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Reform and Efficiency: An Application to Iranian Regional Electricity Companies

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Abstract

The electricity in Iran, like many other countries, has undergone a reform. This reform which separated the distribution sector from the regional electricity companies took place in 1993. The main objective of this paper is to analyze the cost structure of Iranian regional electricity companies with respect to scale and cost efficiency, in order to evaluate the changes in the performance of these companies through the reform. To that end, a translog average cost function was estimated for a panel of 16 Iranian regional electricity companies over the period 1989–1990 to 2002–2003, using the time–varying cost efficiency frontier model suggested by Cornwell, Schmidt and Sickles (1990). The results indicate the existence of economies of scale pre and post–reform for all companies; however, it is more evident after the reform. In addition, the findings on cost efficiency show that most of these companies were suffering from the low efficiency, and the reform has improved the efficiency of the majority of companies.

Keywords: Reform; Regional Electricity Companies; Average Cost Frontier Model; Economies of Scale; Cost Efficiency; Iran.

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1- Introduction

Several countries have undergone reforms in the institutional and organizational framework of their electricity industry since the late 1980s. In Iran, too, in line with the government policy to reduce government's undertaking and to enhance economic efficiency, the ministry of energy (MOE) has reformed the organizational structure of the state owned companies affiliated to the ministry. One of these reforms was the separation of distribution activity from regional electricity companies (RECs) in 1993. The Iranian electricity distribution units are public and act under the supervision of TAVANIR Company[1] (Iran Power Generation, Transmission and Distribution Management Company). There exists little work on evaluation of such reform policies2. Benchmarking models have played a crucial role in evaluating of regulatory policies in the electricity sector, both in transmission and distribution. One of the most interesting approaches in benchmarking models is based on the estimation of a frontier function for a sample of firms.

Basically, the literature on the measurement of productive efficiency utilizes both frontier and non–frontier approaches. The measurement of efficiency has been one of the main motivations for the study of frontier functions. Two distinct approaches, namely econometric method and data envelope analysis (DEA), exist for estimating the efficiency, in which both methodologies involve the estimation of "best practice" frontiers, with the efficiency of specific firms, measured relative to frontiers. In the econometric method, different approaches to production and cost frontiers are used to obtain the components of productive efficiency; technical and allocative efficiency. Although, most applications of the frontier methodology have been to estimating production frontiers, but estimation of production frontiers yields information only on technical efficiency. The cost frontier yields information on the extra cost of both technical and allocative inefficiency[3].

1- TAVANIR is responsible for generation, transmission and distribution of electricity in Iran. This company acts under the supervision of MOE.
2- For example see Meibodi (1998) and Sadjadi and Omrani (2008).
3- For more details and good discussions in this subject refer to Kumbhakar, and Lovell (2000). New developments are available in Fried, Lovell, and Schmidt (2008).

A number of relative efficiency studies have addressed different aspects of the electricity industry. The focus of many of them is on economies of scale and density or the relationship between ownership and efficiency[1].

Cost functions in the electricity distribution industries are well documented in empirical research. Based on the experience of other researchers and given the nature of the data available to us, we decided to apply stochastic average cost frontier approach on 16 Iranian RECs, over the period 1989–1990 (1368) to 2002–2003 (1381)[2], to obtain their cost efficiency in order to judge the success of structural reform in RECs through improvement of their performance. A frontier average cost function defines minimum average costs given output level, input prices, output characteristics and the existing production technology. It is unlikely that all firms will operate at the frontier. Failure to attain the average cost frontier implies the existence of cost inefficiency, including both technical and allocative inefficiency.

The rest of the paper proceeds as follows: In the next section an average cost frontier model for RECs is developed. In section 3 a data set of 16 Iranian RECs is presented. Section 4 summarizes the estimation results and gives some insights on scale and cost efficiency of the Iranian RECs. In section 5, results are summarized and some conclusions are drawn.

2- Average cost frontier model for RECs

2-1- The stochastic average cost frontier model

In this work we consider the estimation of a stochastic average cost frontier using the approach suggested by Cornwell, Schmidt and Sickles (1990) for panel data. To illustrate this econometric approach, consider the average cost function in the separated intercept form[3].

1- See Jamasb and Pollitt (2001) for a survey of international experience and Farsi and Filippini (2009) as the most recent work in this area.

2- Iranian Solar Hegira year begins on 21st of March of Christian year and ends on 20th of March of next year.

