A REVIEW AND SYNTHESIS OF EMPIRICAL STUDIES ON TECHNICAL EFFICIENCY MEASUREMENT IN TURKISH ELECTRICITY MARKET

TÜRKİYE ELEKTRİK PAZARINDAKİ TEKNİK ETKİNLİK ÖLÇÜMLERİ ÜZERİNE AMPİRİK ÇALIŞMALARIN TARAMASI VE SENTEZİ

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Abstract

In this study, we survey studies measuring the efficiencies in Turkish electricity market. At the end of this survey, we observed an eager interest in electricity distribution market rather than generation market because of the data availability. Another result drawn from these studies is that in Turkey private electricity utilities are more efficient than their public counterparts in both electricity distribution and generation segments. On the other hand, the studies reviewed suffer from a lack of consistency in terms of their efficiency estimations. Thus, the robustness condition of the efficiency estimations should be first satisfied if they are used in regulatory proceedings to set electricity tariffs.

Keywords: *Technical Efficiency, Turkish Electricity Market, Data Envelopment Analysis - DEA, Stochastic Frontier Analysis - SFA, Review Study.*

Öz

Bu çalışmada, Türkiye elektrik pazarında etkinlik ölçen çalışmalar taranmıştır. Bu tarama sonucunda, verilerin bulunabilirliği sebebiyle elektrik üretiminden ziyade elektrik dağıtımına yönelik yoğun bir ilgi olduğu gözlenmiştir. Bu çalışmalardan çıkarılan diğer bir sonuç ise Türkiye'deki özel teşebbüslerin kamu teşebbüslerine göre hem elektrik dağıtım hem de üretim segmentlerinde daha etkin olduklarıdır. Diğer yandan, taranan çalışmaların etkinlik tahminleri arasında tutarlılık sorunu bulunmaktadır. Bu nedenle, bu etkinlik tahminleri düzenleyici işlemlerde elektrik tarifelerinin belirlenmesi amacıyla kullanılacaksa öncelikle etkinlik tahminlerinin tutarlılığının sağlanması gerekmektedir.

Anahtar Kelimeler: *Teknik Etkinlik, Türkiye Elektrik Pazarı, Veri Zarflama Analizi - VZA, Stokastik Sınır Analizi - SSA, Tarama Çalışması.*

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INTRODUCTION

Electricity markets are vertically segmented into three phases: (i) generation, (ii) transmission, and (iii) distribution. Looking at the structure of electricity price in Turkey, we observe that generation cost makes up 64% of electricity price paid by a household in Turkey in 2008. Generation cost is followed by distribution cost, which is 11% of the electricity bill.[1]

Similar to other power sector reforms, the main objective of the regulatory reforms in the electricity markets is to improve the efficiency of the market by introducing competition into these three segments of the electricity market. To achieve this, the incentive regulations are applied in the sense that the actual performances of utilities are compared against to some predefined reference or benchmark performance, and then good performances are rewarded. Thus, for electricity sector regulation, the selection of the most appropriate benchmark efficiency level and the method to measure the actual efficiency levels of the utilities turn out to be very critical issues. There are several methods of benchmarking for performances of utilities. The most popular ones are Data Envelopment Analysis (DEA), Stochastic Frontier Analysis (SFA) and Corrected Ordinary Least Squares (COLS).

The electricity markets in most of the countries have always become a good candidate to apply these efficiency measurement methods. Turkey is not an exception to this. To the best of our knowledge, there exist 19 studies measuring efficiency in the Turkish electricity market. In this study, we survey these efficiency measurement studies. In doing this, our aim is to try to determine some robust policy issues from these studies. If the results are not robust to different model specifications or to the data sets used, they will be called into question especially in using for the regulatory purposes. The studies reviewed include several topics such as the economies of scale in the electricity market, determinants of the efficiency of the electricity utilities, the effect of the ownership (private vs. public) on efficiencies, the role of the incentives in promoting efficiency, etc. In Section 1, the most popular efficiency measurement techniques, DEA and SFA, are explained. Section 2 reviews the studies aiming to measure the efficiency performances of electricity firms in Turkey. Finally, some conclusions of this survey are drawn in the Section entitled "Implications and Conclusion".

[1] ERDOĞDU, E. (2009), "Some Thoughts on the Turkish Electricity Distribution Industry", *Renewable & Sustainable Energy Reviews*, No:13, p.1492.

1. BENCHMARKING METHODS

The efficiency measurement methods can be categorized according to their assumptions and techniques which are used. First, the frontier on which the most efficient utilities operate may be determined *parametrically* or *non-parametrically*. Parametric models impose an explicit functional form for the model and distribution assumption on the data, and then the frontier is estimated using econometric techniques. Non-parametric approaches, on the other hand, neither impose any *a priori* assumptions about functional form of the frontier nor make any distributional assumptions for the deviations from the frontier. Instead, nonparametric approaches rely on linear programming to calculate piecewise linear segments of the efficient frontier. Another categorization of the efficiency measurement methods is based on the structure of the deviations from the frontier. In this respect, the technical efficiency can be calculated *deterministically* or *stochastically*. In the deterministic approach, the distance between inefficient firms and the efficient frontier is entirely attributed to the inefficiency. On the contrary, in stochastic approaches, one can attribute some part of the deviations from the frontier to random noises.

