International Journal of Energy Economics and Policy

ISSN: 2146-4553

available at http: www.econjournals.com

International Journal of Energy Economics and Policy, 2015, 5(4), 1010-1015.

The Impact of Electricity Competitive Market Establishment on Technical Efficiency of Thermal Power Plants in Iran

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ABSTRACT

Power industry like other network industries, due to economies of scale, has monopolistic operation for many years. Over the last three decades, electricity sectors in most countries have experienced major structural changes including entry of private capital and competition increase. Although the effects of such reforms in developed economies are now well documented, in developing countries, a few studies have examined the effects of these changes due to a variety of reasons. In Iran, structural problem is one of the main problems in the energy sector, which has had an important role in low efficiency of this sector. To solve this problem, in two past decades, restructuring and promoting competition have been in the forefront of government policy and programs in the energy sector. So that substantial reforms occurred in electricity industry structure after establishing power market in 2003. After a decade of reforms in power market, it is necessary to investigate the effects of these reforms on electricity supplier performance, since it will be helpful for progress of electricity industry restructuring and implementing similar reforms in other network industries. The aim of this study, given its real importance in the issue, is examining the effects of market restructuring on technical efficiency in thermal power plants of Iran. For this purpose, technical efficiency of 35 thermal power plants has been calculated in the period 1999-2011 using Data Envelopment Analysis method, then the impact of market restructuring on technical efficiency has been estimated by applying panel data Tobit model. The results indicated that market restructuring has had positive effects on technical efficiency of power plants.

Keywords: Electricity Industry, Market Restructuring, Technical Efficiency, Thermal Power Plants, Panel Data Tobit
JEL Classifications: C14, C51, C61, D24, L33, L51, L94

1. INTRODUCTION

Until the early 20th century, electric power generation, transmission and distribution were vertically integrated and owned by the government in many countries. The role of electricity in the economic development of countries become vital in the wake of the industrialization of nations and the demand for this strategic commodity and input has undergone a significant growth. This has caused researchers to become more focused on the factors affecting price and production costs and seek solutions to increase the efficiency in power generation. Meanwhile, the theories of industrial organization emphasizing the effect of market structure on the performance of firms have led to severe criticism of the monopolistic structure of the power industry in recent decades, forcing governments to take initiatives in major structural reforms of the power generation industry since 1982. These reforms have been practiced in the form of privatization in some countries, while in others; it is in the form of power market restructuring and some others, it is a combination of both depending on the specific requirements. Power market restructuring indicates the procedure for replacing a monopolistic system with a market structure wherein several competitive suppliers take action in selling power, and retailers are given the option of choosing from a host of suppliers. Restoration of market structure would lead to increased motivation to decrease the costs of production due to the increased competition among suppliers and subsequently increasing the efficiency. In line with increasing concern in the issue, numerous empirical studies have been conducted in recent years to examine the effects of restoring market structure on the performance of power industry in various countries. An overview of these studies shows that although in most cases the exertion of these reforms has been followed by an improvement in the performance of suppliers, some evidence still shows adverse or insignificant effects of these reforms, thus making the problem even more perplexing.

In Iran, the power market was established in 2004 following the regulations issued under the title "method, the rates and conditions of purchase and sale of electricity in the national grid." This market is based on an hour-to-hour tendering mechanism, whereby the power suppliers active in the market would submit their proposals for energy generation as well as its prices to the Network Management Company. The structure of the power market in Iran is in the form of an exclusive procurement in which all buyers and sellers are present in a market in the form of a pool that creates an utterly new context in this regard. In such a market, reimbursement to the suppliers is either based on price discrimination or payment on the basis of proposals. The competition in the power market of Iran is among the suppliers of energy rather than among other parties and agents. The suppliers are allowed to provide the power market with energy supply curves in ascending steps with a maximum of 10 steps in order to keep the order and quench the needs. In case these prices are accepted within the power market, the sums will be disbursed based on the proposed bids. In addition, an amount is paid for the prepared capacity of power generation in power plants per megawatt (MW)-hour of capacity. This sum will be paid regardless of whether the power plant generates power or not. The preparation rate is constant for all the power plants of country, regardless of their status. Moreover, the selling price of energy to buyers is constant, or in other words, the intake from buyers is always constant. At this point, the average paid price is calculated throughout the country for each of power plants; each of the buyers would pay the price to the market manager for the supplied energy according to this rate and no other influencing factors. Currently, the power suppliers include the Power Company/Regional Water Company (as representative of its own power plants), the Tavanir Company, and power plants having guaranteed procurement.