3- Note that in this specification, $\ln Ac(y_{it}, w_{it}; \alpha)$ is still a function, therefore, there is no need for the coefficient yet. In page 6 where we specify the complete model we have included coefficients in the model.

$$\ln Ac_{it} = \alpha_{\circ t} + \ln Ac(y_{it}, w_{it}; \boldsymbol{\alpha}) + v_{it} + u_{it} \quad -\infty < v_{it} < +\infty \;\; \& \;\; 0 \leq u_{it} < +\infty \qquad (1)$$

In this specification the error term is composed of two components; first, v_{it} is a two–sided disturbance capturing the effect of random noise, which is usually assumed to follow a normal distribution; second, u_{it} is a one–sided non–negative cost inefficiency component. By defining $\alpha_{it} = \alpha_{\circ t} + u_{it}$, where $\alpha_{\circ t}$ is the average cost frontier intercept common to all firms in period t, and α_{it} is the intercept for firm i in period t, the model could be written as:

$$\ln Ac_{it} = \alpha_{it} + \ln Ac(y_{it}, w_{it}; \boldsymbol{\alpha}) + v_{it} \qquad (2)$$

where Cornwell, Schmidt and Sickles proposed α_{it} to be a flexibly parameterized function of time, with parameters that vary over firms. The model could be estimated by different estimation strategies, such as fixed effects approach and random coefficients approach.

Using estimates of the α_{it}, the estimated intercept of the average cost frontier in period t, $\hat{\alpha}_{\circ t}$, is obtained through $\min_i \hat{\alpha}_{it}$, and the cost efficiency of each firm in period t is then estimated as $CE_{it} = \exp(-\hat{u}_{it})$, where $\hat{u}_{it} = (\hat{\alpha}_{it} - \hat{\alpha}_{\circ t}) \geq 0$.

One of the main advantages of stochastic frontier analysis method is its ability to control for unobserved heterogeneity among companies. In particular, panel data models are highly suitable for data exhibiting such behavior. This turns out to be an important issue in network industries like electricity distribution sector, where different companies deal with the network at different junctures and face different consumer densities and topographical conditions. Those factors as well as other potentially unobserved characteristics do affect the production costs but are not necessarily indicative of different efficiencies. The inefficiency measures may therefore be affected by these confounding factors. In this case companies that face more difficult conditions may be classified as inefficient producers. Therefore, given that the electricity distribution utilities provide service via a network, an analysis of their cost structure must take account of the fact that the same quantities of electricity can be distributed on differently shaped service areas and that different quantities of electricity can be distributed on the same service area. For this reason, the average cost model specification should incorporate a number of network characteristics, which capture the heterogeneity dimension of the distribution system.

2-2- Specification of the frontier average cost function for RECs

16 Iranian RECs are responsible for the transmission and distribution of reliable electricity for the entire residential, commercial, industrial, agricultural, and public service users. The costs of operating a transmission and distribution system are the costs of building and maintaining the system of serve lines, mains and transformers. These costs depend upon:

- The total KWH electricity delivered;
- The price of inputs including labor and capital;
- The total number of customers served;
- The size of the distribution area;
- The dispersion of consumers in the service area;
- The length of transmission and distribution lines.

The total KWH delivered can be interpreted as an output indicator, whereas the total number of customers, the size of the distribution area and the length of transmission and distribution lines can be classified as network characteristic variables.

The specification used here draws basically from the model proposed by Fillippini (1998). This study and most of the empirical research in this area estimated a cost function, which includes the expenditure on purchased electricity in the total costs. But as Fillippini and Wild (2001) emphasize, such studies do not separate the sale function of a utility from the delivery function, and therefore are not ideal for benchmarking rates[1]. Hence, we will exclude the expenditure on purchased electricity from the total costs. For the purpose of our analysis we specify the following average cost frontier model for RECs,

1- In this study we adopted a simple unbundling of costs between the network activities and the purchasing activities: only the costs of electricity purchasing belong to the supply, all the other costs belong to the network. This seems a reasonable approach because the supply activities in comparison to the network operation need only a limited amount of resources in terms of labor and capital.

$$Ac = \frac{c}{y} = Ac\,(y, w_l, w_k, CD, LF) . \qquad (3)$$

where c represents total cost, Ac is average cost, and y is output. w_l and w_k are the prices of labor and capital, respectively. CD is the customer density, and finally LF is the load factor which should capture the impact of the intensity of use on average cost[1].

It has been argued that in industries such as electricity distribution, the production technology is rather complex and depends on a variety of external parameters associated with the production environment and demand characteristics. Hence the reliability of inefficiency scores is crucial. In particular, if the estimated inefficiency scores are sensitive to the benchmarking method, a more detailed analysis to justify the adopted model is required. To crosscheck our results, we estimate different models using fixed effects and random coefficients approaches in the two functional forms of Cobb–Douglas and translog. The translog model is preferred, because it offers an appropriate functional form for answering questions about economies of scale. It does not impose any technological restrictions and allows the economies of scale to vary with output[2]. The translog approximation[3] of the average cost function in (3) can be written as:

1- Size of the service territory is also one of the variables which could be included in the model, in which its value remains constant over time for a firm, but since the fixed effects approach for the estimation of the model cannot estimate the effect of time–invariant factors, this variable is discarded from the list of the variables.

