Efficiency Analysis of German Electricity Distribution Utilities – Non-Parametric and a Parametric Test

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ABSTRACT

This paper provides a productivity analysis of German electricity distribution companies. It addresses both traditional issues in electricity sector benchmarking, such as the role of scale effects and optimal utility size, as well as new evidence specific to the situation in Germany. Regarding the latter, we consider the potential effects of the three structural variables defined in the association agreements ("*Verbändevereinbarung Strom VV II+*"): consumer density, grid composition (cable versus aerial lines), and differences between East and West German distribution companies. We use labour, capital, and peak load capacity as inputs, and units sold and the number of customers as output. The data covers 380 (out of 553) German electricity distribution utilities. We apply a non-parametric data envelopment analysis (DEA) with constant returns to scale (CRS) as the main productivity analysis technique, whereas stochastic frontier analysis (SFA) is our verification method. The results suggest that returns to scale play a minor role: only very small utilities have a significant cost advantage. Low customer density is found to affect the efficiency score significantly in the lower third of all observations. The grid composition does not produce systematic effects. Surprisingly, East German utilities feature a higher average efficiency than their West German counterparts. The correlation tests imply a high coherence of the results.

Keywords: Electricity distribution, efficiency analysis, benchmarking, Germany

JEL Classification: L51, L 43, L94

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1. INTRODUCTION

Productivity modelling has played a crucial role in defining regulatory policies in the electricity sector, both in transmission and distribution. Benchmarking models for electricity distribution utilities have been introduced at a general level in the UK and the U.S. (e.g. Pollitt, 1995, Burns and Weyman-Jones, 1996, Burns, Davies and Riechmann, 1999) and have now become commonplace throughout Latin America (Estache, Rossi, and Ruzzier, 2004) and Europe, e.g. Hjalmarsson and Veiderpass (1992) for Sweden, Foresund and Kittelsen (1998) for Norway, Auer (2002) for Austria, and Filippini (1998) and Filippini and Wild (2001) for Switzerland. Many authors concentrate on scale effects, and the optimal size and relative efficiency of utilities. See Jamasb and Pollitt (2001) for a survey of international experience.

The paper is the first productivity analysis of a large number of German electricity distributors to date. In it, we address both traditional issues of electricity sector benchmarking, such as the role of scale effects and optimal utility size, as well as new evidence specific to the situation in Germany. Regarding the latter, we consider the potential effects of three structural variables: consumer density, grid composition (cable versus aerial lines), and differences between East and West German distribution companies. Our empirical section thus follows the structural criteria set out by the German association agreements ("*Verbändevereinbarung Strom VV II+*"). The data covers 380 (out of 553) German electricity distribution utilities.

Our study is motivated by two factors: first, efficiency analysis in electricity distribution currently faces serious issues in determining whether there are significant returns to scale (as suggested by a number of studies, e.g. Filipini, 1998). The question arises whether or not smaller utilities should have systematically lower efficiency scores than larger ones, implying increasing returns ("big is beautiful"); which in turn would suggest that the current, atomised structure of the German electricity utilities is not sustainable. Second, the German electricity industry is currently undergoing structural change from local monopolies to regulated competition. Observers suggest that liberalisation will lead to a structural change of the industry, which has up to now comprised a large number of companies: four in high-voltage transmission, 56 in regional distribution, and 553 in local electricity distribution. These numbers contrast sharply with the U.K. system, for instance, which features only 13 regional electricity companies altogether.

The paper is structured as follows: Section 2 gives a brief survey of the empirical literature on efficiency analysis and its theoretical basis. Section 3 describes the institutional context of electricity sector reform. Section 4 presents our methodology, data, and results from the basic and extended models that we estimate using non-parametric data envelopment analysis (DEA). Section 5 provides correlation analysis and a verification test using the stochastic frontier analysis; Section 6 concludes.