In the literature, one of the most common methods in measuring the efficiency of firms is SFA, which is a stochastic and parametric method. Among the nonparametric methods, DEA has been used widely. The pros and cons of these methods have been extensively discussed in the literature.

The main advantage of DEA is that it does not need any restriction on the functional form of the production relationship between inputs and outputs. In other words, this method allows the data to "speak for themselves".[2] SFA, in contrast, requires strong assumptions regarding the form of the frontier. Similarly, DEA does not require any assumption for the underlying distribution of the inefficiency term while SFA imposes distributional assumption on inefficiency term.

As a result of requiring no assumptions regarding the form of the frontier and inefficiency term, DEA is a deterministic method in nature. In other words, all deviations from the efficiency frontier are assumed to be under control of the firm, so attributed as inefficiency. Another drawback of DEA is that it does not allow any statistical significance tests. On the contrary, SFA can model the stochastic shocks by help of the random error introduced into the specification of the frontier. With SFA one may also carry out statistical tests on different models with alternative specifications.

[2] MORTIMER, D. (2002), *Competing Methods for Efficiency Measurement A Systematic Review of Direct DEA vs SFA/DFA Comparisons*, Working Paper No. 136, University of East Anglia, Norwich, p.1

There exists a sharp trade-off in making a selection between these two methods. Thus, the literature comparing empirically and experimentally these two methods is growing extensively. The literature comparing these two methods has no conclusion on which method is more advanced and correct. Nevertheless, in this literature, one can find some suggestions as to selecting the correct method, although they should be considered just as rule of thumb in nature. For example, Banker et al. (1993) favor DEA method where measurement error is unlikely to occur and the assumptions of the neoclassical production theory are open to discussion.[3] In contrast, they claimed that econometric methods performs well when severe measurement errors exist and the underlying production technology can be illustrated by help of a simple functional form.

We may mention additional strengths and weaknesses of these methods. For instance, with DEA it is possible to identify "peers" for the inefficient firms, in this way inefficient firms can compare directly themselves with their efficient counterparts. However, the efficiency estimations of DEA method are extremely sensitive to variable selection, size of the sample and data errors. For example, as more variables are included in DEA models, the number of firms on the frontier increases. In other words, the number of the firms found to be full efficient increases as the model studied includes more variables. In addition, in DEA at least one of the firms should obtain full efficiency score, namely 1. This is so because of the fact that DEA only measures efficiency relative to best practice in the sample studied. For this reason, it is not meaningful to compare efficiency scores calculated from two different DEA studies. On the other hand, SFA method usually necessitates estimating a considerable amount of parameters, some of which may be frequently found insignificant or even with wrong signs.

2. TECHNICAL EFFICIENCY MEASUREMENT IN TURKISH ELECTRICITY MARKET

We identified 19 studies assessing the efficiency performance in Turkish electricity sector by applying one of the benchmarking methods described in the previous section. Among them, all except one[4], use frontier benchmarking such as DEA

[3] BANKER, R.D., V.M. GADH and W.L. GORR (1993), "A Monte Carlo Comparison of Two Production Frontier Estimation Methods: Corrected Ordinary Least Squares and Data Envelopment Analysis", *European Journal of Operational Research*, No:67, p.333.

[4] ÇELEN, A. (2012), "Performance Evaluation of Turkish Electricity Distribution Market Using a Combined FAHP / TOPSIS Method", *Energy Education Science and Technology Part A: Energy Science and Research*, No:29(2), p.1263-1276. Çelen evaluates the performances of electricity distribution utilities using Fuzzy Analytic Hierarchy Process (FAHP) and Technique for Order Preference by Similarity to Ideal Solution (TOPSIS) methods together. With FAHP method, the weights attached to these performance criteria by decision markers were determined. Then, TOPSIS method was used to rank the performances of the distribution utilities. Since the methodology of Çelen is completely different from other studies measuring efficiency in Turkish electricity market, it is not incorporated into Table 1 tabulating other empirical studies on Turkish electricity market.

and SFA, which are explained in the previous section. Out of 19 studies reviewed, 16 studies aim to measure the efficiency of electricity distribution utilities, while only three are related with the electricity generating power market. All studies reviewed in our study use input-oriented model specification. In other words, they search an answer to the question of “By how much can input quantities be proportionally reduced without altering the output quantities?”. Indeed, this is understandable in the case of electricity utilities: In Turkish electricity market, similar to those of other countries, electricity utilities have been responsible from serving all customers, making the outputs as exogenous. Six applied the SFA method. Among them, five selected the translog form to specify the input-distance function, while the remaining used the Cobb-Douglas functional form, which is not flexible in the sense that it restricts the elasticity of substitutions.