2- In translog functional form, economies of scale vary with output, while it is assumed constant in the Cobb-Douglas functional form.

3- A translog function requires the approximation of the underlying cost function to be made at a local point, which in our case, is taken at the point (1,1, …,1) so that at the expansion point, the logarithm of each variable is a convenient zero. Thus, all independent variables are normalized by dividing by 1, which turns out the same values for these variables.

$$\ln(\frac{Ac}{w_k})_{it} = \alpha_{it} + \alpha_y \ln y_{it} + \alpha_l \ln(\frac{w_l}{w_k})_{it} + \alpha_c \ln CD_{it} + \alpha_f \ln LF_{it} + \alpha_{yy} \frac{1}{2}\left[\ln y_{it}\right]^2 +$$

$$\alpha_{ll} \frac{1}{2}\left[\ln(\frac{w_l}{w_k})_{it}\right]^2 + \alpha_{cc} \frac{1}{2}\left[\ln CD_{it}\right]^2 + \alpha_{ff} \frac{1}{2}\left[\ln LF_{it}\right]^2 + \alpha_{yl} \ln y_{it} \ln(\frac{w_l}{w_k})_{it} + \alpha_{yc} \ln y_{it} \ln CD_{it} +$$

$$\alpha_{yf} \ln y_{it} \ln LF_{it} + \alpha_{lc} \ln(\frac{w_l}{w_k})_{it} \ln CD_{it} + \alpha_{lf} \ln(\frac{w_l}{w_k})_{it} \ln LF_{it} + \alpha_{cf} \ln CD_{it} \ln LF_{it} + v_{it}$$

Linear homogeneity in input prices is imposed by normalizing money values, i.e. average cost and input prices, by one of the input prices. Here the price of capital acts as the numeraire.

We have used the fixed effects approach rather than the random coefficients approach, as the fixed effects approach controls for unobservable firm specific effects, such as inefficiency, that are not captured by control variables. Another important advantage of the fixed effects specification is that the estimates are unbiased even if explanatory variables are correlated with firm specific effects, whereas in the random coefficients approach any correlation between random effects and other explanatory variables may result in biased estimates. Therefore, in network industries, such as the electricity distribution industry, with firm specific characteristics, in the absence of information regarding the unobserved heterogeneity among firms, the fixed effect approach is to be preferred[1]. Cost efficiency scores are obtained from this model and the performances of the companies were evaluated based on these scores.

3- Data

A balanced panel on 16 Iranian RECs[2] for a 14–year time period, 1989–1990 to 2002–2003, with a total of 224 observations is used in this study[3].

1- However, as a check, we also estimated the model using the Cobb–Douglas functional form and the random coefficients approach. As expected, these results were inferior to those obtained from the fixed effects translog model.

2- The lists of RECs in this study with their related numbers are presented in the appendix.

3- We are indebted to Parviz Mohamadzadeh for providing the original data set for us.

The data are mainly based on the information form the annual detailed statistics of electric power industry in Iran published by MOE. The financial data are obtained from the annual reports of the "Independent Auditing and Legal Inspection Organization". The necessary data include total cost, output, the prices of labor and capital, as well as the number of customers, the length of transmission and distribution lines, and load factor. All money values including total cost and input prices were deflated to 1990–1991 constant Iranian Rials[1] using the Iranian global consumer price index.

For simplicity, total cost is equated to total expenditure of company excluding the expenditure for purchased and produced electricity. For those companies that produce part of their power, the average price of input electricity is assumed to be equal to the price of purchased power. Output is represented by the quantity of KWH electricity delivered. Average cost represents the cost per KWH delivered electricity and is obtained through dividing the total cost by the total quantity of KWH electricity delivered. Labor price is defined as the average annual salary of the company's employees, which is estimated as the labor expenditure [in transmission and distribution sections] divided by the total number of employees [in transmission and distribution sections]. The capital price is calculated from the residual capital cost divided by the capital stock. Residual cost is total cost minus labor cost. Because of the lack of inventory data, the capital stock is approximated by the total installed transformer capacity [in transmission and distribution sections], measured in KVA. Customer density is measured as the ratio between the number of customers and the length of transmission and distribution lines measured in kilometers. Finally, load factor is defined as the ratio of company's peak demand on its maximum capacity, multiplied by 100. Table 1 presents a summary of descriptive statistics of the variables used to construct a panel data set in this study.