2. STATE OF THE LITERATURE - PRODUCTIVITY ANALYSIS IN THE ELECTRICITY MARKET

Data envelopment analysis (DEA) and stochastic frontier analysis (SFA) are the most commonly used methods in the literature on benchmarking and efficiency analysis in the electricity sector. They have been particularly useful in the regulatory process in Great Britain, Switzerland, the Nordic States, and Austria. Jamasb and Pollitt (2001) assembled an extensive comparison of international efficiency studies for the electricity sector stressing the importance of the proper variable choice. In this paper as well as in the literature in general, a wide variety of different specifications are employed depending on what exactly is being investigated, and what variables are being used as inputs and as outputs.[2] In a subsequent paper, Jamasb and Pollitt (2003) performed an international benchmarking study of 63 utilities from six European countries comparing several SFA and DEA specifications. Although they determined a high correlation among the models, the results for single utilities differed noticeably.

Filippini (1998) and Filippini and Wild (2001) applied SFA in a productivity study of 39 and 59 Swiss electricity distribution utilities respectively. Both studies find that regional differences in service territory influence productivity significantly, wherefore they recommend to consider structural variables in efficiency measuring. Furthermore, the studies identify significant economies of scale: smaller utilities could reduce costs by merging and thereby extending their sub-optimal service territory size.

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[2] For example, most studies consider the grid size as an input to approximate the capital costs whereas other studies cited by Jamasb and Pollitt specify the total length of line as output variable to approximate the complexity of the grid structure. Likewise, the transformer capacity is found to be an input in 11 of the 20 studies analysed, whereas two of the studies chose it as an output.

Burns, Davies and Riechmann (1999) conducted a dynamic benchmarking analysis for 12 regional electricity distribution utilities in Great Britain for the period 1990-1999 using a DEA approach and also investigated efficiency changes over time. Another way to extend the classical efficiency measurement approach is to consider quality in the model: service quality is approximated by the number of supply discontinuities and the total time of the discontinuities. In both cases, the results for single utilities vary significantly. The most important result, however, is that a panel analysis delivers more robust results than studies based on cross sectional data. Other examples of panel-data approaches are Hjalmarsson's (1992) analysis of Swedish electricity retail distributors as well as the productivity study of Norwegian electricity utilities conducted by Forsund and Kittelsen (1998).

Auer (2002) used DEA in a comprehensive efficiency analysis of the 13 largest electricity distribution companies in Austria. He measured the effect of the settlement density and the proportion of cable to aerial lines on the relative efficiency of the single utilities, extending parts of the basic model specification. He too identified noticeable differences in efficiency measures due to the grid composition and the structural variables.

So far, the literature on the German electricity sector is sparse. Haupt, Kinnunen and Pfaffenberger (2002) were the first to compare network access prices of German electricity distributors and to identify reasons for differences beyond the decision framework of the companies. They considered structural variables in order to take explicit account of regional specificities, for example settlement density and consumer structure. Their study, however, was based on a single utility benchmarking approach that dealt exclusively with prices and did not contain a comparative efficiency analysis. Riechmann (2000) investigated the efficiency of the 53 regional distributors in Germany with DEA and found significant cost reduction potentials. However, he included no discussion of structural variables' impact on efficiency. In a recent study for the German energy consuming industry, Frontier Economics and Consentec (2003) assessed a sample of 27 regional and local electricity distributors, using turnover as input, and peak load, units sold, and structural parameters as output. Interestingly, a regional distributor in East Germany was found to be on the efficiency frontier, indicating that the traditional post-reunification bias towards higher costs in East German distribution may have abated by now.

3. THE INSTITUTIONAL CONTEXT

Electricity sector restructuring in Germany is taking place in the midst of an institutional overhaul of the entire industry. At the European level, the European Union has accelerated its attempts towards liberalisation and vertical unbundling of the electricity sector. The so-called "acceleration directive" 2003/54/EC requires legal unbundling of electricity distribution companies with more than 100,000 connected customers, i.e. to create legally independent commercial units for generation, transmission, and distribution. This goes well beyond the old EU electricity directive 96/92. Given the slow progress of liberalisation in most member states, the acceleration directive also called for an intensification of regulatory oversight, and the introduction of an explicit regulatory body in each country.

