.864138	0.820091	0.843344	0.854779
2008	0.865490	0.821881	0.868553	0.856224
2009	0.866828	0.823653	0.869861	0.857655
2010	0.868153	0.825408	0.871156	0.859071

Figure-7.1: Average Cost Efficiency Scores for Public HEIs in Turkey (by Location)



Average Cost Efficiency Scores by Size Groups

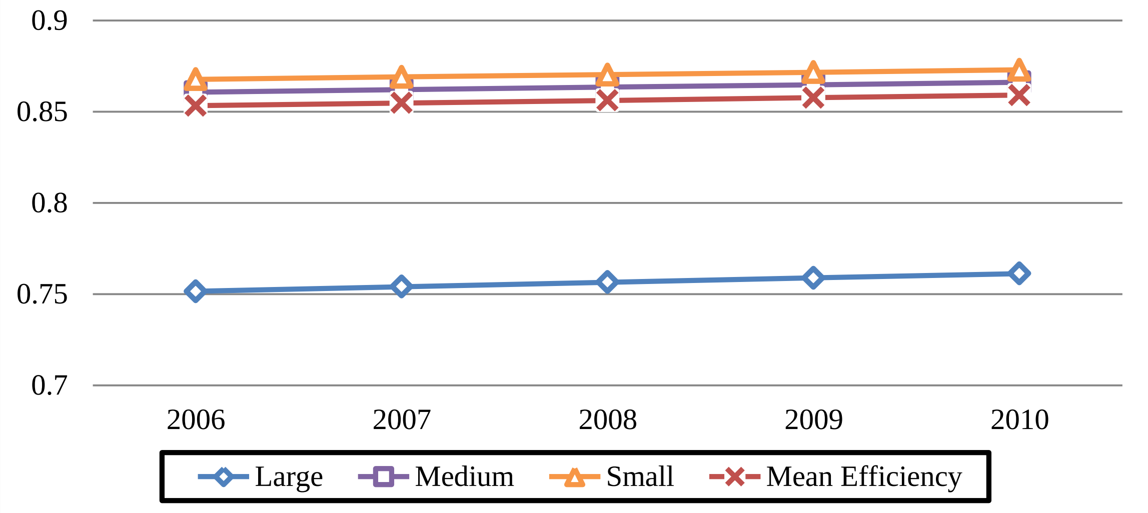
The following comparison is exercised with regards to the size of the universities, which also gives significant insights into the impact of bureaucracy over to the inefficiencies of HEIs. As indicated earlier, the proxy variable for the university size corresponds to the total number of undergraduate and postgraduate students. The observed HEIs for this research are classified in terms of their sizes as follows: i) small size HEIs if their sizes are below 20000, and ii) large size HEIs if the size is above 50000; iii) the rest of them which are located between 20000 and 50000 are labelled as medium size HEIs. Findings of this particular analysis are uncovered in Table-7.3 and shown in time profile in Figure-7.2.

At the very first glance, small size universities can be put forward as the best-practising units in comparison with their medium and large size counterparts. However, the efficiency gap between small and medium size HEIs is not as noteworthy as the gap between small and large size HEIs. Moreover, medium size universities are performing quite well than large size universities in excess of 10% concerning overall efficiency level. Therefore, the size effect on the cost efficiencies of HEIs needs to be scrutinised attentively both in the economies of scale and determinants of inefficiency sections. Lastly, there is not any sign of time effect on the mean efficiency levels of segregated HEIs in terms of their sizes, which was the case for location of HEIs in the prior sub section.

Table-7.3: Average Cost Efficiency Scores for Public HEIs in Turkey (by Size Groups)

Year	Large	Medium	Small	Mean Efficiency
2006	0.751549	0.860684	0.867746	0.853320
2007	0.754021	0.862071	0.869062	0.854779
2008	0.756469	0.863443	0.870365	0.856224
2009	0.758892	0.864802	0.871655	0.857655
2010	0.761291	0.866147	0.872932	0.859071

Figure-7.2: Average Cost Efficiency Scores for Public HEIs in Turkey (by Size Groups)



Average Cost Efficiency Scores by Age of HEIs

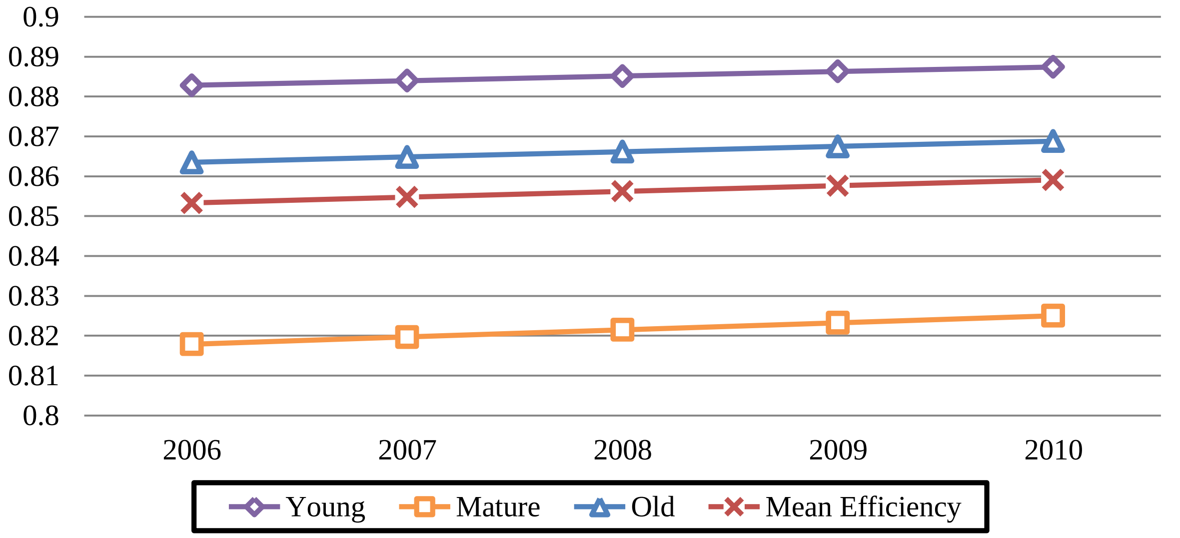
The final comparison is carried out pertaining to age of the universities. Three clusters are formed here consisting of young, mature and old universities. Young universities denote the range of 5-20 years, mature ones are between 20 and 40 and the old ones are above 40 years. To put it bluntly, this classification is selected with a view to reflect three streams of university establishment in the history of Turkish Republic: i) HEIs opened up following the foundation of Turkish Republic and inherited the traditional higher education system of Ottoman Empire ii) HEIs founded at the beginning of 1980s with the establishment of The Council of Higher Education after military coup occurred in 1980 iii) HEIs began their education lives in the midst of 1990s.

As indicated in Table-7.4 and Figure-7.3, young universities outperform that of both mature and old universities over the course of 5 years. This conclusion is tune with the Tullock's (1965) inter-temporal budget analysis in public organizations emphasising the fact that older institutions are expected to face larger inefficiencies than their younger counterparts. However, the difference between young and mature universities is much more remarkable than the difference between young and old universities, which is clearly illustrated in the Figure-3. In relation to the comparison among the mature and old universities, the superiority goes to the old universities. That is to say, throughout the five-year time span old universities surpass the mature ones nearly in excess of 5% of mean efficiency level. Finally, even though young and old universities have not shown any sign of improvement in the given period, mature universities increased their overall efficiency performances by approximately 1%.

Table-7.4: Average Cost Efficiency Scores for Public HEIs in Turkey (by Age)

Year	Young	Mature	Old	Mean Efficiency
2006	0.882836	0.817887	0.863486	0.853320
2007	0.884001	0.819699	0.864844	0.854779
2008	0.885156	0.821493	0.866189	0.856224
2009	0.886298	0.823269	0.867520	0.857655
2010	0.887430	0.825027	0.868838	0.859071

Figure-7.3: Average Cost Efficiency Scores for Public HEIs in Turkey (by Age)



To sum up all the foregoing arguments demonstrated in Table-7.1, 2,3 and 4 as well as Figure-7.1, 2 and 3, following statements could be set forth as:

- There is not any sign of efficiency improvement among public HEIs in Turkey over the course of 5 years
- HEIs located in Istanbul is performing slightly better than average, whereas overall efficiency scores of HEIs in Ankara and Izmir are lower than average
- Large size universities are considerably underperforming if they are compared with their medium and small size universities.
- The efficiency gap between small and medium size HEIs is negligible
- Younger universities are outstripping mature and old universities, whereas their superiority over to the mature universities is fairly excessive *vis a vis* their dominance against old universities.

III. TECHNICAL AND COST EFFICIENCIES BASED ON DEA

Mean cost efficiency scores of public HEIs throughout the given time period alongside with the segregated results in relation to the age, size and location of HEIs are summarised in the previous section through which stochastic frontier framework is carried out. In this section, technical efficiencies of public HEIs in addition to the cost efficiencies are revealed departing from the conclusions yielded by Data Envelopment Analysis.

Technical and cost efficiencies of public HEIs are separated into various categories including age, size and location of the HEI. Besides, Model 4 with Variable Returns to Scale (VRS) is preferred to reflect the technical efficiencies of HEIs, whereas Model 5 with VRS is employed to expose cost efficiencies of HEIs due to the fact that these models are relatively closer to the models developed within stochastic frontier framework.

Average Efficiency Scores for public HEIs in Turkey

Mean efficiency scores computed by the means of non-parametric method are diverging evidently from the values derived from parametric one as clearly indicated in Table-7.5 and Table-7.6. This statement proves the fact that deterministic cost and/or production frontiers are suffering to differentiate the statistical noise and inefficiency term and accordingly assume the calculated distance to the given frontier as inefficient usage of resources.

According to the non-parametric estimation of technical efficiencies of Turkish public HEIs, over the course of the given five years, the overall technical efficiency among them is equal to 56% with its peak at the year of 2007 (63%). Moreover, average technical efficiency scores are experiencing an abrupt decline in 2008 reducing from 63% to 46% corresponding to a nearly 30% decrease. However, mean efficiency performance of HEIs reverts back to its initial position in 2010 where the first and last year's values are equalised at 59%. Eventually, the higher standard deviations are the signs of vastly dispersed HEIs with respect to their efficiency scores.

Table-7.5: Average Technical Efficiency Scores for Public HEIs in Turkey (Yearly Basis)

Year	Mean	St Dev.	Min	Max
2006	0.595539	0.190676	0.25461	1
2007	0.637129	0.213404	0.32328	1
2008	0.460348	0.190701	0.22840	1
2009	0.526149	0.174249	0.25099	1
2010	0.590723	0.234570	0.2408	1
Overall	0.561978	0.209691	0.22840	1

Non-parametric cost efficiency estimation of public HEIs in Turkey on a yearly basis is indicated in Table-7.6. To this table, mean cost efficiency scores of public HEIs is roughly 35% ranging from 25% to 42% throughout the five-year time period. The average cost efficiencies diminish sharply from 2007 to 2008, which apply to the case for technical efficiencies as well. It is appropriate to state that Malmquist index for Period 2 (0.67) - which was already computed in the Chapter VI - referring to the transition from 2007 to 2008 is another indication of this decline. Although this is not supported by the parametric findings put forward in Chapter V, the policy of "conversion of existing faculties belonging to the certain universities into independent public universities" that was put into action by the current government in 2007 would have an impact on this abrupt decline. Therefore, there is a precise need to conduct a rigorous investigation to be able to comprehend this unprecedented reduction among public HEIs in Turkey with the contribution of more comprehensive dataset and possibly a qualitative research, which would in turn give a momentous policy-making manoeuvre to prevent prospective disorders.

Table-7.6: Average Cost Efficiency Scores for Public HEIs in Turkey (Yearly Basis)

Year	Mean	St Dev.	Min	Max
2006	0.419750	0.204956	0.19452	1
2007	0.411580	0.207353	0.16361	1
2008	0.246125	0.148379	0.10103	1
2009	0.301860	0.136732	0.12260	1
2010	0.363154	0.213789	0.14119	1
Overall	0.348494	0.195362	0.10103	1

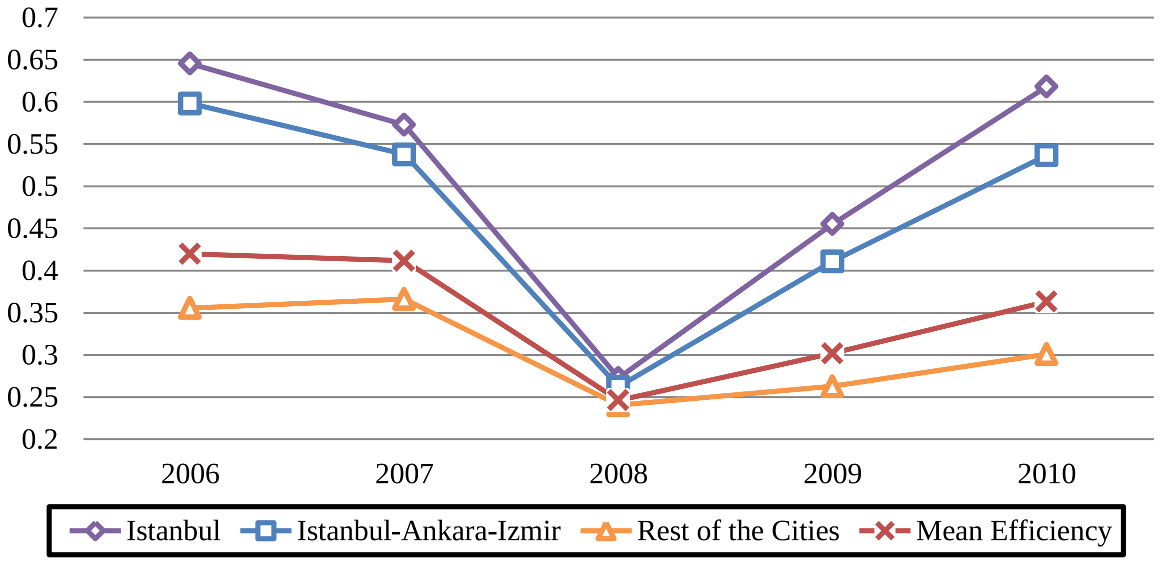
Average Efficiency Scores by Location

Table-7.7 is the summary of the mean cost efficiency results concerning the location of public HEIs in Turkey originated from the non-parametric estimation. The initial indication of this table is that HEIs located in Istanbul is comparatively more efficient than their counterparts sited in the rest of the cities all around the Turkey. Yet, their overall efficiency performance reduced from 64% to 61% throughout the time period specified for this research, which could easily be seen in the Figure-7.4. Secondly, universities in the category of the "rest of the cities" are put forward as the least efficient group, which would be the consequence of larger sample size than the former two categories. Thirdly, universities founded in Ankara and Izmir have relatively poorer efficiency values than the ones in Istanbul as already proposed in the policy-reflection findings of stochastic frontier framework, hence a closer scrutiny on those HEIs would be helpful in terms of efficiency betterment.

Table-7.7: Average Cost Efficiency Scores for Public HEIs in Turkey (by Location)

Year	Istanbul	Istanbul-Ankara-Izmir	Rest of the Cities	Mean Efficiency
2006	0.645518	0.598173	0.355701	0.419750
2007	0.572871	0.537799	0.366270	0.411580
2008	0.272592	0.262450	0.240264	0.246125
2009	0.455129	0.410949	0.262700	0.301860
2010	0.618147	0.536798	0.300821	0.363154

Figure-7.4: Average Cost Efficiency Scores for Public HEIs in Turkey (by Location)

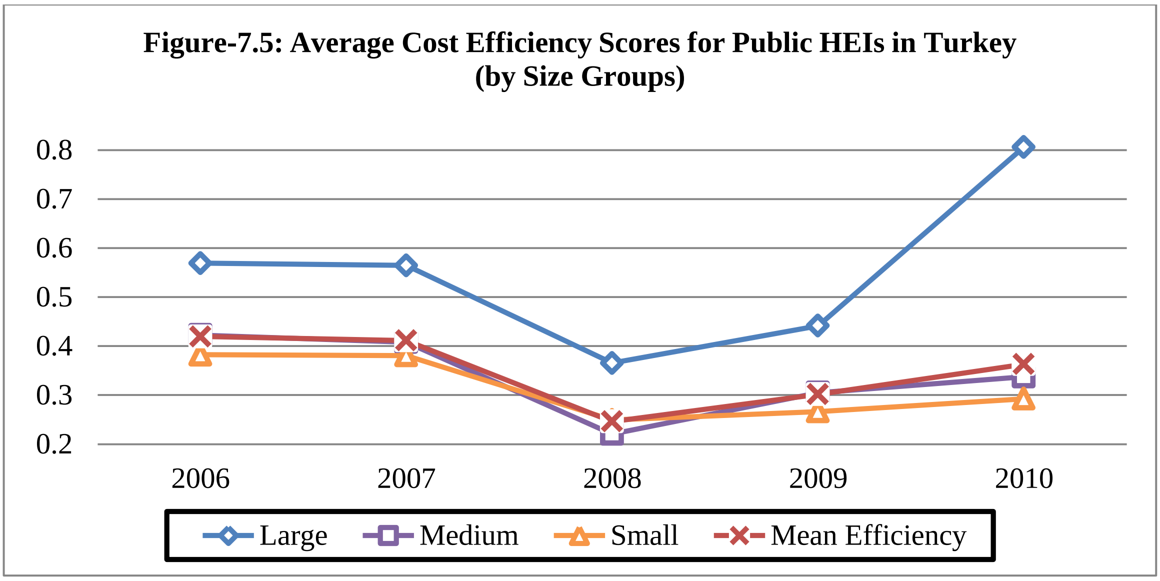


Average Efficiency Scores by Size Groups

Mean cost efficiency scores with regards to the size group of HEIs measured by DEA is a bit at odds with the conclusions stated by the previous SFA estimation. Whereas small size HEIs are doing quite well in the latter, large size universities form the most efficient category in the former. Nonetheless, the difference between small and medium size HEIs is neither systemic nor significant, which is in line with the statements asserted by the parametric estimation. Following the earlier discussions on the impact of time over to the efficiency performances of HEIs, Table-7.8 claims that large size HEIs improved themselves by almost 40% during five years, whilst the efficiencies of medium and small size HEIs deteriorated by approximately 20% and 25% respectively. Figure-7.5 approves this with its illustrative competency and claims that whilst small and medium size universities start the time profile by the line of 0.4, they finally end up with the line of 0.3. On the other hand, large size universities starting point is almost 0.6 and ends with 0.8 corresponding to a 30% increase in overall. However, due to the fact that the sample of large-size universities is narrower than medium and small size universities, this conclusion would not be that much helpful without a full-fledged analysis on the determinants of inefficiencies among the all universities included in the whole sample.