1- Rial is the currency of Iran.

Table 1: Descriptive statistics

Variable	Description	Unit	1st Quartile	Median	3rd Quartile
c	Total Cost	Million Rials	5692.912	11073.669	25033.726
y	Output	Million KWH	1567.25	2930	5534.75
w_l	Labor Price	Million Rials	1.406	1.873	2.325
w_k	Capital Price	Million Rials	0.822	1.311	2.326
CU	Number of Customers	Thousand	295.025	641.8	1018.975
NL	Length of Lines	Kilometers	13734.75	23143.8	33525.43
LF	Load Factor		53.1	57.15	61.7

Analyzing more detailed data shows that for Iranian firms the areas of operation are geographically large, and the number of people serviced is small relative to global norms. Hence, we expect that firms operate on the downward sloping section of the average cost curve, where they experience increasing returns to scale. It means that these firms do not operate at a scale efficient size, and are economically inefficient. To improve the efficiency level of these firms, the MOE reformed the organizational structure of electricity transmission and distribution in 1993, by separating distribution activity from transmission activity. RECs continued to handle the transmission part, and new companies were created to handle distribution. This enabled both sets of firms to specialize and consolidate their activities, thereby reducing costs of operation and improving efficiency. To examine this we estimate an average cost frontier model in translog functional form using fixed effects approach.

4- Empirical analysis

4-1- Estimation results

The estimation results of the fixed effects translog model are set out in table 2. The estimated function is well behaved. A majority of the reported coefficients, 9 out of 14, have the expected signs and are highly significant at the 0.10 level[1].

1- Eight of them are significant even at the 0.05 level, and one is significant at 0.10 level.

Although, the coefficient of the variable $\ln LF$ is positive, the overall impact of load factor on average cost, in the translog model, is computed as following:

$$\frac{\partial \ln Ac}{\partial \ln LF} = \alpha_f + \alpha_{ff} \ln LF + \alpha_{yf} \ln y + \alpha_{lf} \ln(\frac{w_l}{w_k}) + \alpha_{cf} \ln CD$$

If we insert the coefficient estimates and also the mean values for ln LF, $\ln y$, $\ln(\frac{w_l}{w_k})$ and $\ln CD$ of 4.020, 8.007, 0.285 and -3.587, respectively, then we will obtain

$\frac{\partial \ln Ac}{\partial \ln LF}$ = 6.4+(-0.823*4.02)+(-0.038*8.007)+(0.103*0.285)+(0.793*-3.587) = - 0.038

This is in line with our expectations, and indicates that a 1% improvement in the load factor will reduce the average cost by approximately 0.038%. The relatively small magnitude of this result may be due to the small variation of the load factor within the RECs. The impact of output on average cost is calculated as –1.01. This indicates that firms are not operating at optimum levels of capacity utilization. Increasing their operational size would enable them to become more efficient, and produce more at lower costs. This would benefit all concerned. The evidence does not support marked non–linearities in the impact of output on average cost, viz. α_{yy} is statistically insignificant. This suggests that there are only small variations in economies of scale, between firms, in the production process, and the firms are operating on the declining section of the average cost curve. The impact of labor price on average cost is 0.325, which indicates a monotonically increasing average cost function in input prices, with labor costs accounting for 32.5% of average cost, and capital costs for the remaining 67.5%. The elasticity of average cost with respect to customer density is -0.11. This also suggests that firms could benefit from restructuring, so that no firm is supplying exclusively to the sparsely populated southern region. Note that customer density affects the average cost mainly through interactions with labor price and load factor. This is as expected, because the data indicate that firms operating in the south of Iran are faced with low customer density, low wages and low load factor relative to firms in the north of Iran.

Table 2: Average cost frontier parameter estimates
[Translog specification and fixed effects approach]

Parameter	Estimate	Standard Error	t – Statistic	P – Value
α_y	-2.452810	1.246338	-1.968014	0.050
α_l	0.958391	0.319512	2.999551	0.003
α_c	-2.427617	2.019053	-1.202354	0.231
α_f	6.400178	2.465498	2.595897	0.010
α_{yy}	0.181335	0.122946	1.474924	0.142
α_{ll}	0.176342	0.014216	12.40412	0.000
α_{cc}	0.146329	0.289075	0.506197	0.613
α_{ff}	-0.823823	0.398814	-2.065681	0.040
α_{yl}	-0.088607	0.012519	-7.078024	0.000
α_{yc}	-0.047456	0.161988	-0.292962	0.769
α_{yf}	-0.038483	0.109515	-0.351399	0.725
α_{lc}	0.108671	0.030150	3.604381	0.000
α_{lf}	0.103466	0.058254	1.776111	0.077
α_{cf}	0.793657	0.311347	2.549103	0.011
$\overline{R}^2$ = 0.982 D.W – Statistic = 1.748				

In majority of the cases, dummy variables related to either time variable or time–squared variable are significant[1]. This indicates the existence of time–varying firm specific effects, and in result, time–varying cost efficiency of companies.