Table 1. Empirical Studies on Turkish Electricity Sector

Author/Date	Data	Method	Inputs	Outputs	Environment. Variables	DEA		SFA	
						Orientat.	*RTS*	*Form*	*Frontier*
Bağdadioğlu (1996)	1991 28 generat. Utilities	DEA	- number of employees - capital	- net hydro-electric generation	-	input-oriented	CRTS	-	-
Bağdadioğlu et.al. (1996)	1991 70 distrib. Utilities	DEA	- number of employees - transformer capacity - network length - general expenses - network losses	- number of customers - electricity supplied - maximum demand - service area	-	input-oriented	VRTS	-	-
Bağdadioğlu (2005)	1991&2003 21 distrib. Utilities	DEA	- number of employees - transformer capacity - network length - network losses	- number of customers - electricity supplied - service area	-	input-oriented	CRTS VRTS	-	-
Bağdadioğlu et.al. (2007)	1999-2003 82 distrib. Utilities	DEA	- number of employees - number of transformers - transformer capacity - network length - network losses	- number of customers - electricity consumed - service area	-	input-oriented	VRTS	-	-
Sarıca and Or (2007)	2001 65 generat. Utilities	DEA	- fuel cost - operation cost - thermal efficiency - environmental cost	- production - availability - utilization	-	input-oriented	CRTS VRTS	-	-
Odyakmaz and Scarsi (2007)	2004 72 distrib. Utilities	COLS DEA	- total net energy consumed - numbers of customers - network length - national-border dummy	- operating cost	-	input-oriented	CRTS	Cobb-Douglas	input distance

Notes: RTS: Returns to Scale; CRTS: Constant Returns to Scale and VRTS: Variable Returns to Scale.

Table 1. Empirical Studies on Turkish Electricity Sector (continued)

Author/Date	Data	Method	Inputs	Outputs	Environment. Variables	DEA		SFA	
						Orientat.	*RTS*	*Form*	*Frontier*
Bağdadioğlu and Weyman-Jones (2008)	1999-2004 82 distrib. Utilities	SFA	- transformer capacity - network length - network losses - numbers of employees - numbers of transformers	- numbers of customers - electricity consumed	- service area - customer dispersion	-	-	translog	input distance
Bağdadioğlu (2009)	2004 21 distrib. Utilities	DEA	- total expenditures - number of interruptions - interruption time	- numbers of customers - electricity consumed - network length	-	input-oriented	VRTS	-	-
Baykal (2009)	2004-2007 18 distrib. utilities	SFA	- price of electricity - price of capital - price of labour	- electricity supplied - number of customers - network length	- service area - network density dummy variable	-	-	Cobb-Douglas	input distance
Odyakmaz (2009)	2005-2007 21 distrib. utilities	OLS COLS DEA	- electricity consumed - numbers of customers - number of interruptions - investment cost - personnel cost - altitude - service area - residential custom. index	- total expenditures	-	input-oriented	CRTS	Cobb-Douglas	input distance
Bağdadioğlu and Senyücel (2010)	2002-2007 20 distrib. utilities	SFA	- total expenditures - interruption minutes per consumer	- number of customers - electricity supplied	- village customer density - geographic dummy	-	-	translog	input distance

Notes: RTS: Returns to Scale; CRTS: Constant Returns to Scale and VRTS: Variable Returns to Scale.

Table 1. Empirical Studies on Turkish Electricity Sector (continued)

Author/Date	Data	Method	Inputs	Outputs	Environment. Variables	DEA		SFA	
						Orientat.	*RTS*	*Form*	*Frontier*
Bağdadioğlu and Weyman-Jones (2010)	1999-2004 82 distrib. utilities	SFA	- transformer capacity - network length - network losses - numbers of employees - numbers of transformers	- number of customers - electricity consumed	- service area - customer dispersion	-	-	translog	input distance
Bağdadioğlu (2011)	2006 20 distrib. companies	DEA	- operating expenses - network losses - numbers of interruptions - duration of interruptions	- electricity supplied - customer density	-	input-oriented	CRTS VRTS	-	-
Sözen et.al (2010)	2008 15 generat. utilities	DEA	- capacity usage factor - thermal efficiency - average operational time - project production capacity	- fuel cost/actual production	-	input-oriented	CRTS VRTS	-	-
Çelen (2011)	2002-2009 21 distrib. utilities	SFA	- transformer capacity - network length - interruption minutes per consumer - numbers of employees	- number of customers - electricity supplied	- customer density - customer structure	-	-	translog	input distance
Çelen and Yalçın (2012)	2002-2009 21 distrib. utilities	DEA	- numbers of employees - network length - transformer capacity	- electricity supplied - number of customers - quality of service	-	input-oriented	CRTS VRTS	-	-
Senyücel (2012)	2003-2008 20 distrib. utilities	SFA	- total expenditures - interruption minutes per consumer - minutes to repair interruptions	- electricity supplied - number of customers	- rural consumer density - service area	-	-	translog	input distance

Notes: RTS: Returns to Scale; CRTS: Constant Returns to Scale and VRTS: Variable Returns to Scale.