Table-7.8: Average Cost Efficiency Scores for Public HEIs in Turkey (by Size Groups)

Year	Large	Medium	Small	Mean Efficiency
2006	0.569233	0.422496	0.382532	0.419750
2007	0.564668	0.408102	0.380898	0.411580
2008	0.365510	0.220639	0.249111	0.246125
2009	0.441509	0.304916	0.266511	0.301860
2010	0.806079	0.337780	0.292478	0.363154



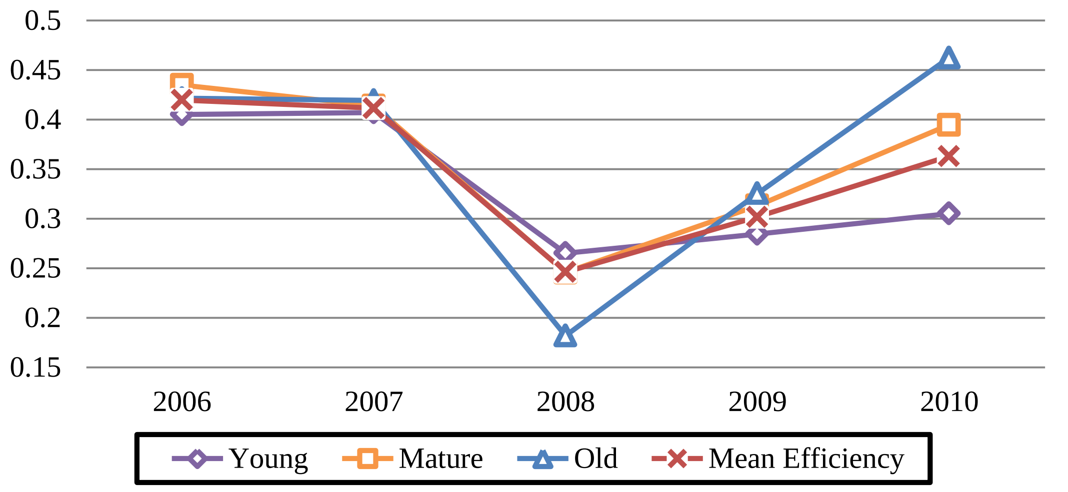
Average Efficiency Scores by Age of HEIs

The last data segregation is performed to point out whether the age of HEIs is influential on the efficiency performances in average. Table-7.9 demonstrates the mean cost efficiencies of public HEIs in Turkey in terms of their age groups including young, mature and old. To keep in mind that these clusters also refer to three streams of university establishment in Turkey since the Turkish Republic was founded. The crucial inference coming out of the table and the Figure-7.6 below is that the efficiency variation among young, mature and old HEIs is blurred; hence any clear-cut conclusion cannot be deduced from these findings. However, young universities are the ones that assign a value lower than mean efficiency four times out of observed five years.

Table-7.9: Average Cost Efficiency Scores for Public HEIs in Turkey (by Age)

Year	Young	Mature	Old	Mean Efficiency
2006	0.405218	0.435015	0.421597	0.419750
2007	0.407148	0.413917	0.419430	0.411580
2008	0.265248	0.245704	0.181879	0.246125
2009	0.284560	0.313221	0.325472	0.301860
2010	0.305191	0.394770	0.462524	0.363154

Figure-7.6: Average Cost Efficiency Scores for Public HEIs in Turkey (by Age)



The summary of the abovementioned findings revealed in the Table-7.5, 6,7,8 and 9 as well as Figure-7.4, 5 and 6 is as follows:

- The average technical and cost efficiencies of public HEIs in Turkey have not shown any sign of betterment throughout the given 5 years
- HEIs located in Istanbul outperform remarkably better than their competitors dispersed to the rest of the cities including Ankara and Izmir
- Small and medium size universities are noticeably operating less efficient then the larger size universities
- The efficiency performances of small and medium size HEIs resemble to each other
- The efficiency gap among young, mature and old universities is blurred; hence any policy-reflection statement cannot be put forward.

IV. ECONOMIES or DISECONOMIES OF SCALE

The economies of scale of multi-product organizations have always been under scrutiny since Kim's paper (1987) in which theory of multi-product firm was developed and empirically tested with the survey of water utilities in US. In relation to the outputs, the firms are expected to develop an optimal behaviour that "chooses the output levels corresponding to the minimum cost of a unit of output, which is closely related to economies of scale" (Dong, 2009). To measure the scale economies of a multi-product firm, following Baumol (1976) and Panzar and Willig (1977)'s methodology, Kim defined the formulation as follows:

$$ES = \frac{1}{{}_i\frac{d\,lnTC}{d\,lnY_i}} \tag{7.1}$$

where TC represents total cost and Y refers to the given output levels for different products. If ES > 1, economies of scale occurs; conversely, if ES < 1 diseconomies of scale is reigning over to the cost function. And eventually, if ES = 1, there is neither economies nor diseconomies of scale.

Although there is a considerable amount of literature on the scale economies of multi-product firms, the number of researches on the HEIs is relatively scarce. The previous literature on the economic efficiency analysis of HEIs has not paid adequate attention to this aspect of the analysis and overlooked it. And accordingly, none of the researches on the Turkish higher education sector has touched upon this topic except Dundar and Lewis (1999). In the related paper, authors argue, "Product specific economies of scale for undergraduate instruction were found for faculties in the social science and engineering subject groups but not in health sciences" (Dundar and Lewis, 1999). Moreover, some of the HEIs were found as exploiting the economies of scale in the postgraduate teaching, nonetheless none of them was stated to face scale economies concerning the level of their research outputs in the cited paper.

In this section, economies of scale assigned to the public HEIs in Turkey is examined concerning the Cobb-Douglas specification due to the following reason: it is highly probable for Translog cost specification to be suffering from multicollinearity as one of the second-order terms (β_{22}) is experiencing a negative value. Although efficiency estimation of the HEIs could be conducted despite of this problem, it would not be appropriate to measure economies of scale with this specification, since the coefficients of first-order terms might have biased values owing to the multicollinearity. For this particular analysis, the economies of scale for public HEIs in Turkey are computed by the formulation below departing from (7.1):

$$ES = \frac{1}{\frac{dlnTC}{dlnUG}+\frac{dlnTC}{dlnPG}+\frac{dlnTC}{dlnRES}} \tag{7.2}$$

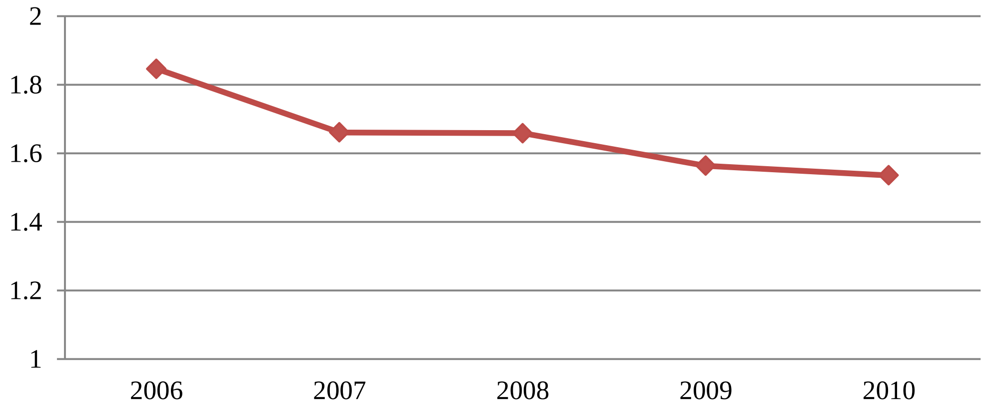
Scale economies of public HEIs in Turkey is measured and summarised in the Table-7.10 as well as put into a time report in Figure-7.7. To these findings, public HEIs are operating in the high levels of economies of scale, which is line with arguments put forward by Dundar and Lewis (1999), although the magnitude of it exhibits a downward trend declining from 1.84 to 1.53 between 2006 and 2010. Since the scale efficient firm produces at a point where there is neither ‘economies of scale’ nor ‘diseconomies of scale’, public HEIs in Turkey are suffering from scale inefficiency in overall over to the course of given five years. So as to overcome this problem, it would be better for public HEIs in Turkey to increase the amount of outputs up to the point where the value of overall economies is equal to 1.

The declining trend in the scale economies might be the sign of this production readjustment; hence a segregated analysis in relation to the type of output would give meaningful insights both to the empirical aspect of this research and the policy-making decision in HEIs alongside the Council of Higher Education. That is to say, the relationship between the scale economies and the types of output including undergraduate and postgraduate teaching as well as the amount of research projects throughout the five-year time span needs to be examined in detail.

Table-7.10: Economies of Scale for Public HEIs in Turkey (Yearly Basis)

Year	Economies of Scale
2006	1.846722
2007	1.661129
2008	1.659200
2009	1.564210
2010	1.536098
2006-2010	1.584283

Figure-7.7 : Economies of Scale for Public HEIs in Turkey (2006-2010)



Overall scale economies results indicated in the Table-7.10 have triggered further inquiry on the yearly change in the level of outputs provided by public HEIs in Turkey. The mean values of outputs on yearly basis are illustrated in Table-7.11. To this table, the number of undergraduate and postgraduate students increased in a remarkable way, even though the number of undergraduate students had experienced ebbs and flows. However, the amount of research projects diminished by almost 10% during five years.

The extent to which these institutions are exploiting economies of scale is profoundly contingent upon the levels of output mentioned above. As indicated earlier, to become a scale efficient firm and sector, HEIs are advised to increase the level of outputs until economies of scale is utilised in a full capacity. So as to achieve this, public HEIs in Turkey have shown an optimistic signal concerning teaching outputs, nevertheless the decline in research output seems to be causing HEIs to experience scale inefficiency. As shown in Figure-7.8, constant increase in the number of undergraduate students throughout five years, had an impact on the magnitude of economies of scale converging to 1.5, and optimistically towards 1 in the couple of years with the accompany of possible increase in the levels of other types of outputs. The minor increase in the amount of research output in 2010 represents the optimistic side of the expectations. Otherwise, the persistent growth in the number of undergraduate students in order to exploit economies of scale fully would have repercussions on the efficiency performances of HEIs, which will be considered in the succeeding section.

Table-7.11: Average Level of Outputs for Public HEIs in Turkey (Yearly Basis)

Year	UG Students	PG Students	Res. Projects (x1000)
2006	38471.1886	2492.56603	2906.1
2007	38745.0754	2419.66037	3480.07
2008	38968.0943	847.264150	2723.7
2009	45190.6415	2351.75471	2523.4
2010	54938.9434	2998.92452	2650.3
2006-2010	43262.78868	2222.03396	2856.7

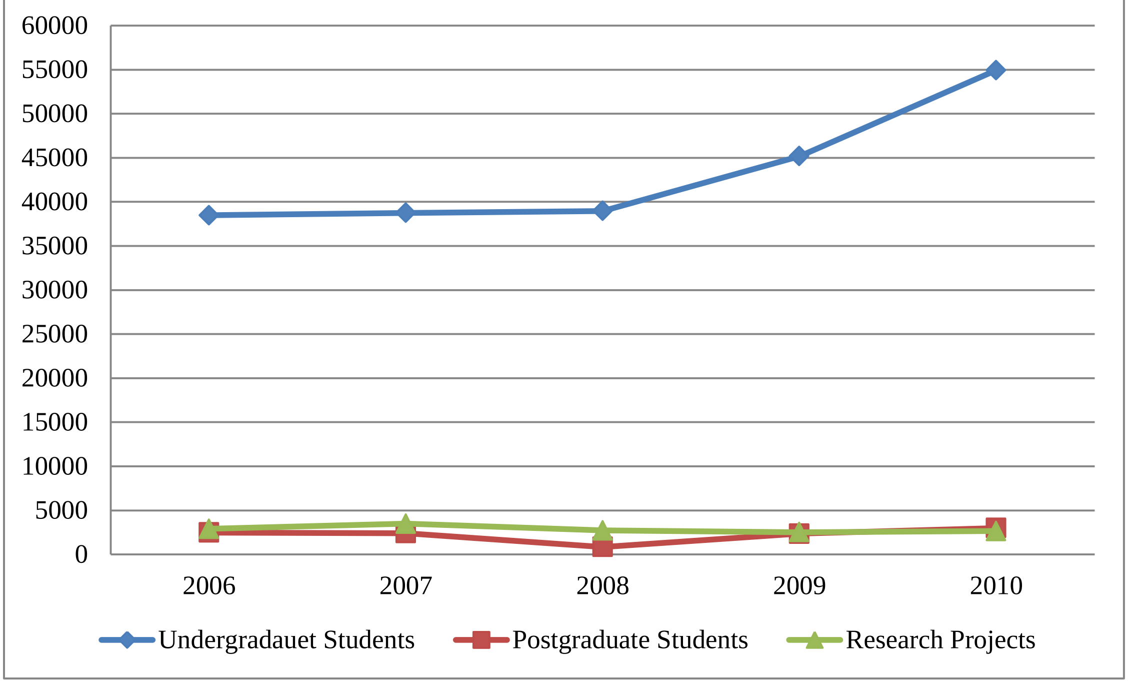


Figure-7.8: Average Levels of Outputs (Yearly Basis)

The findings of the scale economies of public HEIs in Turkey have certain indications for policy recommendation:

- Public HEIs in Turkey are exploiting the economies of scale in greater levels ranging from 1.85 to 1.53 between 2006 and 2010
- There is an obvious decline in the magnitude of economies of scale diminishing from 1.85 in 2006 to 1.53 in 2010
- The respond from HEIs to increase their undergraduate and postgraduate teaching appears to be a wise decision, but is still insufficient to reach the point where economies of scale is entirely cleared
- The reduction in the amount of research output has an adverse effect on this convergence process to end up with constant returns to scale.

V. DETERMINANTS OF INEFFICIENCIES

In the previous sections, policy implications of cost and technical efficiency estimates of public HEIs in Turkey were presented and examined concerning both parametric and non-parametric estimation techniques. Moreover, categorical analysis was performed to see whether efficiency performances vary from one group to another with respect to the location, age and size of HEIs. In this section, so as to comprehend the variation in the efficiency scores of HEIs completely, we will scrutinise the probable factors that might cause this variation. The methodologies to estimate the impact of environmental factors over to the cost efficiencies of public HEIs in Turkey for parametric and non-parametric approaches were illustrated in Chapter V and VI respectively. Whilst the former one uses conditional mean method, the latter employs Tobit regression analysis since the inefficiency terms are ranging from 0 to 1.

The literature on the determinants of cost efficiencies among HEIs is relatively scarce in comparison with the other areas of research in the efficiency analysis. Robst (2001), Stevens (2001) and Daghbashyan (2011) give significant insights on this particular topic focusing on HEIs in South Carolina, England and Wales, and Sweden correspondingly. However, there is not any single research for HEIs in Turkey. Hence, statements put forward by Robst (2001), Stevens (2001) and Daghbashyan (2011) will be tested as long as the dataset for Turkish HEIs allows. To these papers, the share of government revenues, size and load factor of HEIs, student/staff characteristics such as percentage of full-time academic staff, number of professors, number of foreign students have impacts on the efficiencies of HEIs. For Turkish case, age, size and load factor of HEIs; student and staff characteristics alongside the dummy for having medical school form the environmental factors that would have influences on the efficiencies of public HEIs in Turkey either in a positive or negative way are included in the model. Table-7.12 below summarises the statistics for the estimated coefficients of those factors, their individual analyses are performed in the succeeding sub-sections.

Table-7.12: Determinants of Cost Inefficiencies

Variables	DEA 1	DEA 2	SFA 1	SFA 2
AGE	-0.00041009	-0.00030839	0.0054***	0.044586
	(-0.00154432)	(-0.00177478)	(0.0009)	(0.039)
SIZE	-.149576D-05	-.169582D-05	0.00001***	.797D-04*
	(.12252D-05)	(.17329D-05)	(0.0000002)	(.450D-04)
LOAD	0.003159	0.0031588	-.02048***	-0.16852*
	(-0.00219382)	(-0.00296712)	(0.0006)	(0.098684)
PROF	-0.2731	-0.27300681	0.00431235	4.045698
	(-0.41148656)	(-0.52132894)	(0.0617)	(12.60634)
FTS	0.12641**	0.12638375**	0.0519***	0.277591
	(-0.0611377)	(-0.05765066)	(0.0143)	(1.381614)
FORGN	2.80765	2.80685771	3.2903***	55.24667
	(-1.86065793)	(-2.61961309)	(0.8812)	(49.17822)
MED	0.0730076*	0.07392279	0.0527	1.84628*
	(-0.03921196)	(-0.05037202)	(0.1048)	(0.964238)
CON	0.52245***	0.52244864	N/A	1.499941
	(-0.07449951)	(-0.06441148)		(2.63512)
SIGMA (u)	0.02243458***	0.02243458	0.1994***	0.1782***
	(-0.00997657)	(-0.02398005)	(0.002)	(0.0031)
LOG-L	7.8755	7.875583	-2184.374	134.65

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

2. Asymptotic standard errors in parentheses.

Effect of Structure of the Institution on Efficiency

This section deals with possible statistical relationships between the structural properties of HEIs such age, size and load factor of universities as well as having medical school inside the university and the cost inefficiencies of universities. Whereas the age, size and the medical school are expected to have a positive relationship with inefficiencies, the load factor is predicted to lower inefficiencies in HEIs. The rigorous analyses for the each factor are indicated in the next paragraphs.