On the other hand, 16 regional power companies as well as 42 power distribution companies are present as purchasers of power.

The regional power companies as the proprietor of power transmission equipment in the market of Iran play the role of power transmission service suppliers. According to the rules of the market, all buyers including the regional power company procure power directly from the power market at the uniform price of market supply based on the methodology set forth by the Institution for Development of Market Regulations.

Although the modifications in the power market are an important step in the progression of a country towards efficient performance in this sector, it should be taken into account that what is more important than a policy is its effectiveness. It is evident that each policy is assessed according to the success of that policy in achieving the predetermined purposes. The observation of achievements, identification of deviation from them and correct discretion of the required modifications calls for accurate and extended studies in order to be reliable. To this end, this study was conducted to examine the influence of the policy for restoration power market structure on the efficiency of 35 thermal power plants in Iran.

2. REVIEW OF THE LITERATURE

In most countries, the central objective of market restructuring and introducing competition in the power market is to promote technical efficiency. Based on theoretical studies, one of the important channels through which competition affects the technical efficiency is reduction of x-inefficiency in firm. Because of the following reasons, increases in product market competition will reduce the degree of firm x-inefficiency:

- Product market competition provides opportunities for Inter-firm comparison and makes it easier for owners to monitor manager's performance and be more prepared to take the immediate actions in cases required
- This reduces principal agent problems. Equally, managers are able to prove themselves more conclusively, and so have the incentive to work hard to build up a reputation (Vickers, 1995)
- High price elasticity of demand in competitive markets rewards or penalizes changes in the price to a greater extent creating a special condition based on this variable. Firms with lower costs can capture more of the market through price decreases, while those with higher costs stand to lose much of their market. Technical slack therefore comes at a higher cost (Willig, 1987)
- Low profit margins in competitive markets lead to pressure on costs, because lower margin increases the probability of bankruptcy and induces the manager to improve the internal efficiency of their firm (Schmidt, 1997).

The competition also increases workers' effort, because wages would be paid according to efficiency of employees in competitive market, and they would be persuaded to make more effort because of this issue (Nickell, 1996). Furthermore, competition provides motivation to make process and product innovations in firms and leads to better performance, accordingly. Innovations can also cause decrease of costs and creation of technical efficiency (via new and better production methods). Creation will also grow dynamic efficiency (growth of efficiency in the length of time). Dynamic efficiency is the ascending general transition of production possibility frontier (Ahn, 2001).

According to Craig and Savage (2013), in non-competitive electricity markets, increases in fuel and other inputs costs can be passed on directly to consumers through increased prices. Then in these markets, owners and managers of plants have limited incentive to maximize technical efficiency that leads to a worse situation than the status quo. In contrast, managers who are in competitive situations and face the threat of new competitors' entry or their own exit from the market do more efforts to maintain their market share through cost reduction and lower price offers. For example, when a power plant operating in wholesale market bid systems, it is managers who are subject to uniform pricing system (payment to all suppliers based on the highest acceptable bidder) can reduce costs and offer lower prices. This leads to an increased probability of staying in the market on the one hand, and higher profits on the other hand although there may be controversy over its comprehensiveness. In this market, power plants with high costs will be subjected to losses and the probability of exiting from the network.

Craig and Savage (2013) suggested that power plants in restructured markets have a strong incentive to increase efficiency by reducing their plant's heat rate.