Table 1. Empirical Studies on Turkish Electricity Sector (continued)

Author/Date	Data	Method	Inputs	Outputs	Environment. Variables	DEA		SFA	
						Orientat.	*RTS*	*Form*	*Frontier*
Çelen (2013)	2002-2009 21 distrib. utilities	SFA	- transformer capacity - network length - interruption minutes per consumer - numbers of employees	- number of customers - electricity supplied	- customer density - customer structure - dummy variable for restructuring	-	-	translog	input distance

Notes: RTS: Returns to Scale; CRTS: Constant Returns to Scale and VRTS: Variable Returns to Scale.

The first stage in efficiency measurement studies is to determine the inputs, outputs and other (environmental) factors of the relevant sector. Although technologies of the electricity sector are similar all over the world, a wide variety of factor combinations are employed in the efficiency studies of this sector. Jamasb and Pollitt (2001) review 20 efficiency studies regarding electricity distribution sector, and showed that there is no consensus in the literature on which variables best describe the performance of electricity distribution units.[5] A variable has been used as an input, output or environmental variable in different studies. As can be seen from Table 1, the efficiency studies of Turkish electricity sector also exhibit a wide variety in the input-output selection. The absence of consensus on this matter may be explained, to some extent, by lack of data.[6]

2.1. Input Variables

We identified more than twenty input variables used in the studies reviewed, including number of employees, transformer capacity, numbers of transformers, network length, general expenses, network losses, altitude and service area, etc. The inputs considered in these studies are generally found to be of importance in enhancing the technical efficiency of the electricity utilities. One possible reason for this may be that the authors of these studies naturally tend to choose the input variables which are statistically significant while specifying their models. But, these studies generally indicated different input variables as the most crucial one.

In addition to these input variables, the quality of electricity appears as one the most popular variables in the recent efficiency studies. Appa et al. (2010) examine the quality of electricity distribution in detail.[7] Accordingly, the quality of electricity may be separated into two broad categories: technical quality and quality of customer service (ability to meet customers' needs such as new connections or repairs). Technical quality may be measured in terms of interruption of service or regularity in the voltage level supplied. Frequency of outages and duration of outages provide the technical quality in terms of interruption of service. Growitsch et al. (2009), Bağdadioğlu and Senyücel (2010), Çelen (2011), Senyücel (2012) and Çelen (2013) use the average duration of blackouts per customer as a proxy for service reliability.[8] Coelli et al. (2008), on the other hand,

[5] JAMASB, T. and M. POLLIT (2001), *Benchmarking and Regulation of Electricity Transmission and Distribution Utilities: Lessons from International Experience*, University of Cambridge, Cambridge, p.28.

[6] HATTORI, T, T. JAMASB and M. POLLITT (2005), "Electricity Distribution in the UK and Japan: A Comparative Efficiency Analysis 1985-1998", *Energy Journal*, No:26(2), p.30.

[7] APPA, G., C.A.B. COSTA, M.P. CHAGAS, F.C. FERREIRA and J.O. SOARES (2010), *DEA in X-factor evaluation for the Brazilian Electricity Distribution Industry*, Working Papers, LSEOR 10.121, London School of Economics, p.30.

[8] GROWITSCH, C., T. JAMASB and M. POLLITT (2009), "Quality of Service, Efficiency, and Scale in

prefer to use total number of outages for this input variable.[9] Bağdadioğlu (2009) uses both simultaneously.[10] Senyücel (2012) also uses average minutes to repair interruptions. Bağdadioğlu (2011) uses numbers and duration of interruptions simultaneously.[11] Among these studies, Coelli et.al. (2008), Growitsch et.al. (2009), Bağdadioğlu (2009), Bağdadioğlu and Senyücel (2010), Çelen (2011), Bağdadioğlu (2011), Senyücel (2012) and Çelen (2013) are the studies which used quality of electricity distribution as input. This variable is, in contrast, used as an output by Appa et al. (2010) and Çelen and Yalçın (2012).[12]

As adding the quality variable into model specifications, it is aimed to observe whether the measured inefficiency of an individual company is due to poor employment of the other inputs or due to higher input requirements as a result of a higher quality level. The insignificancy of this input variable means that the inclusion of the quality variable into models does not affect estimated efficiency scores of the electricity utilities. In other words, the reason for the inefficiency of a company with a higher quality level is not higher input requirements needed to achieve this high quality level. Instead, the reason is the poor employment of the other inputs, namely just itself of the technical inefficiency.