Effect of Age of the HEI on Efficiency

Although previous researches have not taken the age of the HEI into consideration while accounting for the determinants of inefficiencies, our categorical analysis in section II has paved the way for further investigation on this factor. In the Section II, young universities are found out as the most efficient group of HEIs compared to their old and mature counterparts. Hence, age of the HEI is incorporated both to the conditional mean model of stochastic cost frontier and Tobit regression of two-stage DEA approach. The initial expectation is that if universities get older, their efficiency performances will be diminished; thus expected sign of the coefficient for age of HEI is positive. This expectation is also motivated by Tullock's (1965) inter-temporal budget expectation in bureaucratic institutions particularly in public ones.

To the estimation results yielded from three different models, the age of HEI is founded as significant with its expected sign in only one model. The other two models put forward insignificant coefficients for this factor, and the DEA model stated negative sign that is not expected for the age of HEI. The estimated coefficient of the first model claims that if the age of HEI increases by 1 year, overall inefficiencies rise by 0.5%. Accordingly, elder HEIs are likely to experience higher levels of inefficiencies, which is line with the prior anticipations revealed in the section II. However, this conclusion cannot be directly converted into a policy-recommendation statement since it is not supported with other three models.

Effect of Size of the HEI on Efficiency

The size of HEIs that is proxied by the number of undergraduate and postgraduate students for this research "is expected to increase costs, its effect on economic efficiency is not clear" (Daghbashyan, 2011). Besides, Downs (1965) and Naskanen's (1971) analyses on the bureaucratic size in the public sector organizations are taken into account beforehand. In her paper, Daghbashyan (2011) figured out a negative correlation between the sizes of HEIs and cost efficiencies claiming that "big universities are less efficient" in pooled data analysis, nevertheless in the panel data model, this relationship disappears and therefore the discussion preserves its ambiguity. In the previous sections of this chapter (Section II and III), we presented contradictory conclusions from parametric and non-parametric approaches in relation to the size effect. Whereas former claims that overall efficiencies of small size HEIs are higher than large size HEIs, the latter asserts exactly the opposite.

Estimated parameters for the size effect in Table-7.12 illustrate a positive association between the size of HEI and mean inefficiencies in the last two models even though Tobit regression does not support this. The positive sign for this particular coefficient refers to the fact that if the size of HEI grows, its inefficiency increases and accordingly efficiency performance decreases. However the magnitude of this influence is not as noteworthy as the statistically significant factors. It corresponds to the fact that if the size of HEIs increases by 1000 students, the mean efficiencies of universities diminish by 0.1% and 0.7% according to the third and forth models in sequence. If one considers this conclusion with the estimates of unexploited economies of scale in Turkish public higher education, she can come to the conclusion that public HEIs in Turkey should give more weight to the research output rather than teaching outputs.

Effect of Load of the HEI on Efficiency

Load per lecturer is predicated as an alleviating factor on the cost function of HEIs in all models presented in Chapter V. The resulting question in relation to the load factor is that to what extent it influences cost efficiencies of HEIs. Daghbashyan (2011) argues that high load would decrease the efficiencies of HEIs by “decreasing the quality of teaching”. In her paper, the pooled data analysis fortifies this statement revealing that there is an inverse relationship between the load per lecturer and mean efficiencies of Swedish HEIs albeit panel data models negate it.

For the Turkish case, findings are diverging markedly from the Daghbashyan’s (2011) research and revealing a positive correlation among load per lecturer and cost efficiency estimates of public HEIs in Turkey. The estimated coefficient for the load factor indicates that one point increase in load per lecturer decreases mean inefficiency by nearly 2% which would have a huge impact on the efficiency performances in overall. Yet, as Daghbashyan (2011) argues the constant increase in the load factor would cause inefficiencies at some point through which the decline in the quality of teaching counterweights the gains from cost of labour.

Effect of Having Medical School on Efficiency

None of the previous papers have touched upon the impact of medical schools on the cost structure of HEIs. Hence, incorporating dummy variable for medical school into the cost frontier of public HEIs in Turkey may seem to be a bit odd. However, conventional wisdom among administrative bodies of HEIs as well as the Council of Higher Education emphasises that medical schools and teaching hospitals form the major sources of inefficient usage of resources in the universities. Predicated coefficients of medical school dummy have significant values in the Cobb-Douglas specification (not in the Translog) and claiming that HEIs with medical school are relatively costly than the ones without medical school.

The regression analyses for inefficiency estimates yielded in DEA 1 and SFA 2 support this conventional wisdom. To these models, signs of the estimated coefficients of dummy variable for medical school are positive, which is line with the expectations, nonetheless the value in the SFA 2 –which is 1.8- does not have any realistic insight for policy recommendation due to the fact that inefficiency values are truncated at 1. Eventually, while medical schools would shift the cost function of HEIs to the upward, their impacts on the cost efficiencies are still ambiguous.

Effect of Staff Characteristics of the HEI on Efficiency

The characteristics of academic staff have been included into the efficiency estimation models of HEIs in various specifications such as the proportion of women faculty (Derlacz and Parteka, 2011), share of professors (Stevens, 2001; Daghbashyan, 2011) and the ethnicity of faculty members (Stevens, 2011). The dataset for Turkish public HEIs allows the author of this research to examine the impact of proportion of professors and full-time academic staff as Daghbashyan (2011) put forward that the quality of labour has significant influence over to the cost efficiencies of HEIs.

Effect of Percentage of Professors on Efficiency

In relation to the influence of percentage of professors on the efficiencies of HEIs, both Stevens (2001) and Daghbashyan (2011) claim that it positively affects efficiency performances of HEIs relying upon English and Swedish cases. However, all four models presented in the Table-7.12 are completely giving congruent conclusions concerning the irrelevance of this environmental variable to motivate the cost efficiencies of public HEIs in Turkey. Although share of professors induces higher costs in the universities as suggested by the Cobb-Douglas estimates of cost frontier of public HEIs in Turkey, its impact on cost efficiencies is trivial.

Effect of Percentage of Full-Time Academic Staff on Efficiency

So as to reflect the quality of labour into our analysis, percentage of full-time faculty is amalgamated both into the cost frontier and conditional mean of cost inefficiencies. The effect of share of full-time faculty is found out as the significant component of cost frontier function in almost every model presented in the Chapter V. Therefore, it is reasonable to expect that proportion of full-time academic staff would have an impact on the cost efficiencies of HEIs, since it has an obvious association with the quality of labour and teaching.

The estimated coefficients for share of full-time faculty in SFA 1 and two DEA models figure out a positive correlation between this particular variable and the inefficiency terms. That is to say, if the share of full-time lecturers among the whole faculty increases, the overall efficiency scores of HEIs are expected to move downwards. Therefore, hiring part-time lecturers for certain modules would be constructive in order to alleviate inefficient usage of resources. However, a redundant increase in the number of part-time faculty might deteriorate the student satisfaction concerning lack of fully-fledged teaching provision.

Effect of Student Characteristics of the HEI on Efficiency

The characteristics of students have not attracted the attentions of researchers as much as the staff characteristics have had. Percentage of students with foreign background (Daghbashyan, 2011), the age of the students (Stevens, 2001; Daghbashyan, 2011) and the socio-economic background of the registered students (Stevens, 2001) are the fundamental variables that form the student characteristics in the earlier literature. In this research, dataset gives permission to examine the influence of percentage of foreign students over to the cost efficiencies of public HEIs in Turkey.

Effect of Percentage of Foreign Students on Efficiency

Daghbashyan (2011) revealed an inverse relationship between the share of foreign students and cost efficiencies of Swedish HEIs in the pooled data analysis claiming, "HEI enrolling more foreign students will probably be less efficient ceteris paribus". The estimated coefficient of percentage of foreign students demonstrated in the Table-7.12 is in tune with this statement owing to the fact that it has a positive sign. Yet, both the second model of SFA and the two-stage DEA approach do not endorse this conclusion. Therefore, any policy reflection statement departing from these particular findings would not be appropriate for further decision-making regarding the policy shift in the enrolment of foreign students to the Turkish public HEIs.

VI. SPEARMAN RANK COMPARISON OF EFFICIENCY SCORES IN SFA AND DEA

Estimating economic efficiencies with different methodologies (parametric and non-parametric approaches) provide overwhelming insights so as to comprehend the full picture behind the efficiency performances of organizations either be public or private. In this research, both SFA and DEA are employed to reveal how public HEIs in Turkey utilise their inputs to be able to produce certain set of outputs. As a consequence of these estimations, rankings of the given HEIs are identified as regards to their individual technical and cost efficiency scores. The following question in relation to the efficiency rankings of HEIs is that to what extent they experience similar sequence in different model specifications and estimation method.

Table-7.13 and 7.14 are the illustrations of the Spearman rank correlations of these models developed for SFA and DEA earlier. In the former table, comparison is carried out with stochastic frontier (SF) specifications against the DEA models with constant returns to scale (CRS), the latter prefers to focus on the relationship between same set of parametric models against the DEA with variable returns to scale (VRS) production technology. The first three SF models labelled by A refer to the Cobb-Douglas function, whilst the last three beginning with B correspond to the Translog cost specification.

The correlation between SFA and CRS-DEA models in terms of efficiency rankings of HEIs is almost trivial varying from -11% to 30% as indicated in Table-7.13 fully. The highest correlations exist amongst M6 and A3 as well as M6 and B1. On the other hand, the lowest values are experienced in the row of B2 and B3 implying the fact that efficiency estimates of Translog cost function are utterly diverging from the values obtained through CRS-DEA. Moreover, the correlation scores are getting higher while moving towards right direction revealing that cost specification models of CRS-DEA are behaving relatively closer to the stochastic frontier models.

The efficiency rankings of public HEIs suggested by SFA show slightly better correlations with VRS-DEA in overall. Although the highest correlation score has not changed, the individual scores have improved by smaller amounts. The pairs facing relatively larger values in the Table-7.14 are named as A2-M2VRS and B1-M6VRS. Although rather larger values were experienced while calculating the rank correlations between the models in parametric and non-parametric estimations separately, inter-methodological values are extremely low. Therefore, spearman rank correlations obtained in this section do not provide strong and reliable conclusions for ranking public HEIs in Turkey in the same order and accordingly would cause inconsistent policy reflections.

Table-7.13: Spearman Rank Correlations between SFA and DEA (CRS Models)

SFA/DEA	M1	M2	M3	M4	M5	M6
A1	0.021429	0.065393	0.113137	0.059395	0.093828	0.209057
A2	-0.031838	-0.008397	0.047081	0.012964	0.0197	0.126302
A3	0.164924	0.21829	0.2189	0.156379	0.222275	0.286742
B1	0.07351	0.079148	0.148139	0.122135	0.153768	0.293937
B2	-0.15319	-0.123704	-0.059058	-0.075183	-0.079839	0.025152
B3	-0.111865	-0.052438	-0.004763	-0.026958	-0.048521	0.036357

Table-7.14: Spearman Rank Correlations between SFA and DEA (VRS Models)

SFA/DEA	M1VRS	M2VRS	M3VRS	M4VRS	M5VRS	M6VRS
A1	0.115976	0.195864	0.162811	0.186083	0.191467	0.20891
A2	0.048712	0.095744	0.085643	0.091816	0.090115	0.110613
A3	0.237726	0.307955	0.25147	0.268254	0.29484	0.296588
B1	0.217003	0.240123	0.189069	0.276184	0.282273	0.304895
B2	-0.076367	-0.003579	-0.042323	0.003382	0.002167	0.016603
B3	-0.059088	0.031393	-0.012698	-0.014765	0.000486	0.019704

VII. CONCLUSION

This chapter investigates the policy implications of estimated technical and cost efficiencies of public HEIs in Turkey by the means of parametric and non-parametric techniques. Mean technical and cost efficiencies of 53 public HEIs in Turkey as well as the determinants of inefficiencies were examined and discussed from a policy-reflection perspective. So as to suggest consistent and reliable statements, the estimated results in SFA were checked with the conclusions provided by DEA. The overlapping points of the two methodologies were encouraged and put forward as trustworthy recommendations for decision-makers in the higher education sector either in universities or The Council of Higher Education.

The initial inferences illuminated the average technical and cost efficiencies of HEIs in the five-year time span focusing particularly on the categorical analysis of location, age and size of HEIs on the basis of ex ante considerations. Firstly, there is not any improvement observed in the mean efficiencies of HEIs during the given five years. Secondly, HEIs located in Istanbul is operating fairly more efficient than their counterparts founded in the rest of the cities dispersed all over the Turkey. Thirdly, the efficiency gaps between HEIs in terms of their sizes and ages were calculated differently in SFA and DEA models, hence the discussion was left to the following section examining the impact of environmental factors on the efficiencies of HEIs.

The following section scrutinised scale economies within public higher education in Turkey and cross-examine the output choices of universities in the five-year time profile. HEIs were found to exploit greater levels of economies of scale, although it demonstrated a downward slope from 2006 to 2010. The increase in the number of undergraduate students alongside a rather minor rise in the number of postgraduate students provided optimistic signs so as to use economies of scale fully. However, research output was not in tune with this progress and shrunk in five years.

Economic efficiencies of HEIs were discovered to be varying from one to another; hence the factors behind this variation were illuminated and inspected in a separate section. According to the two SFA and two DEA models, none of the environmental variables was found to be significant in all four models. However, the size of university, load factor, having medical school and the percentage of full-time academic staff were found significant in at least two out of four models with their expected signs. Whereas the variables of university size, having medical school and share of full-time academic staff have inverse relationship with the efficiency performances of HEIs, load factor had an encouraging impact on them.

Last inquiry of this chapter concentrated on the Spearman rank correlations of efficiency rankings of HEIs calculated for the SFA and DEA models. Even though the correlations were relatively higher within SFA and DEA models indicated in Chapter IV and V, inter-methodological rank correlations were found extremely low corresponding to 30% at the highest level.

CHAPTER VIII: Conclusion

Although the number of researches conducting an efficiency analysis on higher education institutions has grown specifically for the last two decades, literature of both parametric and non-parametric research on HEIs in Turkey is relatively negligible in comparison with the countries alike. This PhD research that fills this noticeable gap in the literature scrutinises 53 public universities in Turkey between the full academic year of 2005-2006 and 2009-2010 covering 5-year time span. In this research, albeit the slight changes in the non-parametric estimation, 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 features are included into the model so as to capture potential heterogeneities among the universities.

In this dissertation, to measure the economic efficiencies of public HEIs in Turkey, SFA and DEA techniques are employed departing from the conventional efficiency measurement techniques. The former method that requires parametric steps to estimate efficiencies of HEIs is applied to the Turkish dataset in the Chapter V, whilst the latter one is the main focus of the analysis carried out in Chapter VI with slight data differences. The chief aim to accommodate two different methodologies is that the results yielded from parametric technique can be compared and contrasted with the results coming out of the non-parametric technique. Accordingly, policy recommendations emerging from these two distinct efficiency estimation methodologies would have noteworthy insights for the policy-makers.

This research gives meaningful answers by employing SFA and DEA to the following questions framing the summary of the research inquiry of this dissertation:

1. What are the fundamental components of cost function of HEIs in Turkey regarding to the input prices, output levels and university-based characteristics? Is there any sign of economies or diseconomies of scale?
2. What are the overall technical and cost efficiency levels of public HEIs in Turkey concerning different input/output specifications and production/cost frontier? Is there any improvement in 5-year time span?
3. What are the individual economic efficiencies of public HEIs in Turkey?
4. What are the determinants of inefficiencies among public HEIs? Do environmental factors matter for universities concerning their efficiency performances?
5. Do the findings of parametric and non-parametric methods differ from each other?
6. What are the fundamental policy conclusions of the efficiency results?
7. What is/are the limitation(s) of this particular analysis? Are the results reliable for forthcoming academic and policy-based researches?

Summary of the Findings

The brief answers coming out of both parametric and non-parametric models to the questions above are summed up in the following paragraphs:

The parametric estimation suggests, 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.

The results of the non-parametric estimation claims that, firstly, public HEIs in Turkey are performing in unsatisfactory levels although some of them are doing fairly well. The lower results for the non-parametric estimation then the parametric one –which is totally within the expectations-, are referring to the fact that the former method is not able to differentiate the inefficiency from the statistical noise. However, as the non-parametric model gets closer to the full input/output set, both individual and overall efficiency scores are getting relatively higher values. Secondly, even though there is not any systemic increase during this five-year time span, efficiencies of public HEIs in Turkey have increased at the course of last two years. Thirdly, 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.

In addition to that, the determinants of inefficiencies in Turkish HEIs are found to be dependent upon certain variables. According to the two SFA and two DEA models, none of the environmental variables was found to be significant in all four models. However, the size of university, load factor, having medical school and the percentage of full-time academic staff were found significant in at least two out of four models with their expected signs. Whereas the sizes of university, having medical school and share of full-time academic staff have inverse relationship with the efficiency performances of HEIs, load factor has an encouraging impact on them.

Additionally, scale economies within public higher education in Turkey is scrutinised and the output choices of universities in the five-year time profile are cross-examined. HEIs are found to exploit greater levels of economies of scale, although it demonstrated a downward slope from 2006 to 2010. The increase in the number of undergraduate students alongside a rather minor rise in the number of postgraduate students provided optimistic signs so as to use economies of scale fully. However, research output was not in tune with this progress and shrunk in five years.

Last inquiry of the thesis is concentrated on the Spearman rank correlations of efficiency rankings of HEIs calculated for the SFA and DEA models. Even though the correlations were relatively higher within SFA and DEA models indicated in Chapter V and VI, inter-methodological rank correlations were found relatively low corresponding to 30% at the highest level.

Summary of the Policy Conclusions

The initial inferences illuminated the average technical and cost efficiencies of HEIs in the five-year time span have certain policy implications that are summed as follows:

- There is not any sign of efficiency improvement among public HEIs in Turkey over the course of 5 years. Therefore, further budget projections should be allocated while taking this finding into consideration.
- HEIs located in Istanbul is performing slightly better than average, whereas overall efficiency scores of HEIs in Ankara and Izmir are lower than average.
- Large size universities are considerably underperforming if they are compared with their medium and small size universities.
- The efficiency gap between small and medium size HEIs is negligible.
- Younger universities are outstripping mature and old universities, whereas their superiority over to the mature universities is fairly excessive *vis a vis* their dominance against old universities.
- Due to the fact that 'economies of scale' is observed among the observed universities, there is a precise need to increase the level of output to exploit it. However, the size effect motivated mostly by teaching output would have an

adverse impact on the efficiency performances. Therefore, appropriate policy formulations are needed to increase the research output to diminish the magnitude of scale inefficiency.

