Technical Efficiency in Electricity Generation Sector of Pakistan -- The impact of Private and Public Ownership

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Abstract

This paper conducts a comparative technical efficiency analysis of 21 electricity generation plants (12 private and 9 public) using panel data of 6 years (1998-2003), and two stat-of–the art methodologies: Stochastic Frontier Analysis (SFA) and Data Envelopment Analysis (DEA). The results show a mixed technical and scale efficiency scores for the public and private generation plants. There are some public and private firms, which have high technical efficiency scores. However the results also suggest that the public ownership has a negative impact on the technical efficiency of the firms. Due to less apparent differences in production structure between, public and private plants, it is suggested that benchmarking of public firms using private plants as a comparators, is feasible and desirable. On a more empirical basis, our study bridges an important gap in research on the technical efficiency of private and public electricity generation sector.

Keywords: Electricity; SFA; Malmquist DEA; Ownership

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1. Introduction

During the last two decades, many developing countries like India, Pakistan etc have started the reforms in electricity sector. The main objective of these reforms was to shift the ownership from state owned and centralized organization of infrastructure to private ownership. The reasons for this shifting of ownership were the burden of price subsidies, low service quality, low collection rates, high network losses, and poor service coverage. Due to these problems, it is realized that governments are no longer willing to or able to support the existing arrangements (Newbery, 2002; Joskow, 1998). So as a result, the reforms have sought to transform the state-owned and centralized electricity sector into decentralized, market oriented industries with private sector participation.

This paper reports a study technical efficiency in electricity generation sector of Pakistan. Many developing countries are interested in restructuring and privatizing the electricity sector. Some have already done so and some are planning to adopt similar policies and reforms. There are some concerns what model should be used. There is a lack of theoretical and empirical analysis in predicting what type of reform will best suit the developing countries like Pakistan and whether there is any way to avoid the costly regulation for the sector.

There have been major efforts, with the help of international donors like World Bank and IMF, to restructure the power sector of many developing countries. In many cases, the privatization has been proposed as the end goal. The major problem in developing countries is the introduction of competition in generation sector.

This paper aims to test the null hypothesis of the existence of technical efficiency in publicly owned firms. This is achieved by using the annual reports of the companies and collecting data during field visit to electricity sector of Pakistan. For the estimation of the models, two distinct state-of the–art methodological approaches, viz., Data Envelopment Analysis (DEA) and Stochastic Frontier Analysis (SFA) have been used. Such efficiency analysis will help us in exploring how public and private sector are different in technical efficiency and whether ownership does matter?

The present study is an analysis of technical efficiency of 6 years (1998-2003) panel data of 21 electricity-generating plants. This paper is divided into 7 sections. Section 2 provides a short overview of previous empirical studies on this subject matter. Section 3 gives a brief picture of current market structure of electricity sector. Section 4 explains the two methodologies used for estimation of the models. Section 5 provides a brief description on the type and sources of data used in this study. Results are presented and discussed in section 6. Some policy implications of the results for developing countries and some concluding comments are presented in section 7.

2. Review of Previous Empirical Studies

Parametric frontier models and non-parametric methods have almost monopolised the recent literature on efficiency measurement especially for the electricity supply sector. Stochastic Frontier Analysis and Data Envelopment Analysis are the best method to use to determine the efficiency and relative performance of the firms. Empirical applications usually appeared as either one or other of these techniques. The joint use of these approaches can improve the reliability of estimation method and results of the study.

Coelli (1995) Pitt (1981) and Pollitt (1995) have developed used the analysis of efficiency in the economic literature. There has been a numerous and wide ranging collection of papers and articles on the measurement of productivity and efficiency. There has always been a close link between the measurement of efficiency and the use of frontier functions. Different techniques and variables have been used to estimate the frontier production or cost function. In this study we go through the joint use of parametric and non-parametric approaches as well as their application to the electricity generation sector of Pakistan.

Most of the research papers and articles related to the measurement of efficiency have based their analysis on parametric or non-parametric methods. The choice of methods has been an issue of debate. Some researchers like Berger (1993) prefer the parametric approach than a nonparametric technique (Seiford and Thrall 1990). Both approaches have advantages and disadvantages. So therefore, we decided to use the both approaches for our study. By doing so one can hope to avoid the weakness inherent and benefits of each approach.

Meibodi (1998) applied parametric techniques of efficiency measurement for electricity industries of developing countries. He found that public ownership of electricity might have an adverse effect on technical efficiency. The substantial proportion of the variation in efficiency within the electricity industry in developing countries is due to the size of the plant. The results of the study also indicate that increasing returns to scale are present in electricity generation of most developing countries. This study also argues that the developing countries should avoid using the unnecessary resources to increase the efficiency and productivity of the plant It is also argued that the large scale plants are not necessarily have economies of scale.

Meibodi conducted his y in the context of the Iranian electricity sector using panel data for 1990-1995. He estimated a stochastic frontier production function and applied data envelopment analysis. For efficiency determination of the firms, we decided to use the similar methodology. By looking the results, we would be able to analyze the performance and efficiency of the electricity generation sector of Pakistan.

Morten and Estache (2002) believe that the monitoring of performance of private and public monopolies in South America is a hard job. The reason is that these monopolies do not provide the proper information to the regulator. These firms only release the information when they have an interest to do so. The paper provides estimates of efficiency levels in South America's main distribution companies between 1994-2000. They estimated SFA and DEA models to measure the efficiency levels of electricity firms included in the sample.

The paper also suggests that to avoid the information problem there should be an international coordination among the regulators. They believe that more comparison across the countries, the more effective would be the form of competition. In this study the determinants of efficiency and sources of inefficiency were not discussed. It is also observed that the authors did not try to find out the relationship between efficiency level and the size of the firms.

Zamorano and Cervera (2000) used both parametric and non-parametric frontier methods to measure the production efficiency in the industrial sector. They argue that the joint use of these approaches can improve the results.