For Turkish electricity sector, Bağdadioğlu and Senyücel (2010), Çelen (2011), Senyücel (2012) and Çelen (2013) are the studies which incorporate the quality of the electricity into their model specifications. Bağdadioğlu (2009) and

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Network Industries: An Analysis of European Electricity Distribution", *Applied Economics,* No:41(20), p.2562. BAĞDADİOĞLU, N. and O. SENYÜCEL (2010), Service Quality Regulation in Electricity Distribution, paper presented in 6th International Scientific Conference, May 13–14, 2010, Vilnius, Lithuania. ÇELEN, A. (2011), *Measuring the efficiency of the Turkish Electric Distribution Sector Using Stochastic Frontier Analysis,* Unpublished M.Sc. Thesis, Middle East Technical University, Ankara, p.72. SENYÜCEL, O. (2012), *Türkiye'de Elektrik Dağıtımında Hizmet Kalitesi ve Etkinlik Ölçümü*, Published Phd Thesis, Graduate Thesis Series, No:19, Rekabet Kurumu, Ankara. ÇELEN, A. (2013), "The Effect of Merger and Consolidation Activities on the Efficiency of Electricity Distribution Regions in Turkey", *Energy Policy,* No:59, p.679.

[9] COELLI, T.J, H. CRESPO, A. PASZUKIEWICZ, S. PERELMA, M.A. PLAGNET and E. ROMANO (2008), "Incorporating Quality of Service in a Benchmarking Model: An Application to French Electricity Distribution Operators", www.cepe.ethz.ch/workshop2008/Plagnet, Date Accessed: 10.12.2012, p.7.

[10] BAĞDADİOĞLU, N. (2009), "Türk Elektrik Dağıtım Sektöründe Hizmet Kalitesine Yönelik Özendirici Bir Düzenleme Uygulaması", *Gazi Üniversitesi İktisadi ve İdari Bilimler Fakültesi Dergisi,* No:11(1), p.37.

[11] BAĞDADİOĞLU, N. (2011), "Regulation in the Turkish Electricity Industry", T. Çetin and F. Oğuz (eds.), in *The Political Economy of Regulation in Turkey*, p.139.

[12] ÇELEN, A. and N. YALÇIN (2012), "Performance Assessment of Turkish Electricity Distribution Utilities: An Application of Combined FAHP / TOPSIS / DEA Methodology to Incorporate Quality of Service", *Utilities Policy*, No:23, p.59-71. In incorporating quality of service, Çelen and Yalçın propose a combined methodology of FAHP/TOPSIS/DEA methods. With FAHP method, the relative importance levels of different quality indicators were determined. Then TOPSIS method was used to generate quality of service variable. And finally this variable was used as an output in the DEA stage, and efficiency performances of the electricity distribution utilities were determined. The most important advantage of the proposed methodology by Çelen and Yalçın (2012) is that it allows taking into account several quality measures simultaneously instead of relying on only one dimension of the quality.

Bağdadioğlu (2011) also took into account quality of the electricity. However, the significancy test of this variable is irrelevant for these studies due to the fact that it used DEA method which does not incorporate significancy tests. While Bağdadioğlu and Senyücel (2010) and Senyücel (2012) reveal the importance and significance of the quality variable in their efficiency analysis, Çelen (2011) and Çelen (2013) conclude that the coefficient of the quality variable is statistically insignificant, meaning that taking the quality into account does not alter the efficiency score estimations drastically. Meanwhile, in the literature, there exist other studies reaching conflicting conclusions regarding the importance of the quality variable in the efficiency analysis. For example, Coelli et al. (2008) also show that the incorporation of the quality does not affect significantly the technical efficiency scores. On the other hand, several studies such as Growitsch et al. (2009) and Giannakis et al. (2005) reveal the importance and significance of the quality variable in the efficiency analysis.[13] However, it should be noticed that Growitsch et al. (2009) find that the inclusion of the quality variable reduces estimated efficiency scores, which is completely in contrast to the finding of Giannakis et al. (2005). Thus, the current studies cannot shed light on the importance of the electricity quality in the efficiency measurement and this issue deserves some further exploration.

2.2. Output Variables

In these studies reviewed, the most common outputs are the number of customers, electricity supplied, maximum demand, service area, network length, etc. By examining the sum of the of the output coefficients in the SFA applications, it is possible to determine the existence of economies of scale, and particularly the optimal size of utilities, which is a classic problem in the electricity market. We found six studies addressing this issue, Bağdadioğlu et al. (2007), Bağdadioğlu and Weyman-Jones (2008), Baykal (2009), Bağdadioğlu and Senyücel (2010), Çelen (2011) and Çelen (2013).[14]

In 2004, Turkish government accepted the Electricity Sector Strategy Paper (Strategy Paper) and determined the necessary steps to be taken in the way of liberalization in the electricity market. In 2005, following several mergers between electricity distribution organizations of Turkish Electricity Distribution

[13] GIANNAKIS, D., T. JAMASB and M. POLLITT (2005), "Benchmarking and Incentive Regulation of Quality of Service: An Application to the UK Electricity Distribution Networks", *Energy Policy*, No:33(17), p.2266.