All in all, this PhD thesis has significant contributions (as well as gains its originality) that can be summed up under three major pillars:

- Efficiency Analysis Framework: To the best of the author's knowledge, this dissertation belongs to the pioneering stream of researches conducting a comprehensive efficiency analysis on the public sector organizations employing both parametric and non-parametric estimation techniques. It applies SFA and DEA simultaneously on the same case and concludes that efficiency estimation conducted by parametric and non-parametric approaches does matter concerning not only mean efficiency values but also efficiency rankings of DMUs. Hence, policy recommendations coming out of one particular estimation method needs to be compared with the other to reach more robust conclusions.
- Efficiency Analysis of Turkish Higher Education: This thesis is the first research that applies simultaneously parametric and non-parametric efficiency estimation approaches to the public sector organizations particularly to the HEIs in Turkey. Besides, it works on a comprehensive and original higher education dataset that includes input prices, output levels and certain university-based characteristics. Accordingly, its results would have remarkable policy conclusions to the administrative bodies as the recent developments in the Turkish higher education makes them highly central for the further policy-devising with regards to the public funding of the universities.

- Efficiency Literature on Higher Education & Public Sector: The parametric and non-parametric efficiency results of Turkish public higher education would offer significant insights for the researchers who are working specifically on the efficiency analysis in higher education. Moreover, as clarified in the second chapter, the theoretical motivation of this dissertation is formed by the literature on efficiency debate in the public sector organizations. The theoretical arguments of the earlier researchers on this area including Niskanen, Tullock, Williamson, and Dunleavy are reconciled and even challenged at some points by the empirical findings of this particular research.

Last but not least, further researches that can be departed from this thesis would tend to focus on certain areas indicated below:

- Developing this dataset by incorporating new input and output measurements, environmental factors and quality indicators to construct more comprehensive models,
- Employing different cost functions (CES, Leontief, Quadratic) and comparing the results with the ones used here,
- Comparative efficiency analysis between public and non-profit HEIs in Turkey would be a good area of research as a following step,
- Due to the fact that the findings suggest that the level of research output needs to be increased to exploit economies of scale, a separate research inquiry can be developed to figure out the determinants of research performance among the public HEIs in Turkey and provide policy recommendations to them.

BIBLIOGRAPHY

Abbott, M., and Doucouliagos, C. 2003, The efficiency of Australian universities: a data envelopment analysis, Economics of Education Review, 22(1), 89–97.

Adler, S., 1990, Economic calculation in the socialist commonwealth, Ludwig Von Mises Inst.

Afriat S.N. 1972, Efficiency Estimation of Production Functions, International Economic Review, 13(3): 568–598.

Ahn, S.C., Lee, Y.H. and Schmidt, P. 1994, GMM Estimation of a Panel Data Regression Model with Time-Varying Individual Effects. Working Paper, Department of Economics, Michigan State University, East Lansing, MI.

Aigner, D.J. and Chu, S.F. 1968, On Estimating the Industry Production Function. American Economic Review, 58(4): 826–39.

Aigner, D.J., Lovell, C.A.K. and Schmidt, P.J. 1977, Formulation and estimation of stochastic frontier production function models. Journal of Econometrics, 6: 21–37.

Alchian, A.A. and Demsetz, H., 1972. Production, information costs, and economic organization. The American Economic Review, 62(5), pp. 777-795.

Alexander F. King 2006, Concluding Remarks, What's Happening to Public Higher Education, The Johns Hopkins University Press.

Alesina, A. and Tabellini, G., 2007, Bureaucrats or politicians? Part I: a single policy task. The American Economic Review, 97(1), pp. 169-179.

Alesina, A. and Tabellini, G., 2008, Bureaucrats or politicians? Part II: Multiple policy tasks. Journal of Public Economics, 92(3), pp. 426-447.

Ali, A.I. 1994, Computational Aspects of DEA, in Data Envelopment Analysis. Theory, Methodology and Applications, Charnes, A., Cooper, W.W., Lewin, A.Y. and L.M. Seiford (Eds.), Boston: Kluwer Academic Publishers.

Ali, A.I. and Seiford, L.M. 1993, The Mathematical Programming Approach to Efficiency Analysis, in The Measurement of Productive Efficiency: Techniques and Applications,

Aljar Meesters 2010, The Influence of Misspecification in Stochastic Frontier Analysis Models: A simulation approach,

Alva Jorge Klor de 2000, 21st Century Challenges to Higher Education in the Age of Information, EDUCAUSE March/April.

Alvarez, A., C. Arias and W. Greene, 2005, Accounting for Unobservables in Production Models: Management and Inefficiency, Working Paper, Department of Economics, University of Oviedo,Spain.

Anouze, A and Emrouznejad, A. 2006, Efficiency analysis of Islamic banks: A case of Gulf Cooperation Council (GCC), paper presented at the OR48 Annual Conference , 11-13 September, United Kingdom

Athanassopoulos, A. D., & Shale, E. 1997, Assessing the comparative efficiency of higher education institutions in the UK by means of data envelopment analysis. Education Economics, 5(2), 117–134.

Atkinson, S.E. and Cornwell, C. 1994a, Estimation of Output and Input Technical Efficiency Using a Flexible Functional Form and Panel Data. International Economic Review, 35(1): 245–256.

Atkinson, S.E. and Cornwell, C. 1994b, Parametric Estimation of Technical and Allocative Inefficiency with Panel Data. International Economic Review, 35(1): 231–243.

Aucoin, P., 1995, The new public management: Canada in comparative perspective. Cambridge Univ Press.

Avkiran, N. K. 2001, Investigating technical and scale efficiencies of Australian universities through data envelopment analysis. Socio-Economic Planning Sciences, 35(1), 57–80.

Bacchiega, A. and Borzaga, C., 2003, The economics of the third sector, The Study of the Nonprofit Enterprise. Springer, pp. 27-48.

Badunenko, M. Fritsch, A. Stephan. 2008, What drives the productive efficiency of a firm? The importance of industry, location, RD and size. CESIS WP 126

Banker, R.D., R.F. Charnes, & W.W. Cooper 1984, Some Models for Estimating Technical and Scale Inefficiencies in Data Envelopment Analysis, Management Science vol. 30, pp. 1078–1092

Banker, R.D., Charnes, A., Cooper, W.W. and Maindiratta, A. 1988, A Comparison of DEA and Translog Estimates of Production Frontiers Using Simulated Observations from a Know Technology. In Applications of modern production theory: Efficiency and Productivity, A. Dogramaci and R. Fare (eds.) Boston: Kluwer Academic Publishers.

Banker, R.D. & Morey, R.C. 1986, Efficiency Analysis for Exogenously Fixed Inputs and Outputs, Operations Research, vol. 34, no. 4, pp. 513-521.

Battese, G.E. and Coelli, T.J. 1988, Prediction of Firm-Level Technical Efficiencies with a Generalized Frontier Production Function and Panel Data. Journal of Econometrics, 38: 387–399.

Battese G. & Coelli T. 1995, A model for technical inefficiency effects in a stochastic frontier production function for panel data. Empirical Economics 20: 325-332

Battese G. 1997, A note on the estimation of Cobb-Douglas production functions when some explanatory variables have zero values, Journal of Agriculture Economics. 48 (2) 250-252

Battese, G.E. and Coelli, T.J. 1992, Frontier Production Functions, Technical Efficiency and Panel Data: With Application to Paddy Farmers in India, Journal of Productivity Analysis, 3(1–2): 153–169.

Bauer, Paul W., Allen N. Berger, Gary D. Ferrier, and David B. Humphrey, 1998, Consistency Conditions for Regulatory Analysis of Financial Institutions: A Comparison of Frontier Efficiency Techniques, Journal of Economics and Business 50, 85-114.

Baumol, W.J. 1976, Scale Economies, Average Cost, and the Profitability of Marginal Cost Pricing, In Public and Urban Economics, ed. R.E. Grieson. Lexington, Mass.: D.C. Heath/Lexington Books.

Beckers, D. and C. Hammond 1987, A Tractable Likelihood Function for the Normal-Gamma Stochastic Frontier Model, Economics Letters, 24, pp. 33-38.

Ben-Ner, A., 2002, The Shifting Boundaries of the Mixed Economy and the Future of the Non-profit Sector, Annals of Public and Cooperative Economics, Vol. 73, No. 1, pp. 5-40, March 2002. Available at SSRN: http://ssrn.com/abstract=313236

Ben-Ner, A., 2006, For-profit, state, and non-profit: how to cut the pie among the three sectors. Jean-Ph.Touffut, Cheltenham, pp. 40-67.

Bera, A.K. and Sharma, S.C. 1996, Estimating Production Uncertainty in Stochastic Frontier Production Frontier Models. Working Paper, Department of Economics, University of Illinois, Champaign, IL.

Besley, T., 2011, Principled agents?: The political economy of good government. OUP Catalogue.

Besley, T. and Ghatak, M., 2005, Incentives, risk and accountability in organizations, Cambridge University Press.

Bettinger Eric P. and Long Bridget Terry 2006, The Increasing Use of Adjunct Instructors at Public Institutions: Are We Hurting Students, What's Happening to Public Higher Education, The Johns Hopkins University Press.

Bhattacharyya, A., Lovell, C.A.K. & Sahay, P. 1997, The Impact of Liberalisation on the Productive Efficiency of Indian Commercial Banks, European Journal of Operational Research, vol. 98, no. 2, pp. 332-345.

Bloed Ben Jong 2010, Funding Higher Education: A View Across Europe, Modern European Platform Higher Education Modernisation

Blose Gary L., Porter John D., and Kokkelenberg Edward C. 2006, The Effect of Institutional Funding Cuts on Baccalaureate Graduation Rates in Public Higher

Education,What’s Happening to Public Higher Education, The Johns Hopkins University Press, 2006

Bloom, N., and Van Reenen J. 2007, Measuring and Explaining Management Practices across Firms and Countries, Quarterly Journal of Economics 122(4): 1351-1408.

Brennan, G. and Buchanan, J.M., 1980, The power to tax: Analytic foundations of a fiscal constitution, Cambridge University Press.

Browne, J., 2010, Browne Review: Securing a Sustainable Future for Higher Education, Browne report executive summary.

Buchanan, J.M. and Tullock, G., 1965, The calculus of consent: Logical foundations of constitutional democracy, University of Michigan Press.

Burgess, S. and Ratto, M., 2003, The role of incentives in the public sector: issues and evidence, Oxford review of economic policy, 19(2), pp. 285-300.

Byrnes, P., Fare, R. and Grosskopf, S. 1984, Measuring Productive Efficiency: An Application to Illinois Strip Mines, Management Sciences, 30: 671–681.

Casu, B. and Thanassoulis, E 2006, Evaluating cost efficiency in central administrative services in UK universities, Omega the international journal of management science 34 (5)pp 417-426

Caudill SB, Ford JM, Gropper DM 1995, Frontier Estimation and Firm-Specific In-efficiency Measures in the Presence of Heteroscedasticity. Journal of Business & Economic Statistics 13: 105-111

Caves R. & Barton D. 1990, Efficiency in US manufacturing industries, MIT Press.

Chakraborty K., Biswas B., Lewis C. 2001, Measurement of technical efficiency in public education: A stochastic and non-stochastic production function approach, Southern Economic Journal 67(4): 889-905.

Chalos, P. and Cherian, J., 1995, An application of data envelopment analysis to public sector performance measurement and accountability. Journal of Accounting and Public Policy, 14(2), pp. 143-160.

Chang, H., 1998, Determinants of hospital efficiency: The case of central government-owned hospitals in Taiwan. Omega International Journal of Management Science 26 (2), 307–317.

Chattopadhyah S, Ray CS. 1996, Technical, scale, and size efficiency in nursing home care: a non-parametric analysis of Connecticut homes. Health Economics; 5:363–73.

Chilingerian, J., and Sherman, D. H. 1990, Managing physician efficiency and effectiveness in providing hospital services, Health Serv. Manag. Rev. 3(1):3-15.

Chilingerian J. 1995, Evaluating physician efficiency in hospitals: A multivariate analysis of best practices. European Journal of Operational Research, 80:548-74.

Chambers R. 1988, Applied production analysis: A dual approach. Cambridge University Press

Charnes, A., Cooper, W. W., & Rhodes, E. 1981, Evaluating program and managerial efficiency: An application of DEA to program follow-through. Management Science, 27(6), 668–697.

Chong A., La Porta R., Lopez-de-Silanes F. and Shleifer A. 2012, NBER Working Paper No. 18268.

Chote, R., Emmerson, C. and Simpson, H., 2003, Measuring public sector efficiency, 190327429X, 9781903274293, London: Institute for Fiscal Studies.

Clotfelter Charles T., Ehrenberg Ronald G., Getz Malcolm, and Siegfried John J. 1991, Introduction to Economic Challenges in Higher Education, Economic Challenges in Higher Education, University of Chicago Press.

Coase, R.H., 1937, The nature of the firm, Economica, 4 (16), pp. 386-405.

Cubbin, J., and Tzanidakis, G. 1998, Regression versus dataenvelopment analysis for efficiency measurement: Anapplication to the England and Wales regulated waterindustry. Utilities Policy, 7, 75–85.

Charnes, A., Cooper, W.W. & Rhodes, E. 1978, Measuring the Efficiency of Decision Making Units, European Journal of Operational Research, vol. 2, no. 6, pp. 429-444.

Charnes, A., Cooper, W.W., Lewin, A.Y. and Seiford, L.M. 1994, Data Envelopment Analysis: Theory, Methodology and Applications. Boston: Kluwer Academic Publishers.

Cobb, C. and Douglas, P.H. 1928, A Theory of Production, American Economic Review, Supplement 18: 139–165.

Coelli, T. 1995, Estimators and Hypothesis Tests for a Stochastic Frontier Function: A Monte Carlo Analysis. Journal of Productivity Analysis, 6(4): 247–268

Coelli T. (1996). Assessing the performance of Australian universities using data envelopment analysis. Centre for science and productivity analysis. NSW: University of New England.

Coelli, T., Rao, D.S.P. and Battese, G. 2005, An Introduction to Efficiency and Productivy Analysis (2nd Edition). Springer Science Business Media,LLC.

Coelli, T., & Perelman, S. 1999, A comparison of parametric and non-parametric distance functions: With application to European railways. European Journal of Operational Research, 117, 326–339.

Cohn E., Sherrie L., Rhine L., Santos M. 1989, Institutions of higher education as multi-product firms: economies of scale and scope. The Review of Economics and Statistics 71 (284-290)

Cooper, W.W., Seiford, L.M. & Tone, K. (eds) 2007, Data Envelopment Analysis: A Comprehensive Text with Models, Applications, References and DEA-Solver Software, second edition edn, Springer, New York.

Cornes, R. 1992, Duality and Modern Economics. New York: Cambridge University Press.

Cornwell, C. and Schmidt, P. 1996, Production Frontiers and Efficiency Measurement, In The Econometrics of Panel Data: A Handbook of the Theory with Applications, Matyas L. and Sevestre, P., (Eds.), Boston: Kluwer Academic Publishers.

Cornwell, C., Schmidt, P. and Sickles, R.C. 1990, Production Frontiers with Cross-Sectional and Time-Series Variations in Efficiency Levels, Journal of Econometrics, 46(1/2): 185–200.

Cummins, J. David and Hongmin Zi, 1998, Comparison of Frontier Efficiency Methods: An Application to the U.S. Life Insurance Industry, Journal of Productivity Analysis, 10: 131–152.

Daghbashyan Zara 2011, The Economic Efficiency of Swedish Higher Education Institutions, CESIS Electronic Working Paper Series, Paper No. 245

Dantzig, G. B. 1951, Maximization of a linear function of variables subject to linear inequalities, In T. C. Koopmans (Ed.), Activity analysis of production and allocation. New York: Wiley.

Davis, M.L. and Hayes, K., 1993, The demand for good government, The review of economics and statistics, pp. 148-152.

De Alessi, L., 1969, Implications of property rights for government investment choices. The American Economic Review, 59(1), pp. 13-24.

De Alva, J.K., 2000, Remaking the Academy: 21st-Century Challenges to Higher Education in the Age of Information, Educause (March/April 2000), 40.

Debreu, G. 1951, The Coefficient of Resource Utilization, Econometrica, 19(3): 273–292.

Declaration, B., 1999, The European higher education area, Joint declaration of the European Ministers of Education, 19.

Declaration, S.J., 2008, Joint Declaration on Harmonisation of the Architecture of the European Higher Education System.(1998). Paris. Internetinis puslapis: http://www.bologna-berlin2003.de/pdf/Sorbonne_declaration.pdf.

Dill David D. (1997), “Higher education markets and public policy”, Higher Education Policy, Vol.10. No. 314, pp. 167-155, 1997

Dixit, A., 2002, Incentives and organizations in the public sector: An interpretative review. Journal of human resources, pp. 696-727.

Dollery, B. and Hamburger, P., 1995, The Dunleavy and Niskanen Models of Bureaucracy: The Case of the Australian Federal Budget Sector, 1982-92. Department of Economics, University of New England.

Downs, A., 1965, A theory of bureaucracy, The American Economic Review, 55(1/2), pp. 439-446.

Duncombe, W., Miner, J. and Ruggiero, J., 1997, Empirical evaluation of bureaucratic models of inefficiency, Public Choice, 93(1-2), pp. 1-18.

Dundar, H., & Lewis, D. R. 1995, Departmental productivity in American universities: economies of scale and scope, Economics of Education Review, 14, 199–244.

Dundar, H. and Lewis, D. R. 1999, Equity, quality and efficiency effects of reform in Turkish higher education, Higher Education Policy. 12, 343-366.

Dunleavy, P., 1991, Bureaucracy, democracy and public choice, Hemel Hemsted, Harvester: Wheatsheaf.

Ehrenberg, R.G., 2003, Reaching for the brass ring: The US News & World Report rankings and competition. The Review of Higher Education, 26(2), pp. 145-162.