Zamorano and Cervera claim that the main disadvantage of nonparametric approach is its deterministic nature. The DEA technique makes no accommodation for statistical noise. However, the parametric approach requires specification of a particular technology for the frontier as well as the definition of a specific distribution for the inefficiency term.

Morten and Estache also claim that the parametric deterministic approach for the measurement of productivity efficiency does not seem to be suitable for this kind of analysis. However, DEA provides a suitable way of treating the measurement of economic efficiency. At the end, they also highlighted the areas for further research such as estimating the efficiency level after adding a variable of 'electricity pricing' and increasing the sample size. It is worth mentioning that this study differs from the study conducted by Meibodi (1998) becuase there is a relationship between the sources of inefficiency and the size of the firms. This study argues that no relationship between the size of firms and their inefficiencies seems to exist. The reason is that they find decreasing returns to scale (DRS) for the large size firms.

Jarm, Jukka and Satu (2002) analyzed the benchmarking results of electricity distribution companies in Finland. They used a DEA approach to measure the efficiency of 95 companies and also completed sensitivity analysis for the period of 1999-2000. The sensitivity analysis showed that the present efficiency benchmarking method treats the network companies unequally. The effects of the changes in operational costs are different for efficient and inefficient companies. For efficient companies, the changes effect slowly or they do not affect at all. For inefficient companies the effects of changes in operational costs are logical because they behave according to DEA approach. They also argue that the affect of the changes in interruption times of customers affect the efficiency scores. The reason is that the more interruption in the electricity supplies decreeses the quality of the service. According to the authors, DEA technique was found as a good base for the efficiency benchmarking of the distribution companies but it has to be further developed by taking into account the special nature of the electricity distribution business.

It seems that the authors faced some problems in measuring and evaluating the results of DEA approach. The reason could be not using the joint approach of parametric and nonparametric approaches. The results of this study could be better if both approaches were used and results were compared with each other's.

Mayer (2000) uses non-frontier regression to study reliability problems of Small Island in electricity generation. He concluded that the inability of most Caribbean and Pacific island to tap power from an inter-continental transmission grid has meant that these islands have significantly larger capacity margins in order to a given reliability criterion. The present paper is an attempt to bridge this gap in empirical research on developing countries.

3. Structure of Electricity Market in Pakistan

Electricity is a main engine for economic activities and industrial growth. Reliable, secure and cheaper electricity supply is needed for commercial activities. In developing countries, it is one of main source of employment, revenue for government. It has main three subsections namely generation, transmission and distribution. Before 1980s, it was considered as a public sector natural monopoly. From the last two decades, it is experiencing the restructuring, privatization and private participation. Due to reforms and globalization process, many countries liberalized it.

In Pakistan, like other developing countries, electricity sector was a vertically integrated public sector. In such a public owned sector, there may have cost of poor planning, which is paid by the customers in the form of higher tariff rates and poor quality of service. One of the reasons for this situation is a political intervention, which is common in developing countries especially in South Asia. As a result, overstaffing, mismanagement, inefficiency and unreliability of supply are the main characteristics of the sector. In addition to, there are high system losses and poor collection of bills from the customer, which leads to affect the financial health of the industry. To overcome the mentioned problems, Government of Pakistan (GOP) realized the situation and pressure from the international donor agencies (IMF, World Bank and ADB) and started the reform process in this sector. Thus in 1980s, GOP liberalized the sector and invited private sector participation and foreign investment in thermal generation. This was the beginning of restructuring of electricity sector in Pakistan.

In this regard, GOP introduced several power policies (see chapter 3) and restructuring plan for the sector. In the following section a current and future structure of the sector is analyzed.

3.1 Overview of Electricity Sector in Pakistan

Electricity sector in Pakistan is characterized as a semi public and semi privatized vertical integrated sector. There are two main players in public sector namely WAPDA and KESC. The overall, Federal Ministry of Water and Power is the principle organ to introduce and implement the policies. WAPDA and KESC are the public owned units. KESC is public limited company established in 1931 under the Indian Act provides electricity for Karachi and its surrounding areas. KESC is ranked among top 15 companies of Pakistan in terms of market capitalization and listed in all stock exchanges of Pakistan. It is principally engaged in generation, distribution and transmission. Its total covered area is around 6000 square kilometers and it has a customer base of 1.7millions predominately urban. The total population in its area is more than 10 millions. It has 9.91 % share in installed generation capacity. Due to poor performance, power losses and financial loss, GOP has decided to privatize it and now it is on the privatization agenda of the government.

WAPDA is a major key player in the electricity sector of Pakistan. It was created in 1958 as a semi autonomous body for the purpose of carrying out accelerated and unified development of water and power resources. It supplies electricity to the entire country except for Karachi and its surrounding areas.

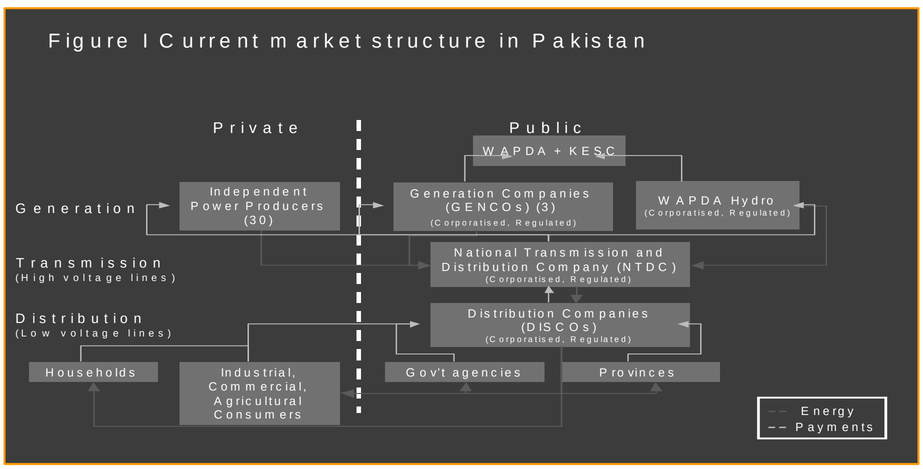


Figure I Current market structure in Pakistan

In case of electricity generation WAPDA produces 54.7% electricity and 100% share in distribution. There are 13 million total numbers of consumers, out of 22 million estimated households. About 55% of the total population is estimated to have access to electricity. Only 40 % of rural areas are electrified. It seems 45 % in total population and 60% in rural areas; people do not have access to electricity. All these people are using the alternative sources of power like oil etc.