Consequently, in Germany the electricity industry will now be subordinated to ex-ante regulation for the first time in its history. Under the former directive 96/92, Germany had implemented a model of negotiated access and had – to that end – authorised industry self-regulation. The electricity industry and the large electricity consumers were given freedom to negotiate network access prices and conditions in so-called association agreements ("Verbändevereinbarungen"). Given the systemic information advantage of the electricity industry over the customers, and the hesitation of the German government to establish a sufficient countervailing power in a regulatory agency, self-regulation did not succeed in bringing prices down or in establishing a significant level of competition. In its annual benchmarking reports, the European Commission has regularly criticised the German approach to self-regulation of network access charges (e.g. European Commission, 2003).[3] The new German energy law, due to come into force in early 2005, therefore sets up a regulatory agency, and requires ex-ante regulation of network access.

As observed in other countries implementing UK-style reforms, e.g. the Netherlands and Austria, the process of unbundling and the introduction of ex-ante regulation are likely to lead to conflicts between the incumbent operators, potential market entrants, and the regulatory authorities. These conflicts revolve around the absolute level of access tariffs, the relative level, and non-tariff discrimination. The next two sections should provide

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[3] See for a detailed account Brunekreeft (2003). Müller and Wienken (forthcoming) estimate that the German electricity sector is 61% open to competition to only (when based on the number of customers).

information on the relative level of access tariffs, e.g. potential reasons for cost differences, and thus price differences between distribution utilities.

4. METHODOLOGY, DATA, AND EMPIRICAL RESULTS

4.1. Methodology

We use traditional data envelopment analysis (DEA) to assess the relative efficiency of the distribution utilities, and stochastic frontier analysis as a verification method. The data envelopment analysis (DEA) is a nonparametric approach determining a piecewise linear efficiency frontier along the most efficient utilities to derive relative efficiency measures of all other utilities. DEA is used by most analyses of the electricity sector because of its simplicity and the useful interpretation of results it yields even with limited data sets. Within this framework, one can take either a constant returns to scale (CRS) or a variable returns to scale (VRS) approach. The CRS hypothesis suggests that companies are flexible to adjust their size to the one optimal firm size. By contrast, the VRS approach is less restrictive in that it compares the productivity of companies only within similar sample sizes; this approach is adapted if the utilities are not free to choose or adapt their size. The comparison between the two approaches also provides some information about the underlying technology: if the results of the CRS and the VRS approaches are similar, then returns to scale do not play an important role in the process. Most studies opt for the CRS approach, including ours: we assume that the objective of liberalising and unbundling the regional distribution companies is precisely to use potential cost savings generated by mergers between utilities. In particular, in the German context, an adaptation of the firm size is possible, and should therefore be taken into account in the model.

In addition, we chose an input-oriented approach that considers the output to be fixed so that the input has to be adjusted in order to maximise efficiency. It is reasonable to assume that output is fixed in a market with the legal duty to serve all customers in a predefined service territory.

Figure 1 shows a case of 3 utilities for the two input one output case. B is efficient both under the CRS and VRS assumption, whereas A is inefficient under the stricter CRS assumption. C is inefficient in both cases.