[14] BAĞDADİOĞLU, N., C. WADDAMS PRICE and T. WEYMAN-JONES (2007), "Measuring Potential Gains from Mergers among Electricity Distribution Companies in Turkey Using a Non-parametric Model", *The Energy Journal*, No:28(2). BAĞDADİOĞLU, N. and T. WEYMAN-JONES (2008), "Panel Data Stochastic Frontier Analysis for Energy Network Regulation", www.cepe.ethz.ch/workshop2008/Weyman-Jones, Date Accessed: 10.12.2012. BAYKAL, S. (2009), *The Cost Efficiency Analysis of Turkish Electricity Distribution Firms*, Unpublished M.Sc. Thesis, Eidgenöessische Technische Hochschule, Zürich.

Co. (TEDAŞ) (82 in total), the Turkish electricity distribution network was divided into 21 regions, as announced in the Strategy Paper. Bağdadioğlu and Weyman-Jones (2008) analyze the scale elasticity in Turkish electricity distribution utilities before the 2004 reform and they suggested the consolidation among smaller utilities which were still in the range of increasing returns to scale prior to the consolidations in 2004. Bağdadioğlu et al. (2007) examine the potential efficiency gains of the mergers outlined in the Strategy Paper. This is performed by comparing the actual efficiency levels of observed distribution organizations with those of the merger of proposed aggregated companies. The results indicate potential for considerable efficiency gains from the proposed mergers. Bağdadioğlu et al. (2007), however, suggest that they have identified the harmony effects as the major source of potential efficiency gains, and it is possible to achieve these without a complete merger. Since the critical aspect of the harmony gains has been found to be related with the elimination of slack in input usage, it is possible that an internal market mechanism, or joint ventures short of full merger, could achieve better use of available input services, according to Bağdadioğlu et al. (2007). Çelen (2013) also measures how the efficiency performances of the electricity distribution regions were affected by their mergers occurred in 2005. However, there exists an important difference between Bağdadioğlu et al. (2007) and Çelen (2013). Bağdadioğlu et al. (2007) measures only potential efficiency gains of these mergers by examining 1999–2003 period in the DEA framework. Instead, studying the time period of 2002–2009 by help of SFA method, Çelen (2013) measures the exact efficiency effects of the mergers. Parallel to the prediction of Bağdadioğlu et al. (2007), Çelen (2013) witnesses that the mergers between electricity distribution organizations in 2005 increased the efficiency levels. This study also shows that the positive impact of the mergers on the efficiencies decreases as the proportion of sales to residential customers in regions increases. It is also revealed that the positive impact of the mergers on the efficiencies was not affected adversely by the increases in the customer density. In other words, the restructuring activities occurred in 2005 increased equally the efficiencies of the companies serving in the regions with higher and lower customer densities.

The presence of the scale economies following the 2004 reform is studied by Baykal (2009). It estimated a Cobb-Douglas frontier cost function in order to analyze the efficiency of Turkish electricity distribution utilities. Another study using the Cobb-Douglas cost function is Odyakmaz and Scarsi (2007), studying the efficiency of Turkish electricity distribution utilities by help of DEA and COLS.[15] Their results showed that the efficiency scores are relatively dispersed

[15] ODYAKMAZ N. and G.C. SCARSI (2007), *Electricity Distribution Benchmarking in Turkey for Regulatory Purposes: The Case of TEDAS*, 9th IAEE European Energy Conference "Energy Markets

throughout different regional territories. From this result, they concluded that regional differences might come into play within such large and diverse territories. For this aim, Baykal (2009) utilizes three different random effects model. The results of all models indicate the presence of the economies of scale in the Turkish electricity distribution market. The optimal size of a distribution firm is found to be relatively close to the median value of the sample, which is an annual electricity supply of 4,092 GWh, 17,115 km network length and 1,328,385 customers. This study suggests that some of the firms (especially those in low-density areas) may benefit from mergers with adjacent utilities. Similarly, Çelen (2011) and Çelen (2013) also conclude that there exists increasing returns to scale in Turkish electricity distribution market. In contrast, Bağdadioğlu and Senyücel (2010) find decreasing returns to scale at the sample mean, and calculated the optimal firm size around 1.4 million customer, which is rather close to the figure of Baykal (2009). Bağdadioğlu and Senyücel (2010) also suggest that before privatization the Privatization Administration (ÖİB) should consider merger of low scale utilities to achieve the optimal firm size and to increase technical efficiency. In the light of all these studies, one may mention some consensus regarding the existence of scale economies and efficiency gains associated with the economies of scale in Turkish electricity distribution market.

2.3. Environmental Variables

In addition to the inputs, several environmental factors, which are generally uncontrollable by utilities, may be also included into model specifications. Among the studies reviewed, four examined the environmental factors which have the potential to affect the efficiencies of the electricity utilities. Service area of regions (in km^2) is the most popular and significant environmental variable, which is studied by Bağdadioğlu and Weyman-Jones (2008), Baykal (2009), Bağdadioğlu and Weyman-Jones (2010) and Senyücel (2012).[16] Several variables are used in order to take into account the customer density of the regions: Bağdadioğlu and Weyman-Jones (2008) and Bağdadioğlu and Weyman-Jones (2010) use customer dispersion, i.e. the reciprocal of customers relative to service area while Çelen (2011) and Çelen (2013) prefer to use the number of customers per km of distribution line. From these studies, one may draw the conclusion that the utilities operating in a region with higher customer density are more efficient than other firms. The structure of the customers in regions is another environmental factor examined in the studies. For this aim, Bağdadioğlu and Senyücel (2010) and

and Sustainability in a Larger Europe", Florence Italy.