1-These dummy variables are introduced to capture the firms' specific effects. The magnitudes of these variables, not presented here, are available upon request.

4-2- Economies of scale

Since we did not separately include the number of customers and the size of the service territory in our average cost model specification, we are unable to distinguish between economies of output density, economies of customer density and economies of scale. In this work, we define economies of scale [ES] as the proportional decrease in average cost brought about by a proportional increase in output, holding all input prices, customer density, and the load factor fixed. This is equivalent [in absolute value] to the elasticity of average cost with respect to output. Economies of scale [ES] can thus be defined as:

$$ES = \frac{\partial \ln Ac}{\partial \ln y} .$$

An ES smaller than 0 indicates economies of scale, and accordingly, diseconomies of scale is present when ES is greater than 0. In the case of $ES = 0$ no economies or diseconomies of scale exist. Economies of scale exist if the average cost of a REC decreases as the volume of electricity delivered in a service territory of a given customer density increases. This measure [ES] is relevant for analyzing the impact on cost of merging two adjacent companies.

As mentioned, the translog model offers an appropriate functional form to answer questions about economies of scale. This is, as explained earlier, of particular interest in the Iranian case, where we wish to investigate the hypothesis that firms operate at a level where there are increasing returns to scale. In this functional form, economies of scale are computed as:

$$ES = \frac{\partial \ln Ac}{\partial \ln y} = \alpha_y + \alpha_{yy} \ln y + \alpha_{yl} \ln(\frac{w_l}{w_k}) + \alpha_{yc} \ln CD + \alpha_{yf} \ln LF \cdot$$

Using this formula the calculated ES for entire sample of companies is -1.01, which indicates an increasing returns to scale for the RECs in our sample. This suggests that the majority of the Iranian RECs operate at an inappropriately low scale level. In other words, most of the companies in our sample are too small and do not reach the minimum efficient scale.

In order to gain a better idea of economies of scale in this industry, we calculate ES for each of the 16 companies. Table 3 reports the results ordered by the size of the companies.

Table 3: Economies of scale ordered by the size of the companies

Number of Company	Size of the Company	Economies of Scale
6	566	-1.207
7	660	-1.098
12	767	-1.180
11	1194	-1.132
14	1405	-1.089
2	1435	-1.093
1	1542	-1.104
3	2256	-0.971
5	2369	-1.036
4	3064	-0.949
8	3067	-0.950
13	3740	-0.902
9	4122	-0.873
15	4818	-0.894
10	6854	-0.932
16	15520	-0.758

The results provide two important conclusions. First we find that each of the 16 companies face increasing returns to scale, and all of the companies operate at a low scale level, i.e., this industry is characterized by notable scale inefficiency. Secondly, the magnitude of the ES differs across the companies so that larger companies are performing better than smaller ones from the economies of scale point of view. To examine this, we run the signed rank test for two independent samples, where the samples are small companies with 5 first observations and large companies with 5 last observations. We apply the Mann–Whitney test and Kolmogorov–Smirnov test, two commonly used tests in this area. These tests help us to determine whether two samples have come from identical populations. If it is true that the samples have come from the same populations, it is reasonable to assume that the means of the two samples are equal. The results show that there is a statistically significant difference between the means of the two samples.

In the next step, in order to observe the variations of ES, resulted from the structural reform, we calculate ES for each of the 16 companies at pre–reform time period and post–reform time period. The obtained results are presented at table 4. Considering pre–reform and post–reform values of ES for each of the 16 companies, it is observed that the magnitude of ES has improved at post–reform time period relative to pre–reform time period.

To examine this statistically, we apply nonparametric tests for two related samples [paired samples] using Wilcoxon signed ranks test and sign test. These tests help us to test the null hypothesis that the two related variables [i.e., pre–reform ES and post–reform ES] have the same distribution. The results show that the mentioned null hypothesis is rejected. This suggests that structural reform has had a positive effect on the performance of these companies. This is further analyzed in the next section by calculating cost efficiency for each company and testing whether efficiency of firms has improved over this period.