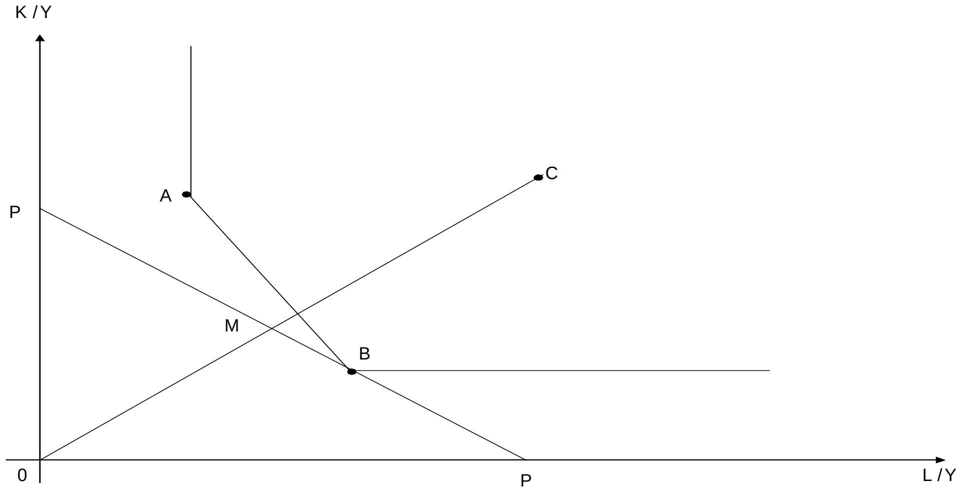

Figure 1: Data Envelope Efficiency Frontier for the Input oriented Case (two inputs, one output)
Source: Jamasb, T. and Pollitt, M. (2003, 1611).

The determination of the efficiency score of the ith firm in a sample of N firms in the CRS model is equivalent to the optimisation of the following equation considering three conditions:

$\min_{\theta,\lambda}\theta$
s.t.
$-y_i + Y\lambda \geq 0,$
$\theta x_i - X\lambda \geq 0,$
$\lambda \geq 0.$

θ is the efficiency score, and λ a Nx1 vector of constants. Assuming that the firms use E inputs and M outputs, X and Y represent E*N input and M*N output matrices respectively. The input and output column vectors for the ith firm are represented by x_i and y_i. The constraints ensure that the ith firm is compared to a linear combination of firms similar in size. To determine efficiency measures under the VRS assumption a further convexity constraint $\sum\lambda = 1$ has to be considered. The system is solved once for each firm (see Jamasb and Pollitt, 2003, 1612, and Coelli, et al., 1998, chapter 6).

DEA is a relatively uncomplicated approach. The determination of an explicit production function is not required. However, since DEA is a nonparametric approach the impact of the respective input factors on the efficiency can not be determined. Furthermore, DEA does not regard possible noise in the data and outliers can have a large effect on the outcomes. Currently, however, it is the most commonly applied analysis technique in productivity analysis.

The choice of physical input and output data is dictated by limited data availability. We estimate different models taking labour, network size, and peak load as the inputs, and units sold and the number of customers as the output. In addition, we add the inverse density index as a structural variable to compensate on the output side in some of the models:

- Labour input is estimated by the number of workers.[4] As employment data covers all workers in the electricity utility, we subtract one employee for each 20 GWh electricity produced (following Auer, 2002, p.128);
- capital input is approximated by the length of the existing electricity grid. We differentiate between voltage levels (high, medium, and low voltage) by introducing a cost factor for each type of line.[5] In addition, in subsequent models we distinguish between the cable grid and the aerial grid (following Auer, 2002, and others); cable is supposed to be more expensive than aerial grid. Thus, we substitute the simple grid size variable of the basic model by a weighted sum of cable and aerial grid. The share of cable lines of total lines is one of the structural variables in the German association agreements;
- the amount of electricity distributed to end users (units sold) and the total number of customers are used as output variables;
- in an extended model we also take into account the maximum peak load as further cost factor to approximate transformer capacity;
- the use of the inverse density index (settled area in kilometres per customers supplied) in one of the model specifications is motivated by the argument that utilities with a dense customer structure have a natural cost advantage over those with a weak customer density. When taken as an output, the inverse density index improves the performance of sparsely inhabited distribution areas. Density is one of the structural variables defined in the German association agreements.[6]

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[4] We are aware of the criticism of this choice of variable due to the potentially distortive effect of outsourcing: a utility can improve its efficiency simply by switching from in-house production to outsourcing.

[5] Following standard practice: factor 5 for high voltage, 1.6 for medium voltage, and 1 for low voltage cables.

[6] The sources of the data are the following:

Labour, network size, units sold and the number of customers are available for 380 utilities. We have verified that the sample is representative in terms of utility size. We cover 71% of the total number of utilities, and 60.3% of electricity sold.