Ehrenberg, R.G., 2006, What's happening to public higher education? Praeger Pub Text.

Emrouznejad, Ali 2000, The assessment of dynamic efficiency of decision making units using data envelopment analysis. PhD thesis, University of Warwick.

Erkoc, T. E. 2011a, Non-Profit Universities and the Challenges of Public Higher Education in 21st Century: The Case of Turkey, CEBA 2011 Conference Proceedings.

Erkoc, T. E. 2011b, Mapping out Economics of Non-Profit Sector in Turkish Context, European Journal of Economic and Political Studies, Vol.4, No.2.

Erkoc, T. E. 2012, Estimation Methodology of Economic Efficiency: Stochastic Frontier Analysis vs. Data Envelopment Analysis, International Journal of Academic Research in Economics and Management Sciences, Vol. 1, No. 1.

Fare, R., S. Grosskopf, and J. Logan: 1983, The Relative Efficiency of Illinois Electric Utilities, Resources and Energy, Vol. 5, No. 4, pp. 349-367.

Fare, R., Grosskopf, S. and Lovell, C.A.K. 1985, The Measurement of Efficiency of Production. Boston: Kluwer Academic Publishers.

Fare, R., Grosskopf, S. and Lovell, C.A.K. 1994, Production Frontiers, Cambridge, Cambridge University Press.

Fare, R. and Lovell, C.A.K. 1978, Measuring the Technical Efficiency of Production, Journal of Economic Theory, 19: 150–162.

Farrell, M.J. 1957, The Measurement of Productive Efficiency, Journal of the Royal Statistical Society (A general), 120: 253–281.

Farsi, M., Filippini, M. and Kuenzle, M., 2005, Unobserved heterogeneity in stochastic cost frontier models: an application to Swiss nursing homes, Applied Economics, 37(18), 2127-2141.

Ferna´ndez, C., Koop, G. and Steel, M.F.J. 2000a, A Bayesian Analysis of Multiple-Output Production Frontiers, Journal of Econometrics, 98: 47–79.

Ferna´ndez, C., Osiewalski, J. and Steel, M.F.J. 1997, On the Use of Panel Data in Stochastic Frontier Models with Improper Priors, Journal of Econometrics, 79: 169–193.

Fethi M. Duygun and Pasiouras F. 2010, Assessing bank efficiency and performance with operational research and artificial intelligence techniques: A survey, European Journal of Operational Research 204 (2), 189-198, Fethi, M. D. and Weyman-Jones, T.G. 2006, "Stochastic DEA", in Avkiran, N., Productivity Analysis in the Service Sector with Data Envelopment Analysis, ISBN: 0958055017 (3rd edition)

Flegg, A. T., & Allen, D. O. 2007a, Congestion in the new British universities.Economic Issues, 12(2), 47−81.

Flegg, A. T., & Allen, D. O. 2007b, Does expansion cause congestion? The case of the older British universities, 1994 to 2004, Education Economics, 15(1), 75−102.

Flegg, A.T., Allen, D.O., in press. Congestion in the Chinese automobile and textile industries revisited. Socio-Economic Planning Science, (October 2008, Electronic publication ahead of print). (doi:10.1016/j.seps2008.10.003).

Flegg, A. T., Allen, D. O., Field, K., &Thurlow, T. W. 2004, Measuring the efficiency of British universities: a multi-period data envelopment analysis. Education Economics, 12(3), 231−249

Fried, H.O., Lovell, C.A.K. & Schmidt, S.S. 2007, The Measurement of Productive Efficiency: Techniques and Applications, Oxford University Press, New York.

Gabrielsen, A. 1975, On Estimating Efficient Production Functions Working Paper no A-35, Chr. Michelsen Institute, Department of Humanities and Social Sciences, Bergen, Norway.

Glass J., McKillop D, Hyndman N. 1995, Efficiency in the provision of university teaching and research: an empirical analysis of UK universities. Journal of Applied Econometrics 10, 61-72

Gong, Byeong-Ho & Sickles, Robin C., 1991,Finite Sample Evidence on the Performance of Stochastic Frontiers and Data Envelopment Analysis Using Panel Data, Working Papers 91-12, C.V. Starr Center for Applied Economics, New York University.

Greene, W. 1980a, Maximum likelihood Estimation of Econometric Frontier Functions. Journal of Econometrics, 13(1): 27–56.

Greene, W. 1980b, On the Estimation of a Flexible Frontier Production Model, Journal of Econometrics, 13(1): 101–115.

Greene, W. 1982, Maximum Likelihood Estimation of Stochastic Frontier Production Models, Journal of Econometrics, 18(2): 285–289.

Greene, W. 1990, A Gamma-Distributed Stochastic Frontier Model, Journal of Econometrics, 46: 141–163.

Greene, W. 1997a, Econometric Analysis, 3rd Edn, Prentice-Hall: Englewood Cliffs, NJ.

Greene, W. 1997b, Frontier Production Functions. In Handbook of Applied Econometrics. Volume II: Microeconomics, M.H. Pesaran and Schmidt, P. (Eds.), Oxford: Blackwell.

Greene, W.H. 2003, Simulated Likelihood Estimation of the Normal-Gamma Stochastic Frontier Function, Journal of Productivity Analysis, vol. 19, no. 12, pp. 179-190.

Greene, W.H. 2005, Reconsidering Heterogeneity in Panel Data Estimators of the Stochastic Frontier Model, Journal of Econometrics, vol. 126, no. 2, pp. 269-303.

Greene, W.2007, The Econometric Approach to Efficiency Analysis. In The Measurement of Productive Efficiency: Techniques and Applications, Harold O. Fried, Lovell, C.A.K. and Schmidt, S.S. (Eds.), Oxford: Oxford University Press: 68–119.

Gonzalez-Brambila, C., & Veloso, F. M. 2007, The determinants of research output and impact: A study of Mexican researchers. Research Policy, 36(7), 1035-1051.

Groot, H., McMahon, W. W., and Volkwein, J. F. (1991), The cost structure of American Research universities. Review of Economics and Statistics, 73(3), 424-31

Grosskopf, S. 1996, Statistical inference and non-parametric efficiency: A selective survey. Journal of Productivity Analysis, 7, 161–176.

Grosskopf, S. and Hayes, K.J., 1993. Local public sector bureaucrats and their input choices, Journal of Urban Economics, 33, pp. 151-166.

Guermat and Hadri 1999, Misspecification in Stochastic Frontier Models Back propagation Neural Network versus Translog Model: A Monte Carlo Comparison Harold O. Fried, Lovell, C.A.K. and Schmidt, S.S. (Eds.), Oxford: Oxford University Press: 121–159.

Hausman, J.A. 1978, Specification Tests in Econometrics, Econometrica, 46(6): 1251–71.

Hayes, K. and Chang, S., 1990, The relative efficiency of city manager and mayor-council forms of government, Southern Economic Journal, pp. 167-177.

Hicks, J.R. 1935, "Annual Survey of Economic Theory: The Theory of Monopoly", Econometrica, vol. 3, no. 1, pp. 1-20.

Holloway, G., D. Tomberlin and X. Irz, 2005, "Hierarchical Analysis of Production Efficiency in a Coastal Trawl Fishery," in R. Scarpa and A. Alberini, ed., Simulation Methods in Environmental and Resource Economics, Kluwer, Nijoff Academic Publishers, forthcoming.

Hulme, D. and Edwards, M., 1997, NGOs, states and donors: too close for comfort? Macmillan London.

Institute for Fiscal Studies 2002, Chapter 8: Measuring public sector efficiency, The IFS Green Budget: January 2002, Commentary no. 87, IFS, London

Izadi H., Johnes G., Oskrochi R., Crouchley R. 2002, Stochastic frontier estimation of a CES cost function: the case of higher education in Britain. Economic of Education Review 21, 61-71

James, E., 1990, Economic theories of the nonprofit sector: A comparative perspective. The third sector, comparative studies of non-profit organizations, De Gruyter, Berlin, New-York, pp. 21-30.

Jenny Hans H. 1968, Pricing and Optimum Size in a Non-profit Institution: The University, The American Economic Review, Vol. 58, No. 2, Papers and Proceedings of the Eightieth Annual Meeting of the American Economic Association, pp. 270-283

Johnes, G., 2004, CIDEA: Software for evaluating confidence intervals in DEA problems. Mimeo, Lancaster University Management School, available from http://www.lancs.ac.uk/people/ecagj/cidea1.html.

Johnes, J. 2004, Efficiency measurement, In G. Johnes, & J.Johnes (Eds.), The International handbook on the economics of education. Cheltenham: Edward Elgar.

Johnes, J., 2005, Measuring teaching efficiency in higher education: An application of data envelopment analysis to Economics graduates for UK universities. European Journal of Operational Research, forthcoming, 174/1, 443-456

Johnes G. & Johnes J. 1993, Measuring the research performance of UK economics departments: An application of data envelopment analysis. Oxford Economic Papers 45

Johnes G. & Johnes J. 2009, Higher education institutions' costs and efficiency: Taking the decomposition a further step. Economics of Education Review 28(1), 107– 113

Johnstone Bruce D. 2004, The economics and politics of cost sharing in higher education: comparative perspectives, Economics of Education Review 23 (2004) 403 – 410.

Jondrow, J, Lovell, C.A.K., Materov, I.S. and Schmidt, P. 1982, On the Estimation of Technical Inefficiency in the Stochastic Frontier Production Function Model, Journal of Econometrics, 23: 269–274.

Jongbloed, B., 2010, Funding higher education: a view across Europe. Brussels: ESMU.

Kang, B., 1997, Frontier Education Production Functions and the Sources of Public Education Efficiency, PhD thesis, New York: Binghamton University State University of New York.

Karim, M.Z.A and Jhantasana, Ch 2005, Efficiency and Profitability In Thailand's Life Insurance Industry: A Cost Frontier Function and Hausman test, 1997-2002. International Journal of Applied Econometrics and Quantitative Studies,2.

Katharakia M. and Katharakis G. 2010, A comparative assessment of Greek universities' efficiency using quantitative analysis, International Journal of Educational Research 49 (2010) 115–128.

Kim, Y.H. 1987, Economies of Scale in Multi-Product Firms: An Empirical Analysis, Economica 54 (214), 185-206.

Kim, Y. and Schmidt, P. 2000, A Review and Empirical Comparison of Bayesian and Classical Approaches to Inference on Efficiency Levels in Stochastic Frontier Models with Panel Data, Journal of Productivity Analysis, 14: 91–118.

Kleit, A. and D. Terrell, 2001, Measuring Potential Efficiency Gains from Deregulation of Electricity Generation: A Bayesian Approach, The Review of Economics and Statistics, 83, pp. 523-530.

Koop, G. 1994, Recent Progress in Applied Bayesian Econometrics, Journal of Economic Surveys, 8: 1–34.

Koop, G., Osiewalski, J. and Steel, M.F.J. 1994, Bayesian Efficiency Analysis with a Flexible Form: The AIM Cost Function, Journal of Business and Economic Statistics, 12: 339–346.

Koop, G., Osiewalski, J. and Steel, M.F.J. 1997, Bayesian Efficiency Analysis through Individual Effects: Hospital Cost Frontiers, Journal of Econometrics, 76: 77–106.

Koopmans, T.C. 1951, An analysis of Production as Efficient Combination of Activities. In Activity Analysis of Production and Allocation, Koopmans, T.C., eds, Cowles Commission for Research in Economics, Monograph no. 13. New York.

Kopp, R.J. and Diewert, W. 1982, The Decomposition of Frontier Cost Function Deviations into Measures of Technical and Allocative Efficiency. Journal of Econometrics, 19(2/3): 319–332.

Koshal R. K. and Koshal M. 1999, Economies of scale and scope in higher education: a case of comprehensive universities, Economics of Education Review 18 (1999) 269–277.

Kumbhakar SC, Ghosh S., MCGukin J. 1991, A generalized frontier approach for estimating determinants of inefficiency in US dairy firms, Journal of Business and Economics Statistics 9, 279-286

Kumbhakar, S.C. 1988, Estimation of Input-Specific Technical and Allocative Inefficiency in Stochastic Frontier Models, Oxford Economic Papers, 40: 535–549.

Kumbhakar, S.C. 1989, Estimation of Technical Efficiency Using Flexible Functional Form and Panel Data, Journal of Business and Economic Statistics, 7: 253–358.

Kumbhakar, S.C. 1990, Production Frontiers, Panel Data and Time-Varying Technical Inefficiency. Journal of Econometrics, 46(1/2): 201–211.

Kumbhakar, S.C. 1991a, Estimation of Technical Inefficiency in Panel Data Models with Firm-and Time-Specific Effects, Economics Letters, 41: 11–16.

Kumbhakar, S.C. 1991b, The Measurement and Decomposition of Cost-Inefficiency: The Translog Cost System, Oxford Economic Papers, 43: 667–683.

Kumbhakar, S.C. 1996, Efficiency Measurement with Multiple Outputs and Multiple Inputs, Journal of Productivity Analysis, 7: 225–255.

Kumbhakar, S.C. 1997, Modelling Allocative Inefficiency in a Translog Cost Function and Cost Share Equations: An Exact Relationship. Journal of Econometrics, 76(1/2): 351–356.

Kumbhakar, S.C. and Lovell, C.A.K. 2000, Stochastic Frontier Analysis, Cambridge University Press, Cambridge.

Kuo J. & Ho Y. 2008, The cost efficiency impact of the university operation fund on public universities in Taiwan. Economic of Education Review 27-21

Land, K.C., Lovell, C.A.K. & Thore, S. 1993, Chance-constrained Data Envelopment Analysis, Managerial and Decision Economics, vol. 14, no. 6, pp. 541-554.

Lee, Y.H. and Schmidt, P. 1993, A Production Frontier Model with Flexible Temporal Variation in Technical Inefficiency. In The Measurement of Productive Efficiency:

Techniques and Applications, Harold O. Fried, Lovell, C.A.K., Schmidt, S.S. (Eds.), Oxford: Oxford University Press: 237–255.

Leibenstein, H. 1966, "Allocative Efficiency vs. 'X-efficiency'", American Economic Review, vol. 56, no. 3, pp. 392-415.

Lepori, B., M. Benninghoff, B. Jongbloed, C. Salerno and S. Slipsæter 2007, Changing models and patterns of higher education funding: some empirical evidence, in: A. Bonaccorsi and C. Daraio, Universities and strategic knowledge creation, Specialization and performance in Europe, PRIME Series on Research and Innovation Policy in Europe, Cheltenham: Edward Elgar Publishing Limited.

Lewis, W. 2004, The Power of Productivity. Chicago, IL: University of Chicago Press.

Lovell, C.A.K. 1993, Production Frontiers and Productive Efficiency, In The Measurement of Productive Efficiency: Techniques and Applications, Harold O. Fried, Lovell y, C.A.K., Schmidt, S.S. (Eds.), Oxford: Oxford University Press: 3–67.

Madden G., Savage S. & Kemp S. 1997, Measuring public sector efficiency: A study of the Economics Department at Australian universities, Education Economics 5(2), 153–168

Maskin, E. and Tirole, J., 2001, Markov perfect equilibrium: I. Observable actions, Journal of Economic Theory, 100(2), pp. 191-219.

McMillan M. and Chan W. 2006, University efficiency: A comparison and consolidation of results from stochastic and non-stochastic methods. Education Economics 14(1) 1-30

McNutt, P.A., 2002, The economics of public choice, Edward Elgar Pub.

Meeusen, W. and van den Broeck, J. 1977, Efficiency Estimation from Cobb-Douglas production functions with composed error, International Economic Review, 18: 435–444.

Mester, G., 2009, Lisbon Strategy 2000 in Higher Education of Europe, Proceeding of the International Conference on Advances in the Internet, Processing, Systems, and Interdisciplinary research, VIPSI 2009, pp. 1-5.

Mensah Yaw M. and Werner R. 2003, Journal of Accounting and Public Policy, vol. 22, issue 4, pages 293-323

Migue, J. and Belanger, G., 1974, Toward a General Theory of Managerial Discretion, 17 PUB. CHOICE, 27, pp. 29.

Mises L.E. (1935), Economic Calculation in the Socialist Commonwealth, http://mises.org/pdf/econcalc.pdf. 1920, reprinted in Hayek

Ministers, O.E., 2006, Higher education: Quality, equity and efficiency. Retrieved May, 11, pp. 2012.

Mohammadi A. and Habibollah R. 2011, The Application of DEA based Malmquist Productivity Index in Organizational Performance Analysis, International Research Journal of Finance and Economics ISSN 1450-2887 Issue 62

Mostafa, M. 2007, Modeling the efficiency of GCC banks: a data envelopment analysis approach, International Journal of Productivity and Performance Management, 56, 7, 623-643.

Mueller, D.C. 1989, Public choice II, Cambridge Surveys of Economic Literature.

Murillo-Zamorano L. 2004, Economic efficiency and frontier techniques, Journal of Economic Surveys 18(1)

Musgrave, R. A., and Musgrave P.B. 1989, Public finance in theory and practice.

Nguyen H. 2009, What are Country-level Determinants of Economic Research Productivity?, MA Thesis, The University of Texas at Arlington

Niskanen, W.A., 1968, The peculiar economics of bureaucracy, The American Economic Review, 58(2), pp. 293-305.

Niskanen, W. A., 1971, Bureaucracy and representative government.

Okun, A.M., 1975, Equality and efficiency: The big trade off. Brookings Institution Press.

Onder Cetin and Onder Rana Kasapoglu 2011, “Resource endowments and responses to regulatory pressure: Publications of economics, management, and political science departments of Turkish universities in indexed journals, 2000 – 2008”, Higher Education: The International Journal of Higher Education and Educational Planning, v61 n4 p463-481.

Orea, L., Kumbhakar, S.C., 2004. Efficiency measurement using a latent class stochastic frontier model. Empirical Economics 29 (1), 69–183.

Organization for Economic Cooperation and Development 2005, University Research Management, Developing Research in New Institutions, Paris: OECD.

Panzar, J. C. and Willig, R. D. 1981, Economies of scope, The American Economic Review, 71(2): 268–272.

Pedraja-Chaparro, F., Salinas-Jimenez, J. and Smith, P., 2005, Assessing public sector efficiency: Issues and methodologies, available at SSRN 2018855.