Table 4: Variations of Economies of Scale

Number of Company	Pre–Reform	Post–Reform
1	-1.160	-1.072
2	-1.229	-1.016
3	-1.072	-0.915
4	-1.069	-0.882
5	-1.128	-0.985
6	-1.307	-1.151
7	-1.166	-1.059
8	-1.054	-0.892
9	-0.985	-0.810
10	-1.030	-0.877
11	-1.254	-1.064
12	-1.289	-1.119
13	-1.010	-0.841
14	-1.192	-1.031
15	-1.042	-0.812
16	-0.801	-0.733

4-3- Cost efficiency

The estimation results reported in table 2 can be used to recover the level of cost efficiency of each company for each year along the lines suggested by Cornwell, Schmidt and Sickles. This amounts to counting annually the most efficient company in the sample as 100% efficient and measuring the degree of cost efficiency of the other companies relative to the most efficient company. Complete statistics of the estimated cost efficiency scores of each individual company over time are reported in table 5.

Only four companies numbered 6, 7, 11, and 12 have had a cost efficiency level of 50% and above, the rest experienced cost efficiency level of below 50%. Company number 6 has been the most efficient firm in the entire period, and the cost efficiencies of the remaining firms are measured relative to this company. Except for companies numbered 1, 7, 8, 11, and 12, all the other companies have shown improvement in their cost efficiency levels. The reason for a slight decrease in cost efficiency of company number 1 towards the end of the period could be the massive increase in total cost in these years. The reasons for this are unclear. There seems to have been some redefining of categories of costs for this company. The efficiency of company number 7 has increased up to 1997–1998; thereafter it shows a slight decreasing trend, because of the increasing in the average cost of production after 1997–1998. Company number 8 has shown improvement after 1992–1993, suggesting that reform helped turn around this company. Finally, company number 12, and in most of the years company number 11, exhibit decreasing cost efficiency, the reasons for which are not related to increase in input costs. A possible cause may be poor management.

Table 5: Annual cost efficiency levels (%) of the individual companies

Number of Company	1989_1990	1990_1991	1991_1992	1992_1993	1993_1994	1994_1995	1995_1996	1996_1997	1997_1998	1998_1999	1999_2000	2000_2001	2001_2002	2002_2003
1	33.02	33.88	34.65	35.33	35.91	36.38	36.75	37	37.14	37.16	37.06	36.85	36.52	36.09
2	24.91	25.83	26.73	27.58	28.39	29.14	29.84	30.48	31.06	31.56	31.99	32.35	32.62	32.81
3	19.43	21.39	23.39	25.40	27.38	29.31	31.15	32.87	34.44	35.82	37	37.95	38.64	39.07

4	13.62	14.07	14.52	14.96	15.41	15.86	16.30	16.74	17.18	17.61	18.03	18.45	18.86	19.26
5	17.06	17.46	17.91	18.43	19.02	19.68	20.41	21.24	22.15	23.17	24.31	25.57	26.97	28.52
6	100	100	100	100	100	100	100	100	100	100	100	100	100	100
7	65.21	68.70	71.86	74.62	76.94	78.77	80.06	80.79	80.95	80.53	79.54	78.01	75.95	73.42
8	16.46	16.37	16.36	16.42	16.55	16.76	17.05	17.43	17.89	18.44	19.10	19.87	20.77	21.80
9	15.82	16.77	17.70	18.59	19.42	20.21	20.92	21.55	22.10	22.56	22.92	23.17	23.31	23.35
10	6.75	7.44	8.14	8.85	9.55	10.23	10.90	11.52	12.10	12.61	13.06	13.43	13.72	13.92
11	53.60	52.78	52.06	51.44	50.93	50.52	50.21	49.99	49.87	49.83	49.90	50.05	50.30	50.64
12	88.39	85.79	83.32	80.99	78.79	76.70	74.72	72.85	71.08	69.41	67.83	66.33	64.92	63.58
13	13.11	13.29	13.56	13.92	14.40	14.99	15.72	16.59	17.63	18.86	20.31	22.03	24.05	26.44
14	27	27.95	28.89	29.83	30.77	31.71	32.63	33.54	34.44	35.33	36.19	37.03	37.86	38.65
15	8.67	9.50	10.35	11.25	12.17	13.12	14.08	15.07	16.05	17.04	18.01	18.97	19.91	20.80
16	4.82	5.11	5.41	5.72	6.05	6.39	6.74	7.11	7.49	7.88	8.29	8.72	9.16	9.61

Overall, the results indicate that the most of the companies experienced increasing cost efficiency scores over the sample time period. This conclusion is buttressed by the observed slight increasing trend of annual mean cost efficiency of companies. The graph is presented in figure 1.