4.2. Empirical Results

The following analysis is divided into five parts. First the basic Model 1 is estimated for the 380 utilities for CRS and VRS. In a first extension (Model 2) we analyse the influence of the inverse density index on distribution efficiency. Model 2 will also be discussed separately for East and West Germany. This model will then be respecified to take account of differences in costs between cable and aerial lines by factoring cables with 0.75 (Model 3). Model 4 also considers the peak load as further input variable for a reduced sample of 308 utilities. Model 5 is our verification specification and is separately estimated with SFA and DEA to deduce the correlation of the two methods for the one-output case. Table 1 lists the different model specifications in more detail:

	Input 1	**Input 2**	**Input 3**	**Output 1**	**Output 2**	**Output 3**
Model 1	Labour	Grid length		Units sold	Number of customers	
Model 2	Labour	Grid length		Units sold	Number of customers	Inv. density index
Model 3	Labour	Grid length (factor for cable lines: 0.75)		Units sold	Number of customers	Inv. density index
Model 4	Labour	Grid length	Peak load	Units sold	Number of customers	Inv. density index
Model 5	Labour	Grid length	Peak load	Units sold		

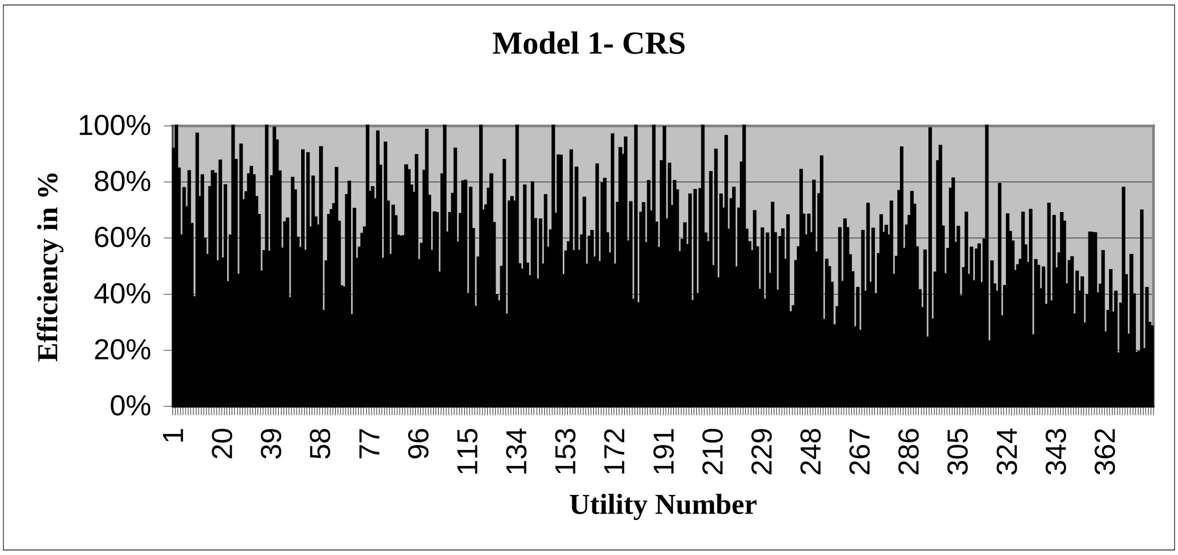
Table 1: Model specification for the upcoming analysis.

4.2.1. Basic Model

For the first model, units sold and the sum of customers are the output variables, the inputs are labour and network size. DEA delivers the efficiency estimates depicted in Figure 2.[7]