[16] BAĞDADİOĞLU, N. and T. WEYMAN-JONES (2010), "Stochastic Frontier Panel Data Modelling for Incentive Regulation: An application to the Turkish Electricity Distribution", *İktisat, İşletme ve Finans*, No:25(297).

Senyücel (2012) take into account the number of village customers relative to the total number of customers, and showed that a small percentage increase in village density may considerably decrease efficiency of electricity distribution utilities. In a similar way, Çelen (2011) and Çelen (2013) include the proportion of sales in MWh to residential customers to total sales, and conclude that efficiencies of the companies serving mostly to the residential customers are higher than those of other companies. Çelen (2013) also concludes that the positive impact of residential customers on the efficiencies decreased significantly following the mergers between electricity distribution utilities occurred in 2005. Bağdadioğlu and Senyücel (2010) also use a dummy variable for the Eastern part of Turkey, by taking into consideration that this area has different geographic and weather conditions compared to other regions. The efficiency scores of the utilities in the Eastern part are found to be significantly lower than those of other utilities. Another dummy variable, used by Baykal (2009), is the network density dummy variable. As expected, the sign of this variable is found to be positive, meaning that an increase in the number of the network nodes makes the network lines more ramified and increases the investment and maintenance costs.

2.4. Main Motivations of the Studies Reviewed

One important aim followed by the studies reviewed is to assess the effect of the ownership on the efficiency of the electricity utilities. Some theoretical models such as public choice theory and principal agent theory claim that private enterprises show superior performance in comparison to public utilities. However, empirical studies on electricity sector from different regions of the world provide contradictory results. As for the Turkish electricity sector, we identified five studies evaluating the effect of the ownership on efficiency:

Bağdadioğlu et al. (1996) compare the performances of the state-owned electricity distribution organizations with those of their private counterparts (KCETAŞ, Çukurova, Kepez and Aktaş) by using DEA method.[17] This study concluded that at 5% significance level, the null hypothesis that there is no significant difference in the efficiency scores between public and private distribution organizations is rejected in favour of the alternative hypothesis that the private distribution organizations have higher efficiency scores. The private distribution firms (four in total) were found to be full efficient. Bağdadioğlu et al. (1996), however, warn about the very small number of private distribution organizations in the sample.

[17] BAĞDADİOĞLU, N., C.M.W. PRICE and T.G. WEYMAN-JONES (1996), "Efficiency and Ownership in Electricity Distribution: A Non-parametric Model of the Turkish Experience", *Energy Economics*, No:18.

Out of four private distribution companies, three were nationalized by State in 2002. Comparing the efficiency performances of the distribution companies in 1991 and in 2003, Bağdadioğlu (2005) aims to reveal whether performances of these companies were affected adversely by public ownership.[18] Examining the individual efficiency performances of the companies showed that most of the regions experienced a worsening performance from 1991 to 2003. As a result of the declines in the individual performances, the mean efficiency score of the companies is also found to be declining between 1991 and 2003. Bağdadioğlu (2005) claims that the efficiency losses are linked to the State's insistence on public ownership of distribution companies.

Sarıca and Or (2007) analyze the operational performance of thermal and renewable source (hydro and wind) electricity power plants using DEA.[19] This study also compared the efficiency performances of public and private electricity power plants. Accordingly, efficiencies of the coal and liquid fuel fired electricity generating utilities are found to be significantly lower than those of natural gas fired utilities. Public-owned natural gas fired power plants operate slightly less efficiently than private-owned natural gas fired power plants. As a result of these two findings, the efficiency of the public sector, which has a high ratio of coal and liquid fuel fired plants in its portfolio, is found to be lower than that of private sector. As for the renewable source power plants, robust and significant conclusions cannot be drawn due to the higher sensitivity of the results to the natural factor such as wind, amount of rain fall etc.

Odyakmaz (2009) utilizes DEA method to measure the technical efficiency scores of electricity distribution firms.[20] This study identified the performance of the only private firm (KCETAŞ) as superior to the performances of the public firms. Bağdadioğlu (2009) also concludes that KCETAŞ is one of the firms operating efficiently.

In contrast to many countries, Turkey does not apply any incentive regulation to promote efficiencies of the electricity utilities. In other words, in Turkey there is no any penalty/reward system for electricity distribution companies for worsening/improving service quality measures of frequency and duration

[18] BAĞDADİOĞLU, N. (2005), "The Efficiency Consequences of Resisting Changes in a Changing World: Evidence from the Turkish Electricity Distribution", *International Journal of Business, Management and Economics*, No:1(2).