Pigou, A., The Economics of Welfare, 1920.

Pitt, M.M. and Lee, L.F. 1981, The Measurement and Sources of Technical Inefficiency in the Indonesian Weaving Industry, Journal of Development Economics, 9: 43–64.

Podinovski, V.V. 2001, Validating absolute weight bounds in Data Envelopment Analysis, Journal Of The Operational Research Society 52 (2001): 221-225.

Richmond, J. 1974, Estimating the Efficiency of Production, International Economic Review, 15: 515–521.

Rizzo Michael J. 2006, State Preferences for Higher Education Spending: A Panel Data Analysis 1977-2001, What's Happening to Public Higher Education, The Johns Hopkins University Press.

Robinson, D., 1997, Social capital and policy development, Institute of Policy Studies Victoria University of Welling.

Robst J. 2001, Cost efficiency in public higher education institutions, Journal of Higher Education 72(6)

Rogoff K. 1985, The optimal degree of commitment to an intermediate monetary target, The Quarterly Journal of Economics 100 (4), 1169-1189

Rosanvallon, P., 2000, The new social question: rethinking the welfare state, Princeton University Press.

Salerno C. 2003, What we know about the efficiency of higher education institutions: the best evidence, The Centre for Higher Education Policy Studies, University of Twente.

Sathye, M. 2003, Efficiency of Banks in A Developing Economy: The Case of India, European Journal of Operational Research, vol. 148, no. 3, pp. 662-671.

Schmidt, P. 1976, On the Statistical Estimation of Parametric Frontier Production Functions, Review of Economics and Statistics, 58: 238–239.

Schmidt, P. and Lin, T.F. 1984, Simple Tests of Alternative Specifications in Stochastic Frontier Models, Journal of Econometrics, 24(3): 349–361.

Schmidt, P. and Lovell, C.A.K. 1979, Estimating Technical and Allocative Inefficiency Relative to Stochastic Production and Cost Frontiers. Journal of Econometrics, 9: 343–366.

Schmidt, P. and Lovell, C.A.K. 1980, Estimating Stochastic Production and Cost Frontiers when Technical and Allocative Inefficiency are Correlated, Journal of Econometrics, 13(1): 83–100.

Schmidt, P., and Sickles, R.C. 1984, Production Frontiers and Panel Data, Journal of Business and Economic Statistics, 2: 299–326.

Schultz, C., 2003, Information, polarization and delegation in democracy, Economic Policy Research Unit, Institute of Economics, University of Copenhagen.

Seiford, L.M. 1996, Data Envelopment Analysis: The Evolution of the State of the Art (1978–1995). Journal of Productivity Analysis, 7(2–3): 99–137.

Seiford, L.M. and Thrall, R.M. 1990, Recent Developments in DEA: The Mathematical Approach to Frontier Analysis, Journal of Econometrics, 46: 7–38.

Sena, Vania 2003, The frontier approach to the measurement of productivity and technical efficiency. Economic issues, 8 (2), pp. 71-97.

Shephard, R.W. 1953, Cost and Production Functions, Princeton, University Press, Princeton.

Sherman D. H. 1986, Managing productivity of health care organizations. Measuring Efficiency: An Assessment of Data Envelopment Analysis. New Directions for Program Evaluation (R. H. Silkman, ed.), Jossey-Bass, San Francisco.

Sherman, D.H. and Gold F. 1985, Bank Branch Operating Efficiency: Evaluation with Data Envelopment Analysis, Journal of Banking and Finance, pp. 297-315.

Shumar, W., 1997, College for sale: A critique of the commodification of higher education, Falmer Press London.

Siddharthan K, Ahern M, Rosenman R. 2000, Data envelopment analysis to determine the efficiencies of health maintenance organizations. Health Care Management Science; 3:23–9

Simar, L., & Wilson, P. W. 1998, Sensitivity analysis of efficiency scores: How to bootstrap in non-parametric frontier models, Management Science, 44(1), 49–61.

Simar, L., & Wilson, P. W., 1999, Performance of the bootstrap for DEA estimators and iterating the principle, Discussion Paper, Universite´ Catholique de Louvain.

Smith, P.C. and Street, A., 2005, Measuring the efficiency of public services: the limits of analysis. Journal of the Royal Statistical Society: Series A (Statistics in Society), 168(2), pp. 401-417.

Stevens P. 2001, The determinants of economic efficiency in English and Welsh universities. National Institute of Economic and Social Research, London. Discussion paper N 185.

Stevenson, R. 1980, Likelihood Functions for Generalized Stochastic Frontier Estimation. Journal of Econometrics, 13(1): 58–66.

Stigler G. 1976, The Xistence of X-efficiency, American Economic Review, 66: 213–6

Stone, M., 2002, How not to measure the efficiency of public services (and how one might), Journal of the Royal Statistical Society: Series A (Statistics in Society), 165(3), pp. 405-434.

Tarmo Räty, 2002. "Efficient Facet Based Efficiency Index: A Variable Returns to Scale Specification," Journal of Productivity Analysis, Springer, vol. 17(1), pages 65-82, January.

Thanassoulis, E. 2001, Introduction to the Theory and Application of Data Envelopment Analysis: A Foundation Text with Integrated Software, Kluwer Academic Publishers, Norwell.

Thanassoulis, E. & Dyson, R.G. 1992, "Estimating Preferred Target Input-output Levels Using Data Envelopment Analysis", European Journal of Operational Research, vol. 56, no. 10, pp. 80-97.

Tullock, G., 1965, The politics of bureaucracy. 1st edn. Michigan: Public Affairs Press.

Tullock, G., 1997, Economics of income redistribution, Kluwer Academic Publishers Boston.

University Ranking by Academic Performance 2011, http://www.urapcenter.org/2010/country.php?ccode=TR.

Van den Broeck, J., Koop, G., Osiewalski, J. and Steel, M. 1994, Stochastic Frontier Models: a Bayesian Perspective, Journal of Econometrics, 61: 273–303.

Varian, H. R. 1985, Non-Parametric Analysis of Optimizing Behaviour with Measurement Error, Journal of Econometrics, Vol. 30, pp. 445-458.

Wang, H. & Schmidt, P. 2002, "One-Step and Two-Step Estimation of the Effects of

Exogenous Variables on Technical Efficiency Levels", Journal of Productivity Analysis, vol. 18, no. 2, pp. 129-144.

Weber, M., 1947, Legitimate authority and bureaucracy, Organization theory, London: Penguin Books.

Weisbrod, B.A., 1988, The nonprofit economy. Cambridge MA. , Harvard University.

Weisbrod, B.A. and Arrow, F.B.K., 1998, To profit or not to profit the commercial transformation of the nonprofit sector.

Wiley John D. 2006, Why We Won't See any Public Universities 'Going Private', What's Happening to Public Higher Education, The Johns Hopkins University Press, 2006

Williamson, O.E., 1964, The economics of discretionary behavior: managerial objectives in a theory of the firm, Carnegie Institute of Technology.

Wolszczak-Derlacz J. and Parteka A. 2011, Efficiency of European public higher education institutions: a two-stage multi country approach, Scientometrics, 2011 December; 89(3): 887–917.

World Bank Group, 2011, World Development Report 2012: Gender Equality and Development, World Bank Publications.

Worthington, A. C., & Lee, B. L. 2008, Efficiency, technology and productivity change in Australian universities, 1998–2003. Economics of Education Review, 27(3),285−298.

Wyckoff, P.G., 1990, The simple analytics of slack-maximizing bureaucracy, Public Choice, 67(1), pp. 35-47.

YÖK (The Council of Higher Education of Turkey) 2006, Türkiye'nin yükseköğretim stratejisi (Turkey's Higher Education Strategy), Ankara, 2006

YÖK (The Council of Higher Education of Turkey) 2007, Vakif Universiteleri Raporu (Report on Non-profit Universities in Turkey), Ankara, 2007

YÖK (The Council of Higher Education of Turkey) 2013, Available at: http://www.yok.gov.tr/web/guest/universiteler (Last accessed 26th April, 2013)

Zhao X. 2006, Essays on the Bayesian Estimation of Stochastic Cost Frontier,PhD Thesis Submitted to Graduate School of the Louisiana State University

APPENDIX A (Supplementary Cost Frontier Results for SFA)

The cost frontier of 53 public universities in Turkey with 5-year time span is already estimated by the means of maximum likelihood estimation (MLE). In addition to the six models indicated in the chapter V, additional six models (3 with pooled, 3 with panel data analysis) with Cobb-Douglas cost specification are developed so as to test the influence of the distribution of inefficiency values as well as the exogenous variables. The findings of the models summarised below by and large do not contradict with the estimates of the models narrated in the Chapter V.

i) Pooled Data

In the pooled data analysis, Model I assumes the distribution as half-normal without exogenous variables, Model II corresponds to the half-normal model with exogenous variables and Model III prefers truncated-distributed values with exogenous variables. As the "estimated variance matrix of estimates is singular" for exponential case, it could not be depicted here. The results derived from this estimation are revealed as follows:

Table A1: Regression Results for Pooled Data						
Variables	**Model I**		**Model II**		**Model III**	
lnTC	Coefficient	St. Err.	Coefficient	St. Err.	Coefficient	St. Err.
Constant	4.05364***	0.50199	5.61273***	0.22057	4.55273***	0.52189
lnLAB	.49087***	0.04947	.57648***	0.02037	1.02739***	0.02496
lnCAP	.44475***	0.04092	.30918***	0.01845	.31542***	0.02789
lnUG	.17093***	0.01547	.25273***	0.01061	.31408***	0.01624
lnPG	.19685***	0.01888	0.01295	0.01046	-.02093	0.01783
lnRES	.10258***	0.0162	.05021***	0.00669	.08455***	0.01126
AGE			.00527***	0.00064	.00228**	0.00091
SIZE			.99514D-05***	.571D-06	.1089D-04***	.764D-06
LOAD			-.01875***	0.00105	-.02106***	0.00142
PROF			-.1572	0.17685	-.54973**	0.22948
FTS			.05616**	0.02694	.08676*	0.04916
FORGN			4.29065***	0.83071	6.37192***	1.4439
MED			.10793***	0.01984	0.04834	0.03641
Lambda	.97528***	0.17108	2.40793***	0.36194	31.5849	299.8731
Log-Likelihood	7.56385		247.2138		130.11114	

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

2. Asymptotic standard errors in parentheses.

The reliability of frontier models is heavily contingent upon the lambda values that denote the contributions of inefficiency term (u_i) and statistical term (v_i) into the traditional error term (e_i). If lambda is strictly higher than 0, that means the share of inefficiency terms cannot be underestimated, therefore the frontier model is worth examining and taking into account regarding econometric paradigms.

All these three models examined above have higher values than 0 for lambda but the value for Model III is not significantly different from 0 corresponding to the fact that its estimations are not eligible for efficiency analysis. Besides, likelihood ratio (LR) test indicates that Model II is the best-fitted model that has the LR value 247.21380, whereas the Model I and Model II have 7.56385 and 130.11114 respectively.

In relation to the estimates of parameters, even though there are couple of dissimilarities they by and large resemble to each other. In three models, *W*s –the parameters of the input prices- are significantly motivating the cost function with different elasticity levels. Besides, as the Table-2 points out apparently, the impact of labour seems to be greater than the capital's influence over to the total cost. That is to say, the elasticity of labour is relatively higher than the elasticity of capital concerning the three different models. Eventually, the total elasticity of input prices is equal to 0.934 in Model I, 0.885 in Model II and 1.34 in Model III.

The estimated parameters of outputs (βs) have positive signs which were expected beforehand as well as statistically significant for all three models except the number of postgraduate students. The coefficient of number of postgraduate students is statistically significant in only Model I in which exogenous variables are excluded. 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 II, and four times greater in Model III.

The last analysis for this part is the interpretation of *Z*s representing the coefficients of the exogenous variables. All exogenous variables are significantly motivating cost function either in one model or both. 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 I and Model II. The load 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. Dummy variable for medical school is raising costs regarding Model I, whereas percentage of full-time academic staff is reducing costs along with Model II.

ii) Panel Data

In addition to the pooled data analysis, this section reveals the results of panel data analysis in which different models have been put forward. Model IV assumes fixed effects with time invariant inefficiency (Scmidt and Sickles, 1984), Model V prefers random effects with time invariant inefficiency (Pitt and Lee, 1981), Model VI corresponds to Battese and Coelli (1992)'s time variant inefficiency model, and all three have half-normal distribution for inefficiency term. The regression results of these models are shown in Table-3.

Table A2: Regression Results for Panel Data

Variables	**Model IV**		**Model V**		**Model VI**	
lnTC	Coefficient	St.Err.	Coefficient	St.Err.	Coefficient	St.Err.
Constant			6.81696***	0.26708	5.61273***	0.20111
lnLAB	.64629***	0.01633	.63597***	0.01594	.57648***	0.02155
lnCAP	.24809***	0.01323	.25873***	0.01066	.30918***	0.01462
lnUG	.05804***	0.02058	.10998***	0.01741	.25273***	0.02429
lnPG	.01610**	0.00761	.02284**	0.01143	.01295	0.0126
lnRES	0.0083	0.00952	0.02105	0.01395	.05021***	0.00993
AGE	.01921***	0.00283	.01415***	0.00163	.00527***	0.00092
SIZE	.40139D-05***	.6406D-06	.47139D-05***	.1791D-05	.98103D-05***	.403D-06
LOAD	-.00752***	0.00122	-.00881***	0.00073	-.01875***	0.00161
PROF	-2.20015***	0.25453	-1.86846***	0.39613	-.15726	0.17692
FTS	.08803*	0.04873	.09353***	0.03473	0.05616	0.05261
FORGN	1.48195	1.76076	4.86780***	1.45	4.29065***	1.08433
MED	0.0.. (Fixed Parameter)		.29244***	0.05829	.10793**	0.04471
Lambda	NA		6.88635	4.40665	2.40793***	0.11732
Log-Likelihood	453.61209		304.73927		246.12648	
Eta					0.01	0.02703

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

2. Asymptotic standard errors in parentheses.

Both Model V and Model IV have higher lambda values than 0, nonetheless the value for Model V is not statistically greater than 0 which proves the fact that variation in error term is predominantly motivated by noise term. Model IV does not have a unique lambda value due to its way of estimation (fixed effects model), but gives noteworthy ideas about the parameters of cost function. Concerning LR test, Model IV has the value with (i) variables and group effect 453.61209 and (ii) only variables 236.05839. Model V's log-likelihood score is 304.73927, whereas Model VI's is 246.12648. Eventually, Model IV considering both variables and group effect seems to be best-fitted model pertaining to LR test.

The cost frontier parameters for these aforementioned models resemble to each other with slight dissimilarities. The parameters of input prices (*W*s) are statistically significant via having expected signs. Besides, the total cost elasticity of input prices for Model IV, V and VI are nearly same (0.893, 0.894 and 0.877 respectively). Number of undergraduate students seems to be most influential component of cost function among the other outputs. However, both number of postgraduate students and research output do impact on total cost for at least one model. 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 have significant coefficients at least in two models (with expected signs).

One of the main discussion points for the panel data analysis is whether or not inefficiency changes over time. In the analysis conducted above, Model IV and V assumed inefficiencies do not alter throughout five years, whereas Model VI took time variant inefficiency into consideration. The estimated eta on the table that tests whether inefficiency is dependent upon time indicates time effect on the inefficiency is insignificant. That is to say, 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.

APPENDIX B

Likelihood Ratio (LR) Test

In statistical theory, a likelihood ratio test is the widely used method to compare the fit of two models, one of which is nested within the other. This test is often carried out when inspecting whether a simplifying assumption for a model is valid, as when two or more model parameters are assumed to be related. That is to say, The LR test scrutinises whether a reduced model (Model R) offers as good a fit to the data as the fully specified model (Model U).

Both models are fitted to the data and their log-likelihood values estimated. The test statistics (usually symbolised by D) is twice the difference in these log-likelihoods as shown in the following steps below:

$$\text{LR-Test (D)} = -2\ log_e(\frac{L_R}{L_u}) ,$$

And, if we take necessary analytical steps, the function will look like:

$$\text{LR-Test (D)} = -2\ \ log_e\ L_R\ \ - log_e\ L_U$$

$$= -2\ log_e\ L_R\ \ + 2\ log_e\ L_U$$

The model with more parameters will always fit at least as well (have a greater log-likelihood). Whether it fits significantly better and should thus be preferred can be determined by deriving the probability or p-value of the obtained difference D. In many cases, the probability of the test statistic can be approximated by a Chi-Square (X^2) distribution with $(df_1 - df_2)$ degrees of freedom, where df_1 and df_2 are the degrees of freedom of models R and U respectively.

The null hypothesis (H_0) for the LR-test claims that the restricted model (Model R) gives nearly similar log-likelihood values as the unrestricted model (Model U). Thus, if the log-likelihood test statistic gets higher value then the appropriate critical value from the Chi-Square (χ2) table, then the null hypothesis is rejected; which means that the restrictions on Model U in terms of the number of parameters are invalid. On the other hand, the null hypothesis is failed to be rejected if the log-likelihood test statistic gets lower value than the Chi-Square critical value, referring to the fact that the restrictions on the Model U are valid.