This is achieved by implementing industry best practice maintenance and operational procedures, downsizing the production process, upgrading to higher quality fuel, and by introducing new technologies. For example, refined technology equipment components provide a more reliable and accurate damper control of boiler due to their inherent merits. This helps the plant optimize the combustion of air and flue gases and reduce the heat rate. In competitive electricity markets, it is also possible that a firm's cost reducing investment reduces the production costs of rival firms. The efficiency gains of these kinds of investments may have spilled over by the exchange of knowledge and workers within the utilities.

Empirical studies of electricity market restructuring effects on electricity generators efficiency are limited and most of them are related to studying the issue in developed countries, especially the USA. Kleit and Terrell (2001) using data from 78 electric power generation plants in the United State and by applying Bayesian Stochastic Frontier Analysis estimated cost efficiency and showed that immediately after reforms, efficiency gains appear to have been and plants costs have decreased.

Wolfram (2003) studied the change in heat rates for plants in regulated and deregulated states of the USA. She found decreases in heat rates of about 2% for deregulated utility-owned plants, and decreases in heat rates of about 2.5% for deregulated independently-owned plants compared to their regulated counterparts. In 1999, she also observed that generators in deregulated states had 20% fewer employees per MW produced and reported 8% lower operating costs than regulated states. Fabrizio et al. (2007) studied the impact of electricity restructuring on efficiency generation in the United States using a difference-in-differences approach to measuring efficient input use. Using a plant-level panel (1981-1999) of gas and coal-fired thermal power plants, the authors estimate cost-minimizing input demands as a function of plant characteristics while controlling the regulatory regime. They showed that employees per megawatt fell by approximately 8% and non-fuel operating expenses per megawatt fell by approximately 14% following the initiation of restructuring. Delmas et al. (2007) applied Data Envelopment Analysis (DEA) method to study restructuring effect on the USA overall plant productivity between the years 1998 and 2001. When controlling the general utility information, Delmas et al. (2007) conclude that deregulation is associated with lower levels of DEA productive efficiency. The authors report that these results illustrate the short-term costs of transitioning from a regulated to deregulated environment. Zhang (2007) applied 73 US nuclear plants data from 1992 (beginning of restructuring in USA electricity industry) till 1998 to estimate electricity industry restructuring effects on plants efficiency. This study shows that the passing of market restructuring legislation was associated with a reduction in fuel, operating and maintenance costs by about 11-23%. Barros (2008) tried to study the competition effects on Portorico powerhouse effectiveness and indicated that more competition has a positive effect on powerhouse effectiveness. In the study, the effect of factors such as powerhouse place, powerhouse age and rainfall rate also are estimated by applying Tobit pattern to bring further clarification to the matter. Blumsack et al. (2008) used a detailed plant-level data set to estimate how the markets and institutions established as a part of "restructuring" have affected the difference between prices and costs in the United States. The results indicated that restructuring has increased the price-cost margin by 2-2.5 cents per KWh this result could be caused by (marginal) costs declining through efficiencies as well as rise of prices. Goto and Tsutsui (2008) applied DEA method to measure technical efficiency and investigated the impact of deregulation on it in US electricity distribution. They found that there is no effect of deregulatory initiatives on technical efficiency between 1992 and 2000, but the issue may also need further examination to be given an absolute verdict and why it is brought further clarification by the other researchers. Zhang et al. (2008) used panel data to estimate the effects of privatization, regulatory change, and competition on the performance of electricity producers in 36 developing countries from 1985 to 2003. The results showed that privatization and regulatory change do not have a significant effect on economic performance, but introducing competition does seem to be effective in stimulating performance improvements. Zarnic (2010) between the years 1996 and 2007 estimated the effect of changing industry structure, ownership structure and regulation with respect to barriers to entry and access to wholesale and retail markets on European electricity industry efficiency at firm level. The results of this study show that reforms have a positive effect on efficiency growth of high-productivity firms in a drastic way. Craig and Savage (2013) examined the effect of deregulation on generator efficiency in the USA over the period of 1996-2006. The results showed that market reforms made a 13% growth in planet efficiency, and improved it in a significant way.