[19] SARICA, K. and İ. OR (2007), "Efficiency Assessment of Turkish Power Plants Using Data Envelopment Analysis", *Energy*, No:32(8).

[20] ODYAKMAZ, N. (2009), *The Comparative Performance Analysis of Turkish Electricity Distribution Companies in the Framework of Performance-based Regulation*, Unpublished Phd Thesis, Hacettepe University, Ankara.

of power interruptions. Bağdadioğlu (2009) illustrates how the Energy Market Regulation Authority (EPDK) could include such a penalty/reward scheme into incentive regulation to monitor and improve the service quality performances of electricity distribution companies. According to Bağdadioğlu (2009), 13 out of 21 electricity distribution companies should improve their service quality to avoid a penalty. The remaining 8 distribution companies may be awarded for being the best performer in meeting the service quality measures.

2.5. Comparison of the Efficiency Results of the Studies Reviewed

We can make direct comparisons between efficiency estimations of the studies reviewed. However, one should not expect a strong consistency between estimations of these studies because of the fact that different data sets (with respect to time periods, utilities, inputs and outputs, etc.) are used in these studies. For this reason, it is more logical to compare mean efficiency estimations of these studies instead of examining the individual efficiencies of each utilities: For example, Bağdadioğlu and Weyman-Jones (2010) report the value of 33% as average efficiency score of the electricity distribution companies in the 1999-2004 period. Baykal (2009) reports rather lower mean efficiency scores of electricity distribution firms for the period 2004-2007. It is found to be about 9-11% for different model specifications. The efficiency estimations of Çelen (2011) for the electricity distribution firms during 2002-2009 is 64%-86% depending on the model specification. Given that the efficiency figures reported by the studies reviewed spread on a large area, they should be treated with caution. It is more difficult to rank the electricity generating utilities according to their efficiencies given that a small number of studies have addressed this issue.

Another way to search consistency between efficiency estimations is to work on different model specifications by using the same data set, which is followed by most of the studies reviewed. Among them, Bağdadioğlu and Weyman-Jones (2008) work on three broad categories of panel data model: (i) Classical SFA-panel models, which assume that all time invariant effects are inefficiency, (ii) True SFA-panel models, which assume that all time invariant effects are latent heterogeneity, and (iii) Classical Random Effects SFA with observable heterogeneity, which permits time invariant effects to be both heterogeneity and inefficiency. This study witnessed that the spread of technical efficiency scores can be large or small depending on the model used. Odyakmaz (2009), producing alternative models, calculates very low correlations between efficiency scores of the alternative methods. Among these alternative methods studied, there exist ratio measures and COLS models, both of which are generally accepted as very primitive in comparison to DEA and SFA. Baykal (2009) also generates three different random effects models, and reported very small consistency between efficiency estimations of these models. Similarly, Çelen (2011) finds that the efficiency and ranking estimations have been rather sensitive to the models used. As a result of these studies, we may reach the conclusion that different models relying on different assumptions fail to generate consistent efficiency estimations. Nevertheless, it continues to be of crucial importance to work on different model specifications in the efficiency studies.

IMPLICATIONS AND CONCLUSION

We surveyed the studies examining the efficiency of Turkish electricity utilities. At the end of this survey, the following key conclusions can be underscored:

- Out of 19 studies assessing the efficiency performance in Turkish electricity sector, 16 studies measured the efficiency of electricity distribution utilities, while only three were related with the electricity generating power market. This uneven distribution does not show that the efficiency measurement is more important for the distribution segment than for the generating segment. Indeed, looking at the structure of electricity price in Turkey, we observe the opposite: Generation and distribution costs make up 64% and 11% of electricity price paid by a household in Turkey in 2008, respectively. The main reason for relatively eager interest in electricity distribution market is that very detailed data is available publicly for distribution market while it is not easy to reach data regarding the generation market. Thus, in the coming years, data availability will probably continue to affect the pace and the pattern of the efficiency studies in this sector.
- If the efficiency estimations of these studies are used in regulatory proceedings to set tariffs, they should be, at least partly, robust to different model specifications. Otherwise, they will be called into question. Bearing in mind this point, when we compared the efficiency estimations of the studies, we cannot observe a solid consistency between efficiency estimations of the studies adopting different model specifications. Hence, the issue of consistency between efficiency estimations deserves more attention in the future.
- In the light of all the studies reviewed, one may conveniently claim that in Turkey private electricity utilities are more efficient than their public counterparts. This statement is valid for both electricity distribution and generation markets. Thus, privatization and liberalization appear as the most suitable path to follow for Turkish electricity sector.
- The authors will continue to test for the structural shifts in the sector on the efficiency given that the electricity sector is passing through a comprehensive

restructuring period. For example, it would continue to be of great interest to work on the effects of the change in the ownerships on the efficiency of the companies. However, it becomes difficult to access the data for the privatized electricity distribution regions. Thus, the most important obstruction to such efficiency studies in the coming years seems to be the lack of available data.

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