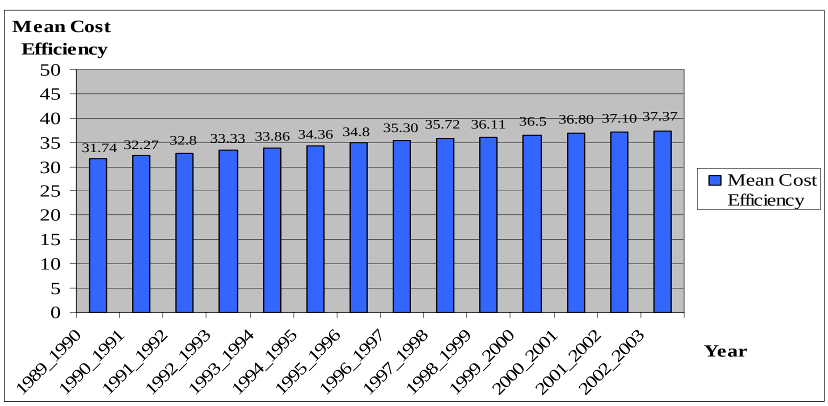

Figure 1: Plot of mean cost efficiency levels of companies over time

Although cost efficiency scores of most of the companies in our sample have increased over time, 75 percent of companies [12 companies out of total 16 companies] continue to exhibit a high degree of inefficiency with cost efficiency levels below 50%. Partly this is due to poor management, but there are some other reasons too. First, some companies operate in regions characterized by difficult production conditions, which are not taken into account in our model specification. Secondly, relatively low cost efficiency scores indicate a high dispersion of cost inefficiencies across companies. It may be because Iranian RECs are not specializing enough. Each REC handles generation, transmission, distribution, and sale of electricity, where in the standard international practices [e.g. EU countries] RECs mostly undertake the transmission activity, and other activities are handled by other different companies. Finally, in average cost frontier framework, fixed effects approach assumes that the unobserved heterogeneity among firms is completely due to differences in efficiency. This assumption leads to an overestimation of inefficiency in fixed effects model for the following reasons. First, the fixed firm specific effects capture both observed and unobserved time–invariant factors. Moreover, since the fixed effects do not follow any distribution and efficiency is estimated compared to the best observed practice [the firm with the minimum fixed effect], the estimators are sensitive to outliers. In fact, the problem of outlier firms is transferred from the average cost function to efficiency estimators, leading to a high degree of inefficiency for some firms.

There are three main hypotheses, which were tested in this study. The first tested whether the efficiency level of different Iranian RECs are equal. To do this, we tested the hypothesis that the mean cost efficiency level of company number 1 over time is equal to that of company number 2, and it is equal to that of company number 3, and so on against the alternative that this is not the case. For this purpose, we use the Wald–statistic, which is asymptotically distributed as chi–squared with the degrees of freedom equal to the number of companies. The calculated value for the Wald –statistic is 11696.35, which is considerably more than the 95 percent critical value of 26.30 obtained from the chi–squared table with 16 degrees of freedom. Hence, the hypothesis of equal efficiency levels is not accepted.

We also wished to test whether the 16 RECs have been operating at low cost efficiency levels. To do this, we tested for each REC the hypothesis that its mean cost efficiency level over time is less than 50%. The calculated t –values for the 16 RECs are presented in table 6. It can be seen from the table that the null hypothesis is rejected for companies numbered 6, 7, 11, and 12 only, all other firms operated at efficiency levels below 50% over the entire period from 1989–1990 to 2002–2003[1].

Table 6: Calculated t –values for companies

Number of Company	t –value
1	-40.20

1- The t –value for company number 6 cannot be computed because of its fixed value of cost efficiency, but its cost efficiency level is 100% all over the time period, which is more than 50% of null hypothesis.

2	-28.97
3	-10.69
4	-68.77
5	-28.92
6	–
7	20.16
8	-66.66
9	-42.89
10	-60.48
11	2.73
12	11.55
13	-28.4
14	-16.87
15	-33.36
16	-104.2

Calculating average cost efficiency level of our sample companies we find that it was only 31.74% in 1989–1990 and 37.37% in 2002–2003. This leads us to our third conjecture. Based on figure 1 and preliminary data analysis we expect the impact of structural reform to be positive, i.e., to improve the cost efficiency of the firms. To examine the improvement of cost efficiency of companies, we run for each REC the signed rank test for two independent samples, where the samples are pre–reform time period with 5 observations and post–reform time period with 9 observations. We apply the Mann–Whitney and Kolmogorov–Smirnov tests, two commonly used tests in this area. These tests help us to determine whether two samples have come from identical populations. If it is true that the samples have come from the same populations, it is reasonable to assume that the means of the two samples are equal. The results show that there is a statistically significant difference between the means of the two samples for all companies except for company number 6[1]. However, it must be noted that these tests show only the differences of the means of the two samples, and not necessarily the directions of changes. Regarding table 5, except companies numbered 11 and 12, all other companies show increasing cost efficiency in most years of the time period under consideration. Cost efficiency level of company number 6 is also fixed at 100% as the most efficient firm. Combining these trends of cost efficiency levels of companies

1- It is the case for company number 6 because of its fixed value of cost efficiency at 100% level all over the time period.

with the results of signed rank test shows that structural reform has improved the cost efficiency of all companies except companies numbered 11 and 12. Hence, our third hypothesis on the positive impact of structural reform on the performance of RECs is accepted for the majority of firms.