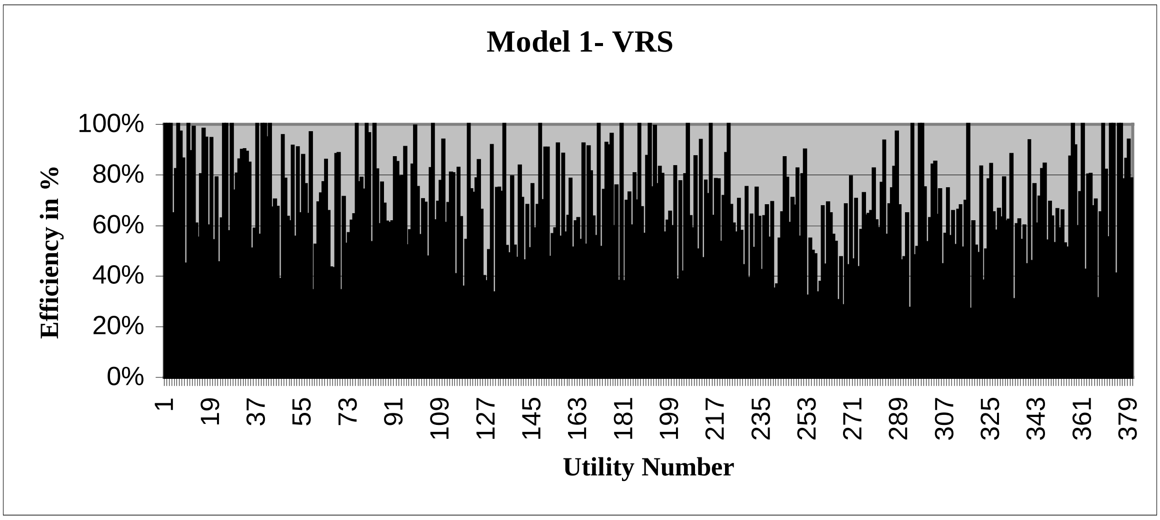
Verlags- und Wirtschaftsgesellschaft der Elektrizitätswerke m.b.H. – VWEW:
-„Jahresdaten der Stromversorger 2001"; VWEW Energieverlag GmbH, Frankfurt am Main, Heidelberg. (2002) for number of customers, units sold, number of employees and grid data.
-VDEW-Statistik 1996/1997 Leistung und Arbeit; VWEW-Verlag, Frankfurt am Main; (1997/98) for inverse density index and peak load.
Some data were also discovered by internet research on the utilities' homepages.

[7] In all subsequent figures, the utilities are ordered by units sold and, thereby, by size. Thus, utility no. 1 is the largest in size, and utility no. 380 the smallest.



Average efficiency: 63.10%.
380 utilities.
Input: labour, grid size.
Output: customers, units sold.

Figure 2: DEA analysis, Model 1 with CRS.



Average efficiency: 69.84%.
381 utilities.
Input: labour, grid size.
Output: customers, units sold.

Figure 3: DEA analysis Model 1 with VRS.

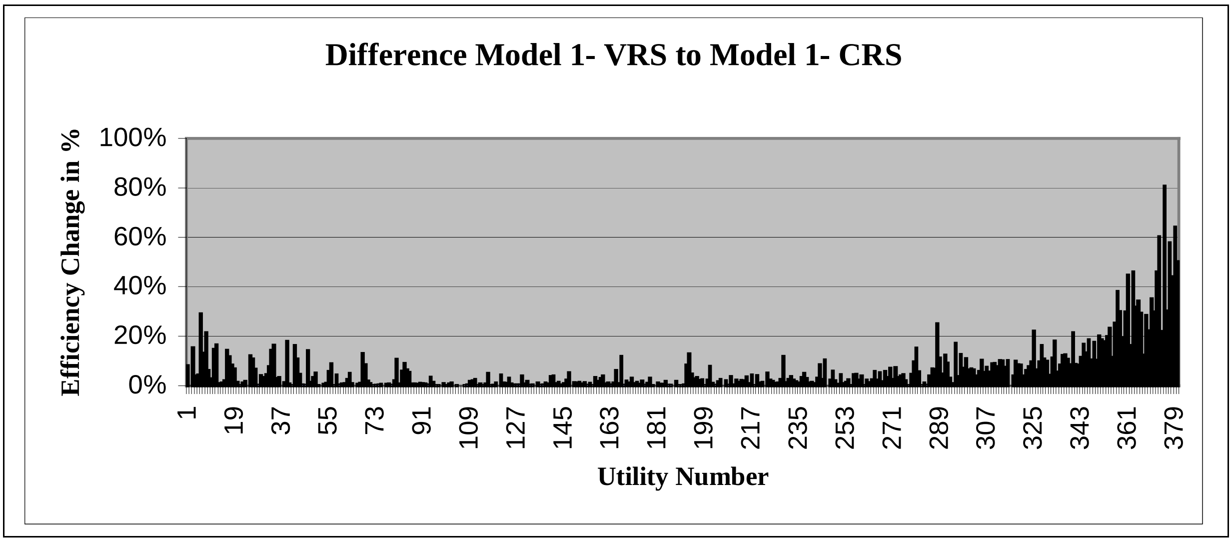


Figure 4: difference between Model 1 with VRS and Model 1 with CRS.

The average efficiency for Model 1 is 63.1%. Thirteen utilities are on the efficiency frontier. One observes a positive correlation between the size of the utility and its efficiency score. This can also be expressed by some global indicators: average efficiency for the 190 largest utilities is 69.8%, whereas for the smaller half of the sample it is only 56.4%. In particular, there seems to be a problem with very small utilities: the smallest 25 distribution companies average an efficiency score of only 41.4 %.

If one used the VRS specification of Model 1 instead, the efficiency scores would rise significantly (Figure 3): 37 of the 380 utilities are 100% efficient, which can be explained by the fact that now utilities of similar size are compared with each other, and not with the best ones in the sample. With VRS, the average efficiency increases to 69.8%, 6.5% higher than the results under the CRS assumption. For individual utilities, this improvement is significantly higher, in particular for the smaller ones. However, also the largest companies are considered slightly more efficient under the VRS assumption.

Figure 4 shows the difference in efficiency scores between the VRS and the CRS model. It looks as if the optimal utility size, i.e. the one where the VRS and the CRS efficiency scores converge, is around utility number 100 in our sample. This corresponds to about 200 GWh sold.[8] Figure 4 also makes one issue clear: smaller utilities could significantly gain in efficiency by merging; in this zone, considerable economies of scale can be realised.

However, all in all, the average efficiency is low in both of the models. The subsequent analyses and specifications will show that some of these inefficiencies can be explained by further firm-specific characteristics or structural variables. In the subsequent models, we apply the (stricter) constant returns to scale approach to the sample.

4.2.2. Impact of Structural Particularities

We now address the first two structural variables that are used in the association agreement's assessment of potential cost drivers: density, and East-West structure. It is reasonable to assume that regional particularities can have a strong impact on the efficiency of distribution utilities, although they are outside their decision framework. An example is increasing costs because of the craggy surface a utility has to cope with; another one is the density of a habitat that a utility has to serve.

We measure the first structural variable by the inverse density index defined as service territory in kilometres divided by the number of inhabitants of the region to take account of the topographical particularities. The idea here is to exclude the influence of structural effects on the efficiency of the utilities. The variable defined as above increases the efficiency of utilities in sparsely settled regions, as DEA considers this effect under the present specification as an increase in output that will consistently increase the estimated efficiency of utilities in sparsely settled areas. Therefore, in our case, companies with a higher inverse density index and thereby a territory with few customers per square kilometre will increase their efficiency.

The average productivity for Model 2 increased significantly compared to Model 1, from 63.1% to 66.8%. Sixteen utilities are 100% efficient, three more than under the CRS assumption for Model 1. Figure 5 compares the CRS result for Model 2, including the inverse density index, with the CRS result from Model 1 (without structural variable). It is evident that for the 190 largest utilities, the structural effect is insignificant (average efficiency increase of 0.4%), whereas for the smaller ones, density is an important cost driver (average increase of 6.9%); the effect is particularly strong for the 50 smallest utilities.[9]

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[8] To make a definitive statement about the optimal utility size for the German electricity distribution sector, a more detailed analysis would be required.

[9] The extreme case is utility no. 378, which increases its efficiency score by 80 percentage points.