3. METHODOLOGY

Empirical studies on the effects of structural reforms have mainly used three different approaches to tackle this tricky issue. After estimating efficiency for different years, some of these studies have examined effective factors on the estimated efficiency and then the effects of structural reforms along with considering a dummy variable in this model. Some of the other studies are comparing average efficiency before and after reforms so that they can judge these reforms in a more refined and accurate way. A third approach that has been used in empirical studies is comparing performances of the firms affected by the reforms and those that have not been affected. In the current study, two approaches can be used according to their relatedness to the methodology being applied. The sample used in this study included 35 thermal power plants in in years 1999-2011. Significant contribution of thermal power plants in providing electricity in the country compared with hydro- and wind power plants is the reason why we are using inputs of these thermal power plants in our study. Thus, for using the first method, firstly technical efficiency of each of these 35 thermal plants during the mentioned interval is estimated on an annual basis and then using the following model, as well as the limited dependent panel data model or namely panel data Tobit, we managed to examine the structural effects of market reforms on technical efficiency.

$$Eff_{it} = f(Dum_{it}, Age_{it}, Fuel_{it}, Cap_{it}, Size_{it}) \quad (1)$$

Where, *i* is the power plant unit, and *t* is the year. Moreover: Eff is the technical efficiency that is calculated using the DEA method, Dum is representing dummy variable, which is an indicator of market reforms and is receiving 0 for the years before reforms in the structure of the electricity market (1999-2003) and 1 for the years after reforms (2004-2011); to be more exact, several control variables which are considered as the effective factors on technical efficiency in the theoretical and empirical studies have also arrived in the model. These variables are as the following:

Age is plant life, logarithm of the number of years after the first utilization of the plant, some studies have exerted the plant age as an effective variable on the technical efficiency into this variable's regression (Pollitt, 1996; Khanna et al., 1999; Hiebert, 2002; Sirasoontorn, 2005).

Overall, it is expected that the new power plants have lower fuel consumptions, low maintenance costs as well as enhanced efficiency, due to the use of new techniques as well as new generators (See, 2011). Nevertheless, older power plants have greater ability to create compliance with the conditions of production and have more experiences in this context. While in newer power plants there will be a need for acceptance of additional costs such as training workforce to comply with new technologies (Khanna et al., 1999).

3.1. Fuel

Type of the power plant fuel, the share of gas-fueling from the total fuel consumption; since the technical efficiency of the plant depends on the type of the fuel, the type of fuel consumed is one of the effective variables on plant performance. This is due to strong dependence of technical efficiency on thermal efficiency of power plant and the importance of fuel input in the process of producing electricity. However, experimental studies results are not showing a clear and general conclusion due to the many variables that may affect it and influence it in one way or another. Some studies such as Diewert and Nakamura (1999) have shown that in Britain, performance of the plants with heavy fuel has been far better than those of the plants with light fuel. Some studies such as Pollitt (1995), and Sarica and Or (2007) indicate that in the plants which use gas for their fuel, technical efficiency is better than those plants which use other kinds of fuel.

In addition, Hiebert (2002) has showed a significant difference of efficiency among gas-fueling plants and coal-fueling ones.

3.2. Cap

Plant capacity utilization rate, the ratio of practical capacity to the rated capacity; usually low rates of utilization means that some of the plant's generators and equipment are left unused and consequently this causes low technical efficiency and additional costs of maintenance. In addition, frequent startups and shutdowns of power plant will reduce efficiency and raise power consumption (Khanna et al., 1999; Hiebert, 2002).

3.3. Size

Size of the power plant; logarithm of number of power plant employees and increase in the size of the boilers saves fuel consumption in the plant, according to the available literature (Joskow and Schmalensee, 1987). However, some studies such as Sarica and Or (2007) have shown that increase in plant size due to lack of coordination problems, mismanagement and problems related to the power plant maintenance will decrease plant's technical efficiency.

4. RESULTS

As mentioned before, in this part, efficiency index for each plant over the desired years is calculated through DEA method. The average amount of efficiency calculated for the years before and after development of electricity market classified in three groups of steam, gas and combined cycle plants is presented in Table 1.

Table 1: The estimated technical efficiency

Planets name	Total average	2004-2011 average	1999-2003 average
Tarasht	0.9949	1.0000	0.9898
Besat	0.9805	0.9930	0.9681
Islamabad (Isfahan)	0.9839	0.9861	0.9818
Shahid Montazer Ghaem	0.9797	0.9840	0.9754
Shahid Beheshti (loshan)	0.9870	0.9865	0.9876
Zarand	0.9801	0.9825	0.9778
Mashhad	0.9862	0.9826	0.9898
Shahid Salimi (Neka)	0.9936	0.9915	0.9958
Ramin	0.9995	0.9989	1.0000
Bandar Abbas	0.9795	0.9723	0.9867
Shahid Montazeri	0.9867	0.9889	0.9845
Tous	0.9958	0.9961	0.9956
Tabriz	0.9711	0.9764	0.9658
Shahid Rajaiee	0.9909	0.9918	0.9900
Bistoon	0.9867	0.9885	0.9850
Mofatteh West	0.9778	0.9739	0.9817
Iranshahr	0.9712	0.9743	0.9681
The average of steam plants	0.9850	0.9863	0.9837
Bushehr	0.9015	0.9293	0.8736
Dorud	0.9267	0.9907	0.8626
Yazd-Shahid Zanbagh	0.9047	0.9593	0.8501
Ray	0.9402	0.9454	0.9350
Uromiyeh	0.9998	0.9995	1.0000
Shariati	0.9839	0.9926	0.9753
Sufian	0.9707	0.9763	0.9651
Zahedan	0.9507	0.9454	0.9559
ghaen	0.8947	0.9253	0.8642
Hesa	0.9179	0.9353	0.9006
Kangan	0.9998	1.0000	0.9996
Shirvan	0.9781	0.9780	0.9782
The average of gas plants	0.9474	0.9648	0.9300
Gilan	0.9980	0.9966	0.9994
Qom	0.9988	0.9982	0.9995
Nayshabur	0.9894	0.9944	0.9845
Fars	0.9981	0.9994	0.9968
Khoy	0.9926	0.9988	0.9864
Kazeroon	0.9979	0.9959	1.0000
The average of combined-cycle plants	0.9958	0.9972	0.9944
Total mean	0.976072	0.9827	0.9693

Table 2: Results of paired t-test for equality of means

Hypothesis	All	Steam plants	Gas plants	Combined cycle plants
The F-statistics for the null hypothesis: Mean of 1999-2003=Mean of 2004-2011	4.450	4.820	5.670	4.520
The F-statistics for the alternate hypothesis: Mean of 1999-2003>Mean of 2004 to 2011	0.000	0.000	0.000	0.000
The F-statistics for the alternate hypothesis: Mean of 1999-2003<Mean of 2004-2011	1.000	1.000	1.000	1.000

Table 3: The results of estimating the impact of market establishment on technical efficiency using panel data tobit method

Variables	1	2	3	4	5
Dum					
Coefficient	0.021	0.023	0.024	0.023	0.026
t value	−9.18	−5.73	−8.48	−6.47	−6.47
Age					
Coefficient		−0.007	−0.005	−0.007	−0.007
t value		−3.28	−4.93	−4.93	−4.82
Fuel					
Coefficient			0.017	0.019	0.021
t value			−5.26	−5.04	−5.84
Cap					
Coefficient				0.043	0.039
t value				−4.38	−7.26
Size					
Coefficient					0.007
t value					8.78
Intercept					
Coefficient	0.935	0.945	0.941	0.943	0.951
t value	−41.14	−38.05	−36.31	−35.15	−37.11

It can be observed from the Table 1 that average of technical efficiency is increased after the electricity market establishment in all plants, while in gas plants this amount is significant. In addition, total average before and after the restructure was 0.983 and 0.969, respectively, which indicates an increase in the technical efficiency in thermal plants.