APPENDIX C (Efficiency Scores by University with SFA)

Table C1 : Efficiency Scores of Public HEIs (Year 2006)

DMU	Year	A1	A2	A3	B1	B2	B3
PU1	2006	0.78399	0.898249	0.878057	0.821898	0.9058333	0.9158799
PU2	2006	0.678519	0.879478	0.837422	0.731415	0.835875	0.876529
PU3	2006	0.862877	0.833423	0.9074355	0.864572	0.880993	0.870437
PU4	2006	0.61225	0.80718	0.53642	0.634353	0.792947	0.870437
PU5	2006	0.527316	0.331731	0.909076	0.705538	0.450127	0.870437
PU6	2006	0.586453	0.886021	0.708885	0.700213	0.829694	0.896341
PU7	2006	0.537357	0.803359	0.649243	0.677597	0.846151	0.870437
PU8	2006	0.894821	0.798202	0.9382472	0.9372701	0.871642	0.870437
PU9	2006	0.847348	0.9126067	0.893291	0.843284	0.9543802	0.950587
PU10	2006	0.514756	0.848543	0.643467	0.666221	0.890133	0.870437
PU11	2006	0.585763	0.752013	0.702777	0.557812	0.9126395	0.954693
PU12	2006	0.663833	0.797558	0.641196	0.96812	0.9362975	0.9467896
PU13	2006	0.937506	0.915845	0.9655775	0.755601	0.772629	0.870437
PU14	2006	0.51746	0.798631	0.599066	0.572623	0.886045	0.9801068
PU15	2006	0.574346	0.741218	0.640634	0.680045	0.714406	0.870437
PU16	2006	0.9611603	0.753951	0.9341284	0.9640287	0.88945	0.912572
PU17	2006	0.521611	0.88638	0.658879	0.681148	0.865445	0.9297352
PU18	2006	0.580086	0.811989	0.563625	0.659216	0.84293	0.870437
PU19	2006	0.534285	0.694024	0.53642	0.526917	0.677786	0.870437
PU20	2006	0.646994	0.9182438	0.53642	0.9220505	0.858145	0.870437
PU21	2006	0.45205	0.710317	0.609611	0.54984	0.711848	0.885316
PU22	2006	0.582148	0.811028	0.623358	0.674119	0.857144	0.870437
PU23	2006	0.9164437	0.832267	0.9124413	0.9203458	0.863235	0.870437
PU24	2006	0.847736	0.770991	0.786631	0.828061	0.899275	0.870437
PU25	2006	0.663622	0.684567	0.665386	0.745251	0.713334	0.870437
PU26	2006	0.697173	0.882228	0.82582	0.799843	0.855691	0.870437
PU27	2006	0.485069	0.759991	0.53642	0.552281	0.819933	0.870437
PU28	2006	0.893804	0.9331578	0.9543462	0.9164666	0.9632006	0.9735254
PU29	2006	0.12562	0.71523	0.53642	0.269967	0.71292	0.870437
PU30	2006	0.895449	0.9294202	0.9042282	0.526708	0.660486	0.870437
PU31	2006	0.9204872	0.874341	0.891569	0.9627565	0.9208762	0.886924
PU32	2006	0.9360508	0.9709218	0.9454489	0.9614591	0.9695697	0.9257918
PU33	2006	0.595892	0.9381395	0.630026	0.653577	0.9454246	0.9224811
PU34	2006	0.647765	0.892151	0.619191	0.692698	0.88275	0.9232459
PU35	2006	0.800859	0.86003	0.9437181	0.887592	0.9260402	0.892393
PU36	2006	0.802792	0.9083875	0.897717	0.879709	0.89786	0.9443358
PU37	2006	0.696773	0.832681	0.712031	0.764961	0.9228166	0.897171
PU38	2006	0.868891	0.804741	0.865603	0.742607	0.9213422	0.9030006
PU39	2006	0.892151	0.9670764	0.9043803	0.9167486	0.843422	0.870437
PU40	2006	0.9250737	0.9500054	0.899742	0.9567117	0.9686385	0.9436172
PU41	2006	0.452332	0.783413	0.53642	0.9512563	0.9388299	0.870437
PU42	2006	0.747187	0.791113	0.877025	0.48015	0.821856	0.870437
PU43	2006	0.563994	0.9400028	0.53642	0.833287	0.881568	0.9084418
PU44	2006	0.645451	0.9451639	0.679596	0.638499	0.9545908	0.9344634
PU45	2006	0.816725	0.9204615	0.842593	0.887573	0.9387974	0.9004487
PU46	2006	0.9258769	0.755618	0.9384443	0.9346695	0.786259	0.870437
PU47	2006	0.81428	0.9892579	0.9261181	0.9250082	0.9849915	0.9869278
PU48	2006	0.785926	0.886692	0.791555	0.876331	0.891239	0.879215
PU49	2006	0.448795	0.777315	0.53642	0.417552	0.9046095	0.9453713
PU50	2006	0.259927	0.710447	0.53642	0.317648	0.729891	0.870437
PU51	2006	0.790936	0.810916	0.886754	0.766904	0.809485	0.870437
PU52	2006	0.551561	0.736205	0.53642	0.572426	0.783589	0.870437
PU53	2006	0.713328	0.829693	0.833568	0.80169	0.9309269	0.9207303

Table C2 : Efficiency Scores of Public HEIs (Year 2007)

DMU	Year	A1	A2	A3	B1	B2	B3
PU1	2007	0.784912	0.899262	0.9098865	0.82367	0.9067702	0.90844
PU2	2007	0.679891	0.880677	0.53642	0.734088	0.837508	0.870437
PU3	2007	0.863462	0.83508	0.9391524	0.86592	0.882177	0.9192091
PU4	2007	0.613905	0.809099	0.774973	0.637991	0.795007	0.870437
PU5	2007	0.529333	0.33838	0.9565608	0.708468	0.455598	0.870437
PU6	2007	0.588218	0.887156	0.66903	0.703196	0.831388	0.870437
PU7	2007	0.539332	0.805316	0.67406	0.680805	0.847681	0.9452166
PU8	2007	0.89527	0.80021	0.898513	0.9378943	0.872919	0.870437
PU9	2007	0.848	0.9134763	0.9124898	0.844843	0.9548341	0.9905329
PU10	2007	0.516827	0.85005	0.68233	0.669542	0.891226	0.870437
PU11	2007	0.587531	0.75448	0.676202	0.562212	0.9135088	0.9775271
PU12	2007	0.665267	0.799573	0.706293	0.9684372	0.9369314	0.9454349
PU13	2007	0.9377727	0.9166824	0.9593184	0.758033	0.774892	0.870437
PU14	2007	0.519519	0.800634	0.53642	0.576875	0.887179	0.888135
PU15	2007	0.576163	0.743793	0.639694	0.683229	0.717247	0.870437
PU16	2007	0.961326	0.756399	0.9425197	0.9643867	0.89055	0.870437
PU17	2007	0.523652	0.887511	0.568806	0.684321	0.866784	0.882285
PU18	2007	0.581878	0.81386	0.628054	0.662607	0.844493	0.870437
PU19	2007	0.536273	0.697068	0.67839	0.531624	0.680992	0.870437
PU20	2007	0.648501	0.9190573	0.59522	0.9228262	0.859557	0.870437
PU21	2007	0.454389	0.713199	0.53642	0.554319	0.714715	0.870437
PU22	2007	0.583931	0.812908	0.59102	0.677362	0.858566	0.876783
PU23	2007	0.9168003	0.833936	0.9306736	0.9211384	0.864596	0.870437
PU24	2007	0.848385	0.773269	0.832905	0.829771	0.9002777	0.9712391
PU25	2007	0.665057	0.687706	0.65022	0.747786	0.716187	0.870437
PU26	2007	0.698465	0.883399	0.722009	0.801834	0.857127	0.870437
PU27	2007	0.487267	0.762379	0.53642	0.556736	0.821724	0.870437
PU28	2007	0.894257	0.9338229	0.9189362	0.9172978	0.9635668	0.9748498
PU29	2007	0.129352	0.718064	0.53642	0.277231	0.715777	0.870437
PU30	2007	0.895895	0.9301224	0.898552	0.531418	0.663864	0.870437
PU31	2007	0.9208266	0.875591	0.9377624	0.9631271	0.9216635	0.917612
PU32	2007	0.9363237	0.9712111	0.9510121	0.9618426	0.9698725	0.9728485
PU33	2007	0.597617	0.9387551	0.709236	0.657024	0.9459677	0.9821918
PU34	2007	0.649268	0.893224	0.53642	0.695755	0.883917	0.870437
PU35	2007	0.801709	0.861423	0.9630706	0.888711	0.9267761	0.899
PU36	2007	0.803634	0.909299	0.9355067	0.880906	0.898877	0.9749609
PU37	2007	0.698067	0.834345	0.838263	0.7673	0.9235846	0.9249283
PU38	2007	0.86945	0.806684	0.874187	0.745168	0.9221248	0.9190408
PU39	2007	0.892611	0.967404	0.9019006	0.917577	0.84498	0.870437
PU40	2007	0.9253935	0.9505028	0.9220488	0.9571424	0.9689505	0.9611319
PU41	2007	0.45467	0.785568	0.53642	0.9517413	0.9394386	0.93853
PU42	2007	0.748265	0.793192	0.812357	0.485323	0.823628	0.870437
PU43	2007	0.565854	0.9405998	0.614385	0.834946	0.882746	0.87376
PU44	2007	0.646964	0.9457096	0.716064	0.642096	0.9550426	0.9605508
PU45	2007	0.817507	0.9212529	0.799104	0.888692	0.9394064	0.9138475
PU46	2007	0.9261932	0.75805	0.9376431	0.9353196	0.788385	0.870437
PU47	2007	0.815073	0.9893648	0.9291189	0.9257544	0.9851409	0.9238465
PU48	2007	0.786839	0.88782	0.839038	0.877562	0.892321	0.873699
PU49	2007	0.451148	0.77953	0.53642	0.423347	0.9055586	0.9161161
PU50	2007	0.263086	0.713328	0.53642	0.324437	0.732578	0.870437
PU51	2007	0.791828	0.812798	0.873815	0.769223	0.81138	0.870437
PU52	2007	0.553475	0.73883	0.56645	0.576681	0.785742	0.870437
PU53	2007	0.714551	0.831388	0.864232	0.803663	0.9316142	0.939898

Table C3 : Efficiency Scores of Public HEIs (Year 2008)							
DMU	**Year**	**A1**	**A2**	**A3**	**B1**	**B2**	**B3**
PU1	2008	0.78583	0.900264	0.620815	0.825425	0.9076979	0.9311718
PU2	2008	0.681258	0.881865	0.614907	0.736734	0.839125	0.9713838
PU3	2008	0.864044	0.836721	0.646943	0.867254	0.88335	0.870437
PU4	2008	0.615553	0.810998	0.53642	0.641593	0.797046	0.870437
PU5	2008	0.531342	0.344963	0.53642	0.711369	0.461015	0.870437
PU6	2008	0.589975	0.888278	0.53642	0.706149	0.833066	0.870437
PU7	2008	0.541298	0.807253	0.53642	0.683981	0.849197	0.870437
PU8	2008	0.895717	0.802198	0.755264	0.9385123	0.874184	0.870437
PU9	2008	0.848648	0.9143372	0.688696	0.846387	0.9552835	0.9175032
PU10	2008	0.518889	0.851542	0.53642	0.67283	0.892308	0.879267
PU11	2008	0.589291	0.756923	0.53642	0.566568	0.9143694	0.9111524
PU12	2008	0.666696	0.801567	0.589055	0.9687513	0.9375589	0.912393
PU13	2008	0.9380383	0.9175114	0.794964	0.76044	0.777131	0.870437
PU14	2008	0.52157	0.802618	0.53642	0.581086	0.888302	0.870437
PU15	2008	0.577972	0.746342	0.53642	0.686381	0.720061	0.870437
PU16	2008	0.9614911	0.758823	0.948134	0.964741	0.891639	0.897019
PU17	2008	0.525685	0.88863	0.53642	0.687462	0.868109	0.870437
PU18	2008	0.583662	0.815712	0.53642	0.665964	0.846041	0.870437
PU19	2008	0.538252	0.700083	0.53642	0.536285	0.684167	0.870437
PU20	2008	0.650001	0.9198627	0.59277	0.923594	0.860954	0.870437
PU21	2008	0.456717	0.716053	0.53642	0.558754	0.717554	0.870437
PU22	2008	0.585707	0.81477	0.53642	0.680572	0.859973	0.870437
PU23	2008	0.9171554	0.835589	0.93603	0.9219231	0.865943	0.9139855
PU24	2008	0.849033	0.775525	0.887051	0.831465	0.9012699	0.894245
PU25	2008	0.666487	0.690813	0.886086	0.750295	0.719011	0.9650608
PU26	2008	0.699752	0.88456	0.53642	0.803806	0.858548	0.870437
PU27	2008	0.489455	0.764744	0.53642	0.561146	0.823498	0.870437
PU28	2008	0.894709	0.9344814	0.696531	0.9181207	0.9639293	0.9545225
PU29	2008	0.133067	0.720869	0.53642	0.284423	0.718605	0.870437
PU30	2008	0.89634	0.9308177	0.829141	0.53608	0.667208	0.870437
PU31	2008	0.9211645	0.876829	0.820758	0.963494	0.922443	0.939704
PU32	2008	0.9365955	0.9714975	0.823228	0.9622223	0.9701722	0.9732484
PU33	2008	0.599334	0.9393644	0.53642	0.660437	0.9465053	0.898898
PU34	2008	0.650765	0.894287	0.53642	0.698783	0.885072	0.9009074
PU35	2008	0.802555	0.862802	0.569627	0.889818	0.9275047	0.9884105
PU36	2008	0.804472	0.9102015	0.610367	0.882091	0.899883	0.9051804
PU37	2008	0.699355	0.835994	0.540955	0.769615	0.924345	0.9308973
PU38	2008	0.870008	0.808608	0.766031	0.747703	0.9228997	0.9592794
PU39	2008	0.893069	0.9677283	0.816635	0.9183971	0.846522	0.870437
PU40	2008	0.9257119	0.9509953	0.881687	0.9575688	0.9692595	0.9736639
PU41	2008	0.456997	0.787702	0.53642	0.9522215	0.9400411	0.9540242
PU42	2008	0.74934	0.795249	0.53642	0.490444	0.825383	0.870437
PU43	2008	0.567707	0.9411908	0.53642	0.836588	0.883913	0.9004071
PU44	2008	0.648471	0.9462498	0.555668	0.645657	0.95549	0.9776771
PU45	2008	0.818286	0.9220365	0.74305	0.889799	0.9400093	0.9629256
PU46	2008	0.9265082	0.760458	0.824046	0.9359632	0.790491	0.870437
PU47	2008	0.815862	0.9894706	0.696557	0.9264931	0.9852887	0.9898175
PU48	2008	0.787749	0.888936	0.53642	0.87878	0.893392	0.870437
PU49	2008	0.45349	0.781724	0.53642	0.429085	0.9064983	0.901003
PU50	2008	0.266231	0.71618	0.53642	0.331159	0.735239	0.870437
PU51	2008	0.792717	0.81466	0.667915	0.771519	0.813257	0.870437
PU52	2008	0.555381	0.741429	0.53642	0.580893	0.787874	0.870437
PU53	2008	0.715769	0.833066	0.653399	0.805617	0.9322947	0.9591514

Table C4 : Efficiency Scores of Public HEIs (Year 2009)							
DMU	**Year**	**A1**	**A2**	**A3**	**B1**	**B2**	**B3**
PU1	2009	0.786744	0.9012564	0.657408	0.827162	0.9086163	0.878574
PU2	2009	0.682618	0.88304	0.736939	0.739353	0.840726	0.9522636
PU3	2009	0.864625	0.838346	0.7146	0.868575	0.88451	0.870437
PU4	2009	0.617193	0.812879	0.639916	0.645159	0.799066	0.870437
PU5	2009	0.533342	0.351481	0.715723	0.714241	0.466378	0.9857623
PU6	2009	0.591725	0.88939	0.53642	0.709073	0.834727	0.870437
PU7	2009	0.543255	0.809171	0.53642	0.687125	0.850698	0.870437
PU8	2009	0.896162	0.804166	0.858556	0.9391241	0.875436	0.891292
PU9	2009	0.849294	0.9151896	0.780545	0.847916	0.9557285	0.9176767
PU10	2009	0.520942	0.853019	0.53642	0.676085	0.89338	0.916084
PU11	2009	0.591044	0.759342	0.53642	0.570881	0.9152214	0.870437
PU12	2009	0.668118	0.803541	0.719359	0.9690622	0.9381802	0.9395134
PU13	2009	0.9383027	0.9183322	0.881946	0.762824	0.779349	0.870437
PU14	2009	0.523612	0.804582	0.53642	0.585254	0.889413	0.884728
PU15	2009	0.579773	0.748866	0.616319	0.689501	0.722846	0.870437
PU16	2009	0.9616554	0.761223	0.9586655	0.9650919	0.892718	0.9044641
PU17	2009	0.527709	0.889738	0.53642	0.690572	0.869422	0.870437
PU18	2009	0.585439	0.817546	0.559522	0.669288	0.847573	0.870437
PU19	2009	0.540223	0.703067	0.53642	0.540899	0.687309	0.870437
PU20	2009	0.651495	0.9206601	0.674467	0.9243543	0.862338	0.9872871
PU21	2009	0.459036	0.718878	0.53642	0.563144	0.720364	0.870437
PU22	2009	0.587475	0.816613	0.571348	0.68375	0.861366	0.870437
PU23	2009	0.9175089	0.837224	0.888036	0.9226999	0.867277	0.877089
PU24	2009	0.849677	0.777759	0.826901	0.833142	0.9022523	0.9553623
PU25	2009	0.66791	0.69389	0.53642	0.75278	0.721807	0.870437
PU26	2009	0.701034	0.885708	0.737679	0.805758	0.859956	0.9082022
PU27	2009	0.491634	0.767085	0.53642	0.565513	0.825254	0.870437
PU28	2009	0.895158	0.9351333	0.871652	0.9189354	0.9642882	0.9705863
PU29	2009	0.136767	0.723647	0.53642	0.291543	0.721405	0.870437
PU30	2009	0.896782	0.9315061	0.873297	0.540696	0.67052	0.870437
PU31	2009	0.9215009	0.878055	0.9262174	0.9638572	0.9232147	0.931875
PU32	2009	0.9368661	0.9717812	0.9157892	0.9625982	0.970469	0.9750103
PU33	2009	0.601044	0.9399678	0.56425	0.663816	0.9470376	0.9531904
PU34	2009	0.652255	0.895339	0.789821	0.70178	0.886216	0.9739506
PU35	2009	0.803398	0.864167	0.700354	0.890914	0.928226	0.9531187
PU36	2009	0.805306	0.911095	0.711514	0.883264	0.9008791	0.870437
PU37	2009	0.700638	0.837626	0.698964	0.771908	0.9250978	0.9522412
PU38	2009	0.870562	0.810512	0.895356	0.750214	0.9236669	0.9502905
PU39	2009	0.893525	0.9680495	0.9128042	0.9192091	0.848049	0.870437
PU40	2009	0.9260289	0.9514829	0.9119821	0.957991	0.9695654	0.9769586
PU41	2009	0.459315	0.789814	0.53642	0.9526969	0.9406378	0.964648
PU42	2009	0.75041	0.797287	0.711943	0.495514	0.827121	0.87557
PU43	2009	0.569552	0.941776	0.53642	0.838214	0.885068	0.877118
PU44	2009	0.649971	0.9467846	0.559341	0.649183	0.9559329	0.9355179
PU45	2009	0.819061	0.9228122	0.77452	0.890896	0.9406063	0.9439158
PU46	2009	0.9268219	0.762841	0.893765	0.9366004	0.792576	0.870437
PU47	2009	0.816648	0.9895754	0.648037	0.9272245	0.9854351	0.9743956
PU48	2009	0.788655	0.890041	0.821396	0.879986	0.894453	0.9419753
PU49	2009	0.455823	0.783896	0.53642	0.434766	0.9074287	0.885371
PU50	2009	0.269362	0.719004	0.53642	0.337814	0.737873	0.870437
PU51	2009	0.793601	0.816505	0.728517	0.773793	0.815115	0.870437
PU52	2009	0.557278	0.744002	0.610246	0.585063	0.789984	0.870437
PU53	2009	0.716982	0.834727	0.644157	0.807551	0.9329684	0.9212938