5- Summary and conclusions

The purpose of this study is to analyze the cost structure of 16 Iranian RECs regarding their cost efficiency, over the period 1989–1990 to 2002–2003, and to examine the impact of structural reform in RECs through the variation of their cost efficiency, and to judge whether the structural reform in RECs has improved their performance or not. To do so, the average cost frontier model is applied to the panel data set for the 16 Iranian RECs during the time period 1989–1990 to 2002–2003 to estimate time–varying cost efficiency of these companies. Our main findings are:

- We found increasing returns to scale for all companies in our sample, where the larger companies are better off than smaller ones from the economies of scale point of view. This implies that majority of the companies are too small and do not reach the minimum efficient scale. The problem of scale inefficiency could be solved through mergers of small companies. Also we found that, for all companies, the magnitude of economies of scale has improved at post–reform time period relative to pre–reform time period.
- Twelve of the sixteen companies have operated with cost efficiency levels less than fifty percent.
- We found that the companies exhibit variation in their cost efficiency levels over the time period, i.e. time–variant cost efficiency. There are statistically significant differences in the companies' performances between the pre–reform and the post–reform periods. The direction of the changes in cost efficiency has been positive for most of the companies. This suggests that the efficiency levels of companies have increased over the period considered, which in turn suggests that structural reform has improved the efficiency of the majority of RECs in our sample.

Thus it seems that the industry needs reorganization. Firm size and activity both need to be adjusted to allow firms to enjoy the benefits of economies of scale and specialization. Since a majority of the companies are too small and do not reach the minimum efficient scale, they should be merged with other companies to enable them to operate at optimal size. Also firms involved in electricity distribution should be completely separated from firms responsible for transmission activity as the nature of the two activities is disparate. They require different kinds of equipment and organization on the part of the firms providing these services. Moreover, many of the transmission and distribution equipment and installations already in operation are very old and inefficient. They should be replaced or upgraded as required. This would improve both efficiency and reliability of the transmission and distribution networks.

References

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

2- Farsi, M., and M. Filippini (2009), "An Analysis of Cost Efficiency in Swiss Multi–Utilities" Energy Economics 31(2), PP. 306 – 315.

3- Filippini, M. (1998), "Are Municipal Electricity Distribution Utilities Natural Monopolies?" Annals of Public and Cooperative Economics 69(2), PP. 157 – 174.

4- Filippini, M., and J. Wild (2001), "Regional Differences in Electricity Distribution Costs and Their Consequences for Yardstick Regulation of Access Prices," Energy Economics 23(4), PP. 477 – 488.

5- Fried, H. O., C. A. K. Lovell, and S. S. Schmidt (2008), The Measurement of Productive Efficiency and Productivity Growth, Oxford University Press, New York.

6- Jamasb, T., and M. Pollitt (2001), "Benchmarking and Regulation: International Electricity Experience," Utilities Policy 9, PP. 107 – 130.

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

8- Meibodi, A. E. (1998), Efficiency Considerations in the Electricity Supply Industry: The Case of Iran, Ph.D. Thesis, Department of Economics, University of Surrey.

9- Sadjadi, S. J., and H. Omrani (2008), "Data Envelopment Analysis with Uncertain Data: An Application for Iranian Electricity Distribution Companies," Energy Policy 36(11), PP. 4247 – 4254.

10- Tavanir (2003), "Statistical Report on 37 Years of Activities of Iran Electric Power Industry (1967–2003)," Tavanir Holding Company, Ministry of Energy, Islamic Republic of Iran.

11- Tavanir (Various Years), "Iran’s Electric Power Industry Annual," Tavanir Holding Company, Ministry of Energy, Islamic Republic of Iran.

12- Tavanir (Various Years), "Detailed Statistics Concerning Iran Electric Power Industry," Tavanir Holding Company, Ministry of Energy, Islamic Republic of Iran.

Appendix

Lists of RECs in this study

Number of Company	Company Name
1	Gilan
2	Hormozgan
3	Kerman
4	Fars
5	Mazandaran
6	Semnan
7	Systan & Baluchistan
8	Bakhtar
9	Khorassan
10	Khuzestan
11	Zanjan
12	Yazd
13	Azarbaeijan
14	Gharb
15	Isfahan
16	Tehran