Before estimating Equation (1), in this section equality of the efficiency average, before and after restructure of electricity market is tested using paired samples t-test. Results of this test are represented in Table 2. According to the results of Table 2, t-value for null hypothesis is equal to 4. 45 based on equality of the two periods, and is an evidence for rejecting null hypothesis against the hypothesis of a greater average for the period after restructuring. In addition, in Table 2, results for steam, gas, and combined cycle plants are presented separately. For all plants, null hypothesis is rejected against the hypothesis of a greater average for the next period after restructuring.

After a preliminary survey of the technical efficiency status of thermal plants in two periods before and after reconstructing, in this part, via estimating Equation (1) using Tobit method, a survey of the effects of reconstructing on the technical efficiency of thermal plants will be carried out. In order to achieve a suitable modeling, the stepwise method is employed and after estimating a model which only includes the dummy variable of reconstruction, other variables, in their order of importance are entered into the equation; then at any time after the entry of a variable, the variables that have already been imported are re-evaluated and removed from the model just as if the significance level was decreased, otherwise they are allowed to remain in the equation. As it is shown in Table 3, in each of five estimations, the coefficients of dummy variable of reconstruction are positive and significant. In all of these estimations, the dummy coefficient is more that 2% and in the final model it is 2.6%, which reflects the positive effect of reconstruction on technical efficiency in thermal plants. The effect of age variable is negative and significant, which shows lower efficiency compared to the newer power plants. The type of fuel random variable is positive, which regards this definition; this means that replacing gas instead of natural gas and fuel oil results in an increase in the technical efficiency of the plants. Variable coefficient of capacity utilization rate reflects the positive and significant effect of this variable on the technical efficiency of the plants. Estimated coefficient for size variable, which represents the number of employees and works as an index for measuring the size of the firm is also positive and significant and shows that with 1% increase in the size of the plant, the technical efficiency of the plant will have an increase equal to 0.7%.

5. CONCLUSION

Electricity has a very high importance as a principal input in the process of production, and is an important customer commodity. With the advancement of technology, electrical power has become the propulsion of industry, agriculture and even services. Therefore, paving the way for the efficient production of energy supply by reducing the price of the product will increase the welfare of society and the improvement of competitiveness of other products. Planning to increase the efficiency of power generation requires knowledge of the effects of the policies that have been implemented in the past. Restructuring of the electricity industry and establishing the electricity market has been one of the most important events in recent decades in the power industry in 2003. Based on the available literature, it is assumed that establishing the electricity market and increasing competition among electricity suppliers has improved performance of plants and increases their incentives for reducing production costs. This study calculates the technical efficiency in power planets of Iran and estimates the effect of electricity market establishment on it. The results showed that establishing the electricity market has led to an increase in technical efficiency in thermal power plants. Comparing these results with other analogous studies is showing that this effect has been very low (2.6%). For example, the study of Craig and Savage (2013) is estimating this effect to be between 13% and 20%, Pollitt (1996) 6% and Zhang (2007) have estimated the value close to 24%. This effect could be low due to the following:

- The pricing system in the electricity market is based on a payment method following the lowest offers, compared to the uniform price, in this method there are lower incentives to reduce costs and the firm attempts to offer the lowest prices just to remain in this network, while in the uniform price, in order to earn higher profits, suppliers have stronger incentives for reducing costs
- Despite many changes in the electricity market, still the majority of suppliers are owned by the government. This has led to managers having no fear of lack of demands as well as consequent reduced earnings for the plants and even in some cases they even have guaranteed purchase agreements and are made sure of sales of their products.

According to the above mentioned issues, confirmed the positive effect of electricity market on the technical efficiency of power plants reflects the principal role of competition in improving plant performance and increase in managers' incentives for reducing costs. Thus, increasing the role of private sector in this market and reduced interference in that reinforces competition and will improve efficiency as well as reducing the price of electricity; this in turn leads to increased competitiveness due to the vital role of electricity power in economic activities.

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