So far the financial health of the sector, the accrued liabilities of WAPDA and KESC run into over Rs. 60-70 billion. Both the key player of public sector is facing losses and their financial position is going down. Due to these problems, GOP introduced a plan for restructuring and privatisation of this sector to improve the efficiency, service and quality. It is expected, as a result reduction on the fiscal losses for government. Almost 60% target is achieved in this regard. The figure II shows the current structure of the sector while the figure III shows the post-restructuring scenario.

The figure I crlearly shows that the public sector side is much hevier than private. Public sector has almost 100% share in distribution and hydroelectricity generation. There are three generation companies (Gencos) working under WAPDA producing thermal electricity generation. As mentioned earlier, WAPDA is under heavy restructuring plan, a full restructured scnario is presented in Figure III. Why WAPDA is restrutured and going to privatized. There are number of reasons which pushed the govt. to privatized its power sector and decided the private sector participation.. The folowing are the main reasons ;

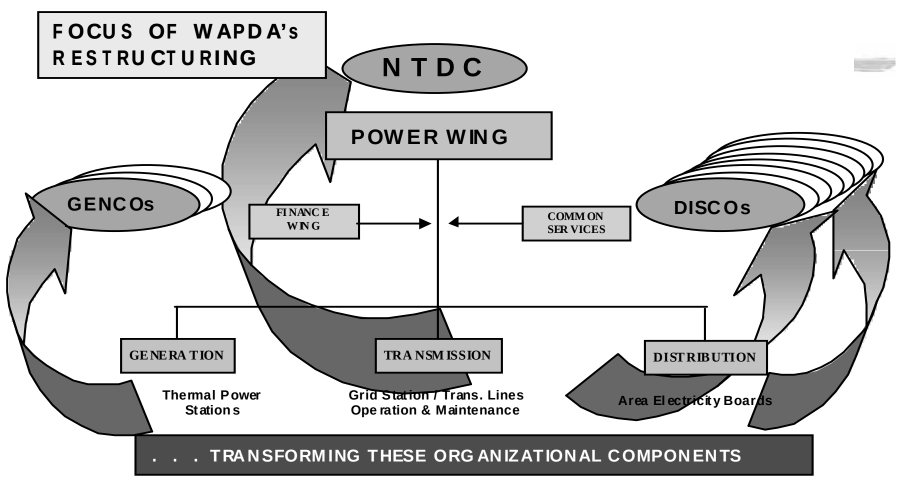


Figure II. Focus of WAPDA's Restructuring

- There were fiscal loses due to power losses. According to estimation there are 30-40% power losses, which has the value of more than 40 Billion Rs (approx 1% of GDP).
- Due to these liabilities to govt. there were serious risks of macroeconomic stability, largest source of contingent liabilities.
- To reduce the fiscal losses, govt. has to raise the tariff rate frequently, which raised the political issue and public anger. A rise in utilities tariff is also considered one of main source of poverty increase in the country, which is currently 33%.
- There was overstaffing, mismanagement and corruption in the sector.

All factors contributed to lead the sector to restructuring and privatization besides, efficiency and competition factor in sector. So in 1992, GOP introduced an unbundling plan for the power sector, which is presented in the Figure III.

4. Frontier Production Function and Efficiency Measurement

4.1. SFA Model Specification

To estimate the efficiency level of the firms, we will use econometric model and Data Envelopment Analysis (DEA) to assess the efficiency performance of Pakistan's electricity generation sector. In our study, we would test two parametric models, a stochastic frontier estimated by Maximum Likelihood (ML) and a random effect model estimated by Feasible Generalized Least Squares (FGLS) and two non parametric DEA (one with variable returns to scale (DEA-V) and other with constant to scale (DEA-C)).

As used by Martin and Christian (2002) the general stochastic frontier production function model would be;

$$\ln Y_{it} = f\left(X_{it}, t; \beta\right) + \varepsilon_{it}$$

Where Y_{it} denotes out put, X_{it} is a matrix of inputs, t represents time, β are technological parameters to be estimated, and f is some appropriate functional form. The error term is $\varepsilon_{it} = v_{it} - \mu_{it}$ where v_{it} are assumed independent and identically distributed random errors which have normal distribution with mean zero and unknown variance, σ_v^2, and μ_{it} are non-negative random variables which represent technical inefficiency.

As we know that mostly plants in our study are publicly owned, and their objective is not to maximize the profit. So, we will use the production function rather a cost function to estimate the efficiency of the firms. The translogarithmic and the Cobb-Douglas production function are the two most common functional forms, which have been used, in empirical studies on production, including frontier analysis. In our study, the most general functional form for the stochastic frontier for electricity generation in Pakistan would be a translog production function:

$$\begin{aligned} \ln Y_{it} &= \beta_0 + \beta_1 \ln X_{1it} + \beta_{2it} \ln X_{2it} + \beta_3 \ln X^2_{1it} + \beta_4 \ln X^2_{2it} + \beta_5 \ln X_{1it} \ln X_{2it} \\ &+ \beta_6 \ln X_{5it} + \beta_7 \ln T_{6it} + \beta_8 \ln T_{7it}^{\;2} + \beta_9 \ln T_{6it} \ln X_{1it} + \beta_{10} \ln T_{6it} \ln X_{2it} + \\ &\beta_{11} \ln X_{8it} + \beta_{12} \ln X_{9it} + v_{it} - \mu_i \qquad (5) \end{aligned}$$

The above model does not include the environmental variables[1]. As pointed out by Coelli, Perelman and Romano (1999), measuring net efficiency is an important issue as it allows one to one predict how companies would be ranked if they were able to operate in equaling environments. Therefore, the most general function to be estimated is as an equation (5) but including four additional environmental variables:

[1] Variables which are beyond the control of the firms e.g service area, customer density etc.

$$\ln Y_{it} = \beta_0 + \beta \ln_1 X_{1it} + \beta_{2it} \ln X_{2it} + \beta_{3it} \ln X^2_{1it} + \beta_4 \ln X^2_{2it} + \beta_5 \ln X_{1it} \ln X_{2it}$$
$$+ \beta \ln_6 X_{5it} + \beta_7 \ln T_{6it} + \beta_8 \ln T_{7it}^{\ 2} + \beta_9 \ln T_{6it} \ln X_{1it} + \beta_{10} \ln T_{6it} \ln X_{2it} + \beta_{11} \ln X_{8it} +$$
$$\beta_{12} \ln X_{9it} + \delta_1 \ln X_{10it} + \delta_2 \ln X_{11it} + \delta_3 \ln X_{12it} + \delta_4 \ln X_{13i} + v_{it} - \mu_i \qquad (6)$$

Where ln = logarithm

Y_i= electricity generated (MkWh) by the ith plant.
X_{1it}= installed capacity (MW)
X_2= Fuel consumption (BTU)
X_8= Ownership (Dummy variable)
X_9= Fuel Type (dummy variable)
X_7= Plant factor (%)
T= Time (dummy variable)
β_i are unknown parameters to be estimated.
δ_1= Load factor (%)
δ_2= System losses (%0)
δ_3= Max. demand (MW)
δ_4= Per capita consumption of electricity (MW)

For the estimation of the model, the program developed by T.Coelli (1996) would be used. As suggested by Coelli (1996), the alternative models would be estimated and the preferred model would be selected using Likelihood Ratio (LR) test. This test would be based on the Log Likelihood functions as follows:

$$LR= -2[L_R-L_U], \qquad (7)$$

Where L_R is the log Likelihood of the restricted model and L_U is the Log Likelihood of the unrestricted model.

As we know that the coefficient of the translog production function will not give any direct interpretation, we will calculate the elasticities of output with respect to each of the inputs corresponding to the model above,

$$El_k=\frac{\partial Y_{it}}{\partial X_k} = \beta_k + 2\beta_{kk}\overline{X_{it}} + \sum_{j\neq k} \beta_{kj}\overline{X_{jit}}, K = 1,2,3; j=1,2,3. \qquad (8)$$

While the returns to scale would be calculated from the sum of the input elasticities as

$$RTS=\sum_k EL_k \qquad (9)$$

The returns to scale after including environmental variables can be defined as relating to a change in all inputs and maximum demand. That would be,

$$\text{RTS}=\sum_k EL_k + \delta_3 \qquad (10)$$

The program FRONTIER 4.1, developed by T. Coelli (1996), is used for the estimations.

4.2 The DEA Model

In order to find the consistency and the comparison of the results, we would also use DEA model. For this purpose, we would use the same model as in the last section to estimate the non-parametric model. The theoretical specification of the DEA model consists in an optimization problem subject to given constraints, like the following:

$$\max \lambda$$
$$\text{s.to } \lambda\mu \leq z\,U\,,\ zX \leq x,\ zE \leq e,\ z\,\varepsilon\ \Re^n_+ . \qquad (11)$$

This problem will give us a solution the proportion (λ) in which the observed out put of the firm being analyzed and could be expanded if the firm would efficient. U is a n*r matrix of out put of the firms in the sample. X is a n*m matrix of inputs of the sample firms. E is an n*s matrix containing all the information about s environmental variables of the n firms. u,x and e are the observed out put, input and environmental variables vector, respectively, of the firms under evaluation. Finally, z is a vector of intensity parameters (z1,z2,z3------zn) that allows for the convex combination of the observed inputs and outputs.

To develop a second model, DEA-V, we would add the following constraints to the above problem (Seiford and Thrall, 1990)

$$\sum_{i=1}^{n} zi = 1 \qquad (12)$$

The model DEA-V would be a desirable choice because it would not restrict returns to scale to be constant.For the estimation of these non-parametric models, DEA-C and DEA-V, panel data would be required. There are several possibilities for estimation but we will try to use the panel data under two different assumptions concerning returns to scale-variable (Model-V) and constant (Model-C), and would calculate average of the efficiency scores of each firm. The results obtained from these models will be compared with the econometric model. There are several possibilities for the estimation of the DEA model. The DEA model may be estimated in the program FRONTIER 4.1, GAMS Version 1.0.4, and can be used the MINOS5 solver for the computations.

4.3 DEA (VR) and Malmquist Indices of Productivity Change

Panel data allows total factor productivity change (TFP) to be estimated using DEA. These indices can be decomposed into technical efficiency change and technical change.

The DEA like program can be used to calculate the Malmquist index of productivity change (Coelli, 1996).

The Malmquist Index measures the TFP change between two data points by calculating the ratio of the distances of each data point relative to a common technology. Following the Fare, Grosskopf, Lindgren and Roos (1998) specification of an output- based oriented Malmquist productivity change, it is expressed as a geometric mean of two output based Malmquist indices as given in equation (13).

$$m_0(y_{t+1}, x_{t+1}, y_t, x_t) = \left[\frac{d_0^t(x_{t+1}, y_{t+1})}{d_0^t(x_t, y_t)} \times \frac{d_0^{t+1}(x_{t+1}, y_{t+1})}{d_0^{t+1}(x_t, y_t)} \right]^{1/2} \quad (13)$$

The equation (13) will give us the productivity of the production point (x_{t+1}, y_{t+1}) relative to the production point (x_t, y_t). d_0 represents the distance from the frontier. A value greater 1 will indicate positive TFP growth from period t to period t+1. The index given in equation (13) is a combination of two indices. One index uses period t technology and other uses t+1 period technology. The subscripts in *m* and *d* indicate that it is an output-based productivity index.

The DEAP 2.1 program developed by Coelli (1996) gives five indices in its output file. It gives technical efficiency change relative to CRS technology (EFFCH), technological change (frontier shifts) abbreviated as TECHCH, pure technical efficiency change relative to a VRS technology (PECH), scale efficiency change (SECH) and total factor productivity change (TFPCH)

We implement DEA in three stages described in Table 1. In model 1, the DEA scores are generated from 1 output and 2 inputs program. In model 2, the same sample data of SFA model were used. In third stage, the efficiency scores calculated in model 1 were used to estimate the Tobit model whereby the regressors are per capita electricity consumption, max. Demand, plant factor, load factor, number of customers and ownership as a dummy variable.

Table 1: Inputs and Output in SFA and DEA Models

Model 1			Model 2
Inputs	**Output**	**Inputs**	**Output**
Installed Capacity (MW)	Units Generated (MkWh)	Installed Capacity (MW)	Units Generated (MkWh)
Fuel Consumption (BTU)		Fuel Consumption (BTU)	**Environmental Variables**
			Load Factor
			System Losses
			Max. Demand
			Per capita Consumption

5. Data and its sources

Our dataset consists of a sample of 21-generation plants in Pakistan (12 private and 9 public) involved in electricity generation. Mostly private plants are newly established after 1995 as compared to the publicly owned plants. KESC is the oldest distribution company and it also has generation capacity (1756 MW) but its major function is retail distribution. For this reason, it is dropped out. It would be included in our next study of electricity distribution sector of Pakistan. Currently, in electricity generation sector, there are three main sources of electricity generation; hydel (28.3%), thermal (69.1%) and nuclear (2.61%). The nuclear generation has a small share in total electricity generation, and hydel has a different production structure, so we decided to stick to the thermal generation. A separate study for hydel can be done in future. In thermal generation, there was issue of comparability of plants because different types of fuel are used for the electricity generation. For this purpose, a commonly used method is adopted. All fuel consumption (gas, high-speed furnis oil, low speed furnish oil high-speed diesel and combined fuel consumption) were converted into British Thermal Units (BTU). The panel data covers the period 1998- 2003 was obtained during the fieldwork and companies annual reports. Table 2 gives some descriptive statistics of key variables.

Table 2: Descriptive Statistics of key variables of the models

Variable	**Units**	**Mean**	**Std.Error**	**Std.Dav.**	**Min**	**Max**
Output	**Units generated (MkWh)**	**1747.04**	**71.09**	1945.01	**4.00**	**7161.00**
Capital	Installed capacity (MW)	483.52	71.09	**462.83**	**117**	**1638**
Fuel Consumption	**BTU**	1.886E+13	**38.74**	2.11628E+14	3770.28	2.376E+15
Plant Factor	**%**	43.05	**67.53**	21.50	**6.67**	**90.70**
Max. Demand	**MW**	10469.5	**11.37**	506.23	9609	11145

Source: Author's own calculation

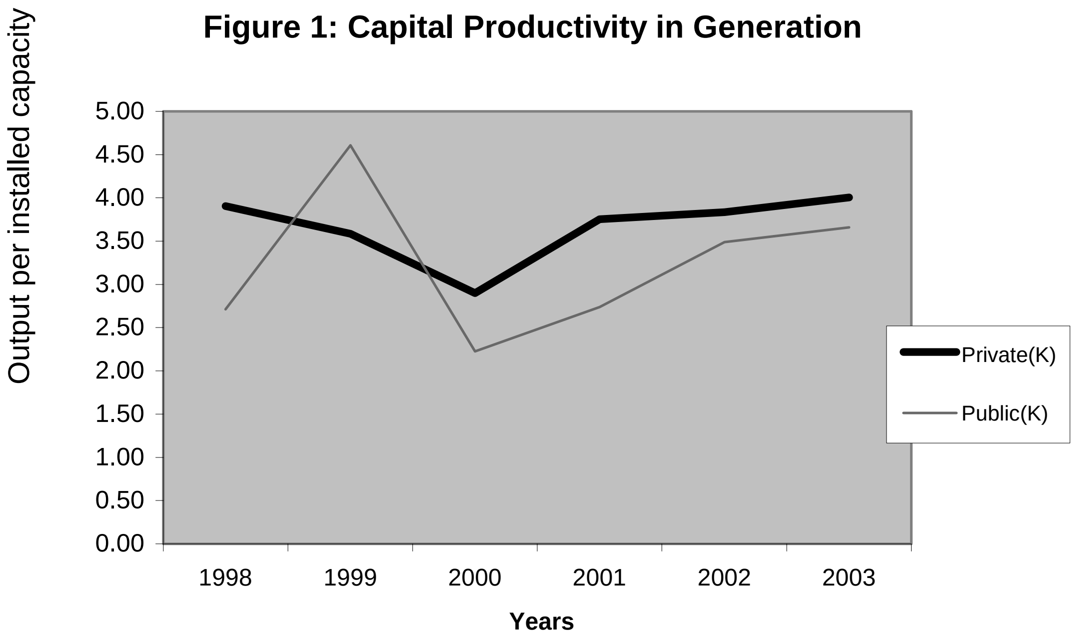
6. Results and Analysis

6.1: <u>Preliminary data analysis : Partial Productivity Measures</u>

A brief overview of the 6 years panel data indicates that there are wider fluctuations in the productivity of public plants than private plants. It also indicates that public plants are more volatile in nature due to policy changes and liberalization of generation sector.

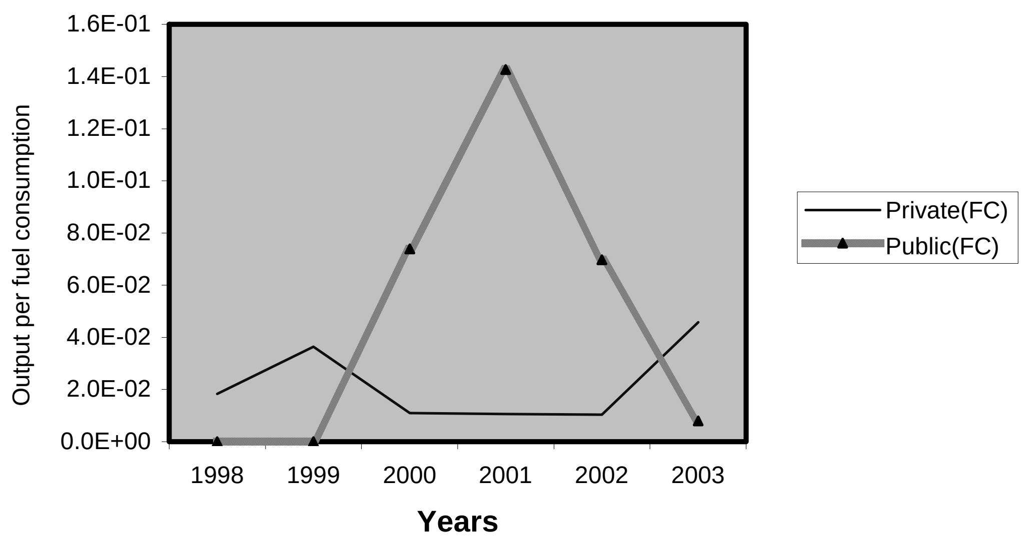
Regarding the productivity of capital (installed capacity) the net generation per installed capacity shows that private plants have relatively stable productivity over the time period of 6 years. There was a big gap before year 2000 ant it started to reduce in 2003. Both sectors are moving almost parallel which give sense of competition between them. There is wider variation capital productivity for public plants. These trends are depicted in figure 1.

Figure 1: Capital Productivity in Generation



The analysis of fuel productivity in generation shows that fuel productivity in the public sector is highly volatile. There is a sharp rise and decline before and after year 2001, while private plants have a stable productivity growth over the period. The trends are presented in figure 2.

Figure 2:Fuel Productivity in Generation



6.2 Results from Stochastic Frontier Analysis

In this section SFA results of the translog equation (6) are discussed. The results and the summary likelihood tests are presented in Tables 3 and 4. Three main results are of interest here. Firstly, the best functional form for the industry is a translog functional form with some environmental variables. Secondly, almost all technical inefficiencies are explained by the model rather than statistical noise ($\gamma = 0.998$). Such inefficiencies are explained by the variable of maximum demand (max.demand) and per capita consumption of electricity (percapcons). Finally, we also found that there is not much difference between the public and private production structure. The main results are explained in the following sections in details.

6.3: Choosing a Preferred Functional Model Specification?

We did several tests to choose the correct functional form of the model for the estimation. The first test is conducted to find whether the Cobb Douglas is the right functional form. The test involves imposing the restrictions $\beta_{11} = \beta_{22} = \beta_{12} = 0$ on the translog model. The likelihood test ratio λ (given in the table 3) is 27.60. The critical value (5% chi-square value) is equal 18.55. So the null hypothesis cannot be accepted. Hence we can conclude that the translog functional form is better than Cobb Douglas function.

Table 3: Likelihood Ratio Tests

Null Hypothesis	χ^2- **Critical Value**	χ^2-**TEST STATISTICS ***	**DECISION**
$H_0: \beta_{11} = \beta_{22} = \beta_{12} = 0$	18.55	27.60*	H_0: Rejected;
$H_0: \gamma = 0$	18.55	72.0*	H_0: Rejected
$H_0: \mu = 0$	7.88	94.30*	H_0: Rejected;
$H_0: \eta = 0$	18.55	72.0*	H_0: Rejected;
$H_0: \delta_0 = \delta_1 = \delta_2 = \delta_3 = \delta_4 = 0$	10.60	75.68*	H_0: Rejected;

Statistically significant at the 0.05 level
Source: Authors own estimation

6.4: Is there Technical Inefficiency in this Industry?

The second test that we performed on the SFA model to find out the whether there is any technical inefficiency in the generation sector. This is done by imposing the restriction on SFA translog model that $\gamma = \delta_0 = \delta_1 = \delta_2 = \delta_3 = \delta_4 = 0$. As we can see in table 3, the calculated statistical value is 75.80, which is higher than the critical value of chi-square of 10.60. This allows us to retain a model that includes the environmental variables.

The preferred translog model has a value $\gamma = 0.998$ for the estimated stochastic model. This indicates two important things; first is that 99.8 % variation in the data among the firms can be explained with in the model. The only 1.2 % is a statistical noise, which is quite low especially for a developing country like Pakistan. So, It shows that most of the differences among firms are due inefficiency and not due to stochastic error. Secondly, all predicted technical inefficiency is fully accounted for by the TE variables (δ_i) used in the translog model. This is an important implication that there are identifiable inefficiencies among firms and on this basis; we can develop reliable benchmarking criteria.

It is interesting to note that all technical inefficiency factors included in the translog model are significant but there is only factor (max.demand), which has positive significant effect.

<u>6.6: Summary of Output Elasticities</u>

SFA allows us to estimate the input elasticities. As we, know the estimated coefficients of translog model do not directly give any interpretation. So, output elasticities are measured at means of relevant data points. The results of the estimated elasticities are presented in the Table 5 and obtained from equation (8).

The output elasticity of capital is equal to 4.41. It shows that in electricity generation capital (installed capacity) has significant positive impact on electricity generation. This elasticity value is not different than the elasticity calculated in other previous studies. Positive but higher output elasticity with respect to installed capacity was also reported by Lovell and Schmidt (1980) and Kopp and Smith (1980).

With regards to the elasticity of fuel inputs (-1.20), we found it negative but greater than unity. It shows that fuel inputs are not significant constraint as compared to capital on production efficiency. It implies that adding more fuel inputs may not increase the generation of electricity. In our case, both input elasticises are more elastic but have different signs to each other.

The regression indicates increasing returns to scale (3.21) for the electricity generation sector. With regard to technical progress, the results show that there is high positive technical growth in public plants as compared to private plants. The technical efficiency change is presented in table 5 indicate the highest technical efficiency change is in a public plant NGPS Multan (89.81%) during the period of 6 years. The lowest technical efficiency change (-12.49) is in the plant of private sector (HUBCO). The reason of lowest technical change for that plant might be the dispute of tariff between government and the HUBCO. The uncertainty about the future of the plant adversely affected the technical efficiency growth. As the results indicate that there are significant positive technical changes in public plants, the government should think twice before privatising such efficient plants. The results contrast to Malmquist DEA results, which also shows that there is a positive technical change in the generation sector over the period of 6 years. The average DEA technical change is still less than unity (0.73), so it implies that still the sector has the capacity of 27% to improve and to achieve the level of full efficiency.

Table 5: Output elasticities for the electricity generation in Pakistan

With respect to	Estimated Elasticity
Capital	4.41
Fuel Consumption	(-1.20)
Time	3.77
Returns to Scale	3.21

Source: Author`s calculation

6.7 Malmquist Efficiency Change

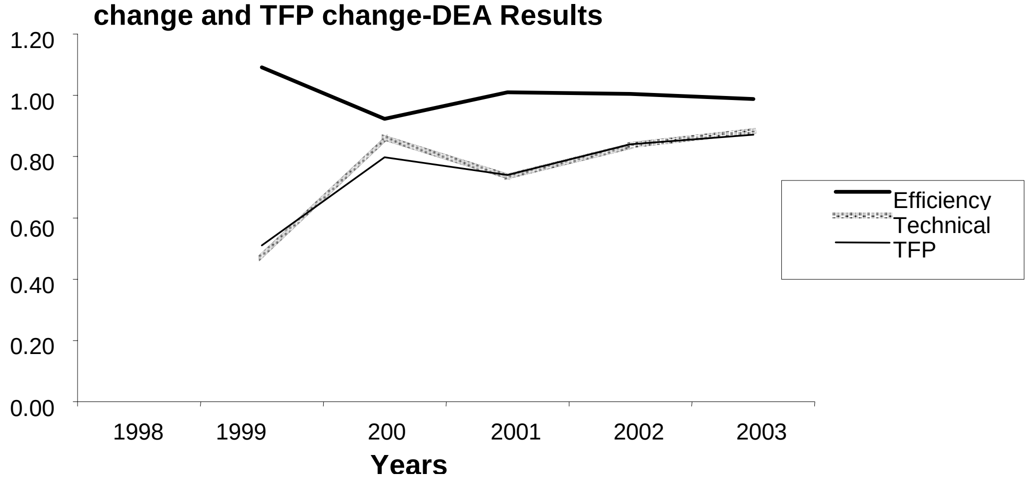
For the reason of space, only the efficiency change, Technical change and TFP change over the period is reported. Table 6 reports the results of Malmquist efficiency change. To estimate the Malmquist efficiency change, the same sample data of SFA were used. The results summarised in table 5 and figure (3) indicates that in technical efficiency, there is decline of 8.6% over the period of six years. Regarding the technical change and TFP change there is a significant growth of 36.8% and 33 % respectively. However, despite a big improvement in technical and TFP change in the sector, there is no single plant in the sector, which is fully efficient. All plants scored less than unity. It is justifiable for the private firms that they are quite new to start the production but for the public plants, it is strong observation that they are still have less than 1 score, producing electricity more than 10 years. Only two private plants, KEL (0.008) and AES Lalpir (0.008) and one public plant FBC Lakhara (0.016) could achieve managerial efficiency (see table 1A). It also confirms what we have observed in the field visit about the relatively efficient firms. There is no frontier shift for any public or private plants (no one could score more than unity). Again KEL (0.031), AES Lalpir (0.031) and FBC Lakhara (0.070) could have pure technical efficiency change over the sample period. Regarding the scale efficiency, KEL, AES Lalpir and FBC Lakhara, has the score less then unity. It may imply these plants are operating less than the scale.

Table 6: Cumulative indices of Technical Efficiency Change, Technical Change and TFP Change – DEA Results

Year	Efficiency Change	Technical Change	TFP Change
1998	-	-	-
1999	1.091	0.468	0.510
2000	0.923	0.864	0.798
2001	1.010	0.733	0.740
2002	1.005	0.836	0.840

Source: Author's calculation

Figure 3: Commulative indices of Efficiency change, Technical change and TFP change-DEA Results



There is divergence in the results derived from the two methodologies. Further research is required to attempt to ascertain the reasons for these differences. However, if we take the TFP change (33.4%), the implied performance of the sector is fairly good and both sector are working closer. No much difference is found between them in this regard. As mentioned earlier, no plants is operating on the frontier and there is no frontier shift for any plants involved in the generation sector which implies a poor performance of the sector over all. This poor performance of the sector requires further reforms, competition and a suitable regulation for this sector to get higher performance.

6.8: Tobit Analysis of Efficiency Scores.

To find out the impact of ownership, Tobit analysis is performed on efficiency scores. Therefore, the efficiency scores of SFA were submitted to Tobit model in order to test that the public ownership might have the adverse impact on technical efficiency. The proffered model is chosen, because the dependent variable is restricted to have the value between zero and one. For estimation, maximum likelihood technique is preferred. The reason is that it gives unbiased and consistent parameters. The results of the model are presented as below.

E*= 1.1585C+0.0005 SIZE- 0.0063 PUBOWN
Se= (0.170) (0.000) (0.0025)
t. Statistics= (1.61) (-2.47)
LR Chi2 (2) = 8.37, Log likelihood value=36.64, N=126
E*= Technical efficiency score (0-1)
SIZE= measured as installed capacity (MW)
PUBOWN= share of public electricity production out of total electricity generation.

The results suggest that there is a negative impact of public ownership. The null hypothesis is accepted that the public ownership might have an adverse impact on technical efficiency scores. The results presented in earlier sections also support that the private plants have less variation and more managerially efficient then public firms. How over these finding are not correct across the board. One this is confirmed by the results that in this sector there is a high capacity to improve the efficiency of the plants involved in the electricity generation.

7. Conclusion

Before concluding this paper three points need mentioning:

1. The electricity generation sector of Pakistan is liberalised in early 1990s. As result of first power policy, private electricity generation was allowed. So mostly private plants started their production after 1995 and quite new in technology and experiences as compared to the public generation plants.

2. There is only almost 2 % statistical noise and 98 % data is explained with in the model. It is interesting to note that all technical inefficiency factors included in the translog model are significant but there is only one factor (max.demand), which has positive significant impact.
3. The mean efficiency of the sector is 78 % and there is 8 % of growth during the period of 1998-2003. In the sector still there is 22 % inefficiency. No firm is on the frontier using DEA and SFA results.

The comparative analysis of technical efficiency of a panel data 21 electricity generation plants over a period of 6 years suggest that there are identifiable technical inefficiencies in electricity generation. It invites further reforms, competition and a suitable regulation for the sector. The SFA analysis shows that all inefficiency factors included in the model are significant and determine the sources of inefficiency.

The Malmquist DEA analysis shows that only two private and one public firm could gain managerial efficiency. Al though, there is a significant growth in technical and TFP but still the DMUs are producing below the frontier. It indicates that there is capacity to improve the performance of the sector.

Regarding the impact of public and private ownership, there is a reason to believe that the public ownership has the adverse impact on the technical efficiency of the plant. Finally, the analysis also shows that there is not a big difference in the production structure of public and private plants, therefore, after adjusting the inefficiency factors like load factor, system losses, maximum demand and per capita consumption of electricity sector could effectively be benchmarked against each other.

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Table 1A: Estimated Efficiencies for Electricity Generation SFA Results

Year/Firm	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**	**Average/ Firm**
KAPCO	0.82	0.80	0.76	0.86	0.87	0.74	0.81
HUBCO	0.90	0.86	0.89	0.93	0.88	0.68	0.85
KEL	0.81	0.80	0.76	0.58	0.69	0.71	0.71
AES LALPIR	0.84	0.85	0.63	0.67	0.63	0.57	0.67
AES PakGen	0.71	0.92	0.89	0.83	0.91	0.81	0.87
SEPCOL	0.17	0.16	0.62	0.67	0.77	0.83	0.61
HABIBULLAH COASTAL	0.94	0.88	0.68	0.95	0.91	0.94	0.87
FKPCL	0.88	0.16	0.75	0.90	0.93	0.91	0.73
ROUSCH	0.92	0.75	0.66	0.92	0.94	0.91	0.84
SABA	0.82	0.82	0.69	0.83	0.79	0.85	0.80
JAPAN POWER	0.68	0.83	0.48	0.74	0.83	0.81	0.74
UCH POWER	0.92	0.77	0.90	0.91	0.89	0.88	0.87
Average Private	**0.78**	**0.71**	**0.72**	**0.81**	**0.83**	**0.80**	**0.78**
TPS JAMSHORO	0.61	0.77	0.77	0.80	0.79	0.80	0.79
GTPS KOTRI	0.79	0.84	0.87	0.90	0.87	0.81	0.86
FBC LKHRA	0.89	0.93	0.87	0.91	0.87	0.83	0.88
TPS GUDDU (1-4)	0.79	0.84	0.49	0.91	0.87	0.86	0.79
TPS GUDDUE (5-13)	0.93	0.95	0.36	0.35	0.89	0.90	0.69
TPS M. GARH	0.66	0.73	0.83	0.84	0.91	0.87	0.84
SPS FAISALABAD	0.20	0.97	0.11	0.66	0.65	0.81	0.64
GTPS FAISLABAD	0.39	0.70	0.72	0.67	0.66	0.66	0.68
NGRPS MULTAN	0.11	0.92	0.77	0.87	0.92	0.87	0.87
Average Public	**0.60**	**0.85**	**0.64**	**0.77**	**0.83**	**0.82**	**0.78**
Average/Year	**0.70**	**0.77**	**0.69**	**0.80**	**0.83**	**0.81**	**0.78**

Source: Author's estimation

Table 2A: SFA and OLS Regression Results

Coefficients	Translog	Cobb-Douglas	OLS
Intercept: β_0	0.7255(0.3454)	0.6252(0.1624)	-0.1199(0.5873)
β_1 (log capital)	0.1919(0.7109)	-0.5426(0.5808)	-0.2847(0.1175)
β_2 (log fuel consumption)	0.3874(0.3639)	0.7923(0.2971)	0.2257(0.5921)
β_3 log (capitol x capital)	0.8137(0.7638)		0.5573(0.1181)
β_4 log (fuel x fuel)	-0.4264(0.3901)		-0.2667(0.5937)
β_5 log (capital x log fuel)	0.1248(0.6937)		-0.1749(0.9115)
β_6 log (ownership)	-0.1948(0.9018)		-0.2472(0.1414)
β_7 log (time)	-0.1301(0.1171)		0.2626(0.1838)
β_8 log (time x time)	0.1238(0.1075)		0.5712(0.1530)
β_9 (log time x capital)	-0.1338(0.6102)		-0.1963(0.1003)
β_{10} (log time x log fuel)	0.6753(0.3014)		0.9299(0.5017)
β_{11} (log fuel type)	0.5078(0.1880)		-0.2487(0.3106)
β_{12} (log plant factor)	0.1212(0.6753)		0.2941(0.1059)
δ_0 (Intercept)	-0.7524(0.4722)	-0.5513(0.3523)	
δ_0 **(log load factor)**	-0.1354(0.8367)	-0.9924(0.6163)	
δ_1 (log system losses)	-0.1053(0.6538)	-0.7718(0.4835)	
δ_2 (log max. demand)	0.1815(0.1137)	0.1209(0.7736)	
δ_3 (per capita consumption of electricity)	-0.1892(0.1166)	-0.1403(0.8663)	
Sigma square	0.6981	0.6618	0.1580
γ	0.9981	0.9964	
LLF	-19.66	-33.46	-55.68
λ		67.81	72.03

Standard Errors in parenthesis

Figure 1A:Technical Efficiency Of Public and Privata Plants SFA Results