Table C5 : Efficiency Scores of Public HEIs (Year 2010)							
DMU	**Year**	**A1**	**A2**	**A3**	**B1**	**B2**	**B3**
PU1	2010	0.787654	0.9022389	0.767158	0.828881	0.9095256	0.9082813
PU2	2010	0.683972	0.884204	0.789741	0.741947	0.84231	0.9605904
PU3	2010	0.865202	0.839954	0.9230925	0.869883	0.88566	0.9464476
PU4	2010	0.618827	0.814741	0.672563	0.64869	0.801065	0.878911
PU5	2010	0.535334	0.357934	0.795343	0.717084	0.471688	0.870437
PU6	2010	0.593468	0.890491	0.53642	0.711968	0.836371	0.870437
PU7	2010	0.545204	0.811069	0.53642	0.690239	0.852183	0.870437
PU8	2010	0.896605	0.806115	0.9149096	0.9397298	0.876675	0.9053305
PU9	2010	0.849937	0.9160334	0.836742	0.849429	0.956169	0.9555686
PU10	2010	0.522987	0.854482	0.53642	0.679308	0.894441	0.9582798
PU11	2010	0.592789	0.761737	0.53642	0.575151	0.916065	0.870437
PU12	2010	0.669535	0.805496	0.605044	0.96937	0.9387953	0.945001
PU13	2010	0.938566	0.9191448	0.9240525	0.765184	0.781545	0.870437
PU14	2010	0.525645	0.806526	0.698886	0.589381	0.890514	0.9134102
PU15	2010	0.581566	0.751365	0.53642	0.692591	0.725604	0.870437
PU16	2010	0.9618191	0.763599	0.9607401	0.9654392	0.893785	0.883814
PU17	2010	0.529725	0.890835	0.53642	0.693651	0.870721	0.870437
PU18	2010	0.587209	0.819361	0.590645	0.672579	0.849089	0.870437
PU19	2010	0.542185	0.706021	0.749438	0.545467	0.690421	0.890029
PU20	2010	0.652982	0.9214495	0.756656	0.925107	0.863707	0.885296
PU21	2010	0.461345	0.721675	0.53642	0.567491	0.723147	0.870437
PU22	2010	0.589236	0.818438	0.679139	0.686897	0.862746	0.9074792
PU23	2010	0.917861	0.838844	0.816461	0.9234691	0.868597	0.870437
PU24	2010	0.850318	0.77997	0.805455	0.834802	0.9032249	0.9672066
PU25	2010	0.669327	0.696935	0.55865	0.75524	0.724575	0.870437
PU26	2010	0.702309	0.886845	0.76448	0.807691	0.861349	0.953199
PU27	2010	0.493804	0.769402	0.539919	0.569836	0.826993	0.885101
PU28	2010	0.895605	0.9357788	0.832429	0.919742	0.9646435	0.9239036
PU29	2010	0.140451	0.726396	0.53642	0.298592	0.724177	0.870437
PU30	2010	0.897223	0.9321876	0.9008094	0.545266	0.673798	0.9385753
PU31	2010	0.9218359	0.879268	0.9280837	0.9642168	0.9239787	0.9404865
PU32	2010	0.9371355	0.9720619	0.9426869	0.9629703	0.9707629	0.9751803
PU33	2010	0.602746	0.9405651	0.570474	0.667161	0.9475646	0.958745
PU34	2010	0.65374	0.89638	0.878038	0.704747	0.887348	0.9860585
PU35	2010	0.804237	0.865519	0.555354	0.892	0.9289402	0.873976
PU36	2010	0.806137	0.9119796	0.636006	0.884425	0.9018654	0.870437
PU37	2010	0.701916	0.839241	0.648122	0.774177	0.925843	0.9198037
PU38	2010	0.871115	0.812398	0.878222	0.752699	0.9244264	0.883835
PU39	2010	0.89398	0.9683674	0.875157	0.920013	0.849561	0.879768
PU40	2010	0.9263446	0.9519657	0.9465662	0.958409	0.9698682	0.968286
PU41	2010	0.461622	0.791905	0.546774	0.9531675	0.9412284	0.9749183
PU42	2010	0.751475	0.799304	0.709876	0.500534	0.828841	0.887617
PU43	2010	0.571389	0.9423553	0.743125	0.839824	0.886212	0.870437
PU44	2010	0.651465	0.9473141	0.640976	0.652673	0.9563713	0.9566871
PU45	2010	0.819834	0.9235803	0.876844	0.891981	0.9411972	0.9732723
PU46	2010	0.9271342	0.765201	0.9115337	0.9372312	0.794639	0.870437
PU47	2010	0.817431	0.9896791	0.655296	0.9279487	0.98558	0.9761378
PU48	2010	0.789557	0.891135	0.888024	0.88118	0.895503	0.9524558
PU49	2010	0.458145	0.786046	0.538432	0.44039	0.9083498	0.887161
PU50	2010	0.27248	0.7218	0.53642	0.344403	0.740482	0.870437
PU51	2010	0.794482	0.81833	0.685451	0.776044	0.816955	0.870437
PU52	2010	0.559168	0.746549	0.676939	0.589192	0.792074	0.870437
PU53	2010	0.71819	0.836371	0.53642	0.809466	0.9336353	0.9213007

APPENDIX D (Efficiency Scores by University with DEA)

Table D1: Efficiency Results of HEIs by DEA (Year 2006)			
DMU	**Year**	**Cost Efficiency (M6)**	**Technical Efficiency (M4)**
PU1	2006	0.262179	0.333098
PU2	2006	0.276096	0.472727
PU3	2006	0.414664	0.516568
PU4	2006	0.266805	0.453831
PU5	2006	0.286331	0.734843
PU6	2006	0.558222	0.616307
PU7	2006	0.397065	0.513855
PU8	2006	0.371578	0.5745
PU9	2006	0.565024	0.676755
PU12	2006	0.598811	0.923331
PU10	2006	0.328986	0.501097
PU13	2006	0.414246	0.566913
PU11	2006	0.275399	0.429099
PU14	2006	0.205531	0.412056
PU15	2006	0.545306	0.615662
PU16	2006	0.569399	0.676372
PU17	2006	0.31085	0.397419
PU18	2006	0.322513	0.621256
PU19	2006	0.345708	0.459482
PU20	2006	0.69661	1
PU21	2006	0.641669	0.74309
PU22	2006	0.194526	0.407197
PU23	2006	0.35764	0.549494
PU24	2006	1	1
PU25	2006	0.248038	0.254616
PU26	2006	0.236026	0.441942
PU27	2006	0.23578	0.653453
PU28	2006	0.793699	0.941645
PU29	2006	0.335461	0.788882
PU30	2006	0.551716	0.842997
PU31	2006	0.357681	0.693732
PU32	2006	0.297158	0.460418
PU33	2006	0.328685	0.50544
PU34	2006	0.290973	0.605465
PU35	2006	0.330799	0.429386
PU36	2006	1	1
PU37	2006	0.272834	0.389623
PU43	2006	1	1
PU38	2006	0.499322	0.76087
PU39	2006	0.365014	0.599386
PU40	2006	0.303157	0.523459
PU41	2006	0.419671	0.679957
PU42	2006	0.227201	0.37347
PU44	2006	0.388515	0.530348
PU45	2006	0.280685	0.400658
PU46	2006	0.707338	0.771117
PU47	2006	0.582704	0.738096
PU48	2006	0.2842	0.394096
PU49	2006	0.287122	0.442521
PU50	2006	0.221141	0.349938
PU51	2006	0.628511	0.665991
PU52	2006	0.361343	0.628765
PU53	2006	0.206848	0.502348

Table D2: Efficiency Results of HEIs by DEA (Year 2007)			
DMU	**Year**	**Cost Efficiency (M6)**	**Technical Efficiency (M4)**
PU1	2007	0.320909	0.496559
PU2	2007	0.24547	0.323287
PU3	2007	0.376216	0.535253
PU4	2007	0.390699	0.526535
PU5	2007	0.447602	0.9137
PU6	2007	0.729051	0.904135
PU7	2007	0.233051	0.394274
PU8	2007	0.357547	0.661801
PU9	2007	0.57948	0.745277
PU12	2007	0.414349	0.683991
PU10	2007	0.289302	0.447529
PU13	2007	0.415663	0.641831
PU11	2007	0.200592	0.387476
PU14	2007	0.190577	0.34191
PU15	2007	0.470126	0.786538
PU16	2007	0.510669	0.682999
PU17	2007	0.278098	0.459451
PU18	2007	0.34637	0.620788
PU19	2007	0.263944	0.402726
PU20	2007	0.568995	0.99279
PU21	2007	0.542044	0.671486
PU22	2007	0.16361	0.387274
PU23	2007	0.295983	0.527974
PU24	2007	0.970593	1
PU25	2007	0.304033	0.487594
PU26	2007	0.203858	0.508806
PU27	2007	0.227318	0.532209
PU28	2007	0.785496	1
PU29	2007	0.307503	0.722894
PU30	2007	0.43307	0.97547
PU31	2007	0.281175	0.682529
PU32	2007	0.270981	0.49455
PU33	2007	0.382771	0.596466
PU34	2007	1	1
PU35	2007	0.714146	1
PU36	2007	0.791499	1
PU37	2007	0.215652	0.39542
PU43	2007	0.762677	0.847433
PU38	2007	0.434651	0.876568
PU39	2007	0.31652	0.571345
PU40	2007	0.26918	0.523996
PU41	2007	0.444391	0.860336
PU42	2007	0.220042	0.390407
PU44	2007	0.33539	0.528439
PU45	2007	0.230128	0.465207
PU46	2007	0.666468	0.76605
PU47	2007	0.734692	1
PU48	2007	0.314659	0.483831
PU49	2007	0.321233	0.510371
PU50	2007	0.180207	0.333912
PU51	2007	0.542475	0.655967
PU52	2007	0.325875	0.589502
PU53	2007	0.19673	0.432994

Table D3: Efficiency Results of HEIs by DEA (Year 2008)			
DMU	**Year**	**Cost Efficiency (M6)**	**Technical Efficiency (M4)**
PU1	2008	0.219306	0.491723
PU2	2008	0.178026	0.384222
PU3	2008	0.232129	0.522696
PU4	2008	0.185273	0.313715
PU5	2008	1	1
PU6	2008	0.268788	0.384252
PU7	2008	0.1198	0.264277
PU8	2008	0.254981	0.539346
PU9	2008	0.277033	0.501346
PU12	2008	0.27265	0.514219
PU10	2008	0.170451	0.372066
PU13	2008	0.187469	0.392684
PU11	2008	0.148269	0.343887
PU14	2008	0.12883	0.348217
PU15	2008	0.18941	0.31191
PU16	2008	0.314185	0.539525
PU17	2008	0.164286	0.29234
PU18	2008	0.198443	0.594374
PU19	2008	0.160028	0.344267
PU20	2008	0.43831	0.981986
PU21	2008	0.172953	0.228404
PU22	2008	0.165518	0.400813
PU23	2008	0.277303	0.53278
PU24	2008	0.721119	1
PU25	2008	0.207822	0.259573
PU26	2008	0.185952	0.418308
PU27	2008	0.154217	0.430891
PU28	2008	0.270913	0.355981
PU29	2008	0.101034	0.229241
PU30	2008	0.385302	0.804373
PU31	2008	0.271016	0.745633
PU32	2008	0.22145	0.452119
PU33	2008	0.209271	0.397311
PU34	2008	0.240567	0.586437
PU35	2008	0.138895	0.253291
PU36	2008	0.265681	0.325446
PU37	2008	0.148289	0.322194
PU43	2008	0.377598	0.542085
PU38	2008	0.320085	0.772965
PU39	2008	0.237561	0.495483
PU40	2008	0.257453	0.508133
PU41	2008	0.464597	0.830392
PU42	2008	0.139066	0.332126
PU44	2008	0.169859	0.388239
PU45	2008	0.212509	0.365793
PU46	2008	0.311365	0.462737
PU47	2008	0.287884	0.387518
PU48	2008	0.198033	0.381385
PU49	2008	0.157368	0.380813
PU50	2008	0.113108	0.294067
PU51	2008	0.235092	0.354775
PU52	2008	0.154116	0.335306
PU53	2008	0.163968	0.386802

Table D4: Efficiency Results of HEIs by DEA (Year 2009)			
DMU	**Year**	**Cost Efficiency (M6)**	**Technical Efficiency (M4)**
PU1	2009	0.256065	0.556161
PU2	2009	0.175412	0.378005
PU3	2009	0.317745	0.566135
PU4	2009	0.174622	0.250999
PU5	2009	0.476182	0.76918
PU6	2009	0.382569	0.621514
PU7	2009	0.299137	0.596411
PU8	2009	0.242759	0.48394
PU9	2009	0.461167	0.667144
PU12	2009	0.297765	0.451621
PU10	2009	0.23918	0.387135
PU13	2009	0.317675	0.58131
PU11	2009	0.184217	0.395073
PU14	2009	0.122601	0.259631
PU15	2009	0.36207	0.518925
PU16	2009	0.439816	0.615246
PU17	2009	0.254332	0.405791
PU18	2009	0.301535	0.709936
PU19	2009	0.207595	0.41233
PU20	2009	0.487408	1
PU21	2009	0.36221	0.595333
PU22	2009	0.170186	0.450857
PU23	2009	0.238573	0.42244
PU24	2009	0.698691	1
PU25	2009	0.234673	0.325069
PU26	2009	0.134307	0.411991
PU27	2009	0.168205	0.413506
PU28	2009	0.553472	0.62611
PU29	2009	0.289564	0.655674
PU30	2009	0.404886	0.707603
PU31	2009	0.225574	0.854871
PU32	2009	0.191522	0.419256
PU33	2009	0.328578	0.496473
PU34	2009	0.1937	0.455771
PU35	2009	0.204868	0.302701
PU36	2009	0.620438	0.699006
PU37	2009	0.152016	0.290404
PU43	2009	0.566646	0.74938
PU38	2009	0.361954	0.649577
PU39	2009	0.253231	0.490035
PU40	2009	0.194725	0.556457
PU41	2009	0.320894	0.744753
PU42	2009	0.170658	0.370733
PU44	2009	0.262671	0.476738
PU45	2009	0.18318	0.344592
PU46	2009	0.582718	0.743388
PU47	2009	0.459155	0.565897
PU48	2009	0.243327	0.342091
PU49	2009	0.234998	0.420434
PU50	2009	0.162708	0.351465
PU51	2009	0.411902	0.5605
PU52	2009	0.23952	0.363896
PU53	2009	0.179017	0.402437

Table D5: Efficiency Results of HEIs by DEA (Year 2010)			
DMU	**Year**	**Cost Efficiency (M6)**	**Technical Efficiency (M4)**
PU1	2010	0.258093	0.447135
PU2	2010	0.173308	0.386538
PU3	2010	0.301877	0.433258
PU4	2010	0.172697	0.2408
PU5	2010	1	1
PU6	2010	0.45827	1
PU7	2010	0.372884	0.75126
PU8	2010	0.225274	0.476348
PU9	2010	0.445015	0.613278
PU12	2010	0.334975	0.435132
PU10	2010	0.223656	0.38806
PU13	2010	0.368342	0.690602
PU11	2010	0.197696	0.40134
PU14	2010	0.173111	0.259036
PU15	2010	0.451961	0.846367
PU16	2010	0.418016	0.686288
PU17	2010	0.262717	0.478091
PU18	2010	0.317823	1
PU19	2010	0.386889	0.586292
PU20	2010	0.517915	1
PU21	2010	0.554127	1
PU22	2010	0.219703	0.435162
PU23	2010	0.237256	0.447909
PU24	2010	0.758289	1
PU25	2010	0.256233	0.376057
PU26	2010	0.141199	0.418938
PU27	2010	0.202506	0.417415
PU28	2010	0.580252	0.698271
PU29	2010	1	1
PU30	2010	0.478677	0.752808
PU31	2010	0.193615	0.8772
PU32	2010	0.267362	0.433021
PU33	2010	0.352723	0.552386
PU34	2010	0.226009	0.516224
PU35	2010	0.211627	0.349878
PU36	2010	1	1
PU37	2010	0.18825	0.332294
PU43	2010	0.726163	1
PU38	2010	0.367048	0.716895
PU39	2010	0.227504	0.419827
PU40	2010	0.181968	0.428097
PU41	2010	0.35646	0.686968
PU42	2010	0.210827	0.440779
PU44	2010	0.286163	0.47783
PU45	2010	0.231405	0.381936
PU46	2010	0.652435	0.782252
PU47	2010	0.476269	0.602942
PU48	2010	0.319599	0.47203
PU49	2010	0.264962	0.46981
PU50	2010	0.191301	0.373061
PU51	2010	0.416804	0.577912
PU52	2010	0.216769	0.330297
PU53	2010	0.193189	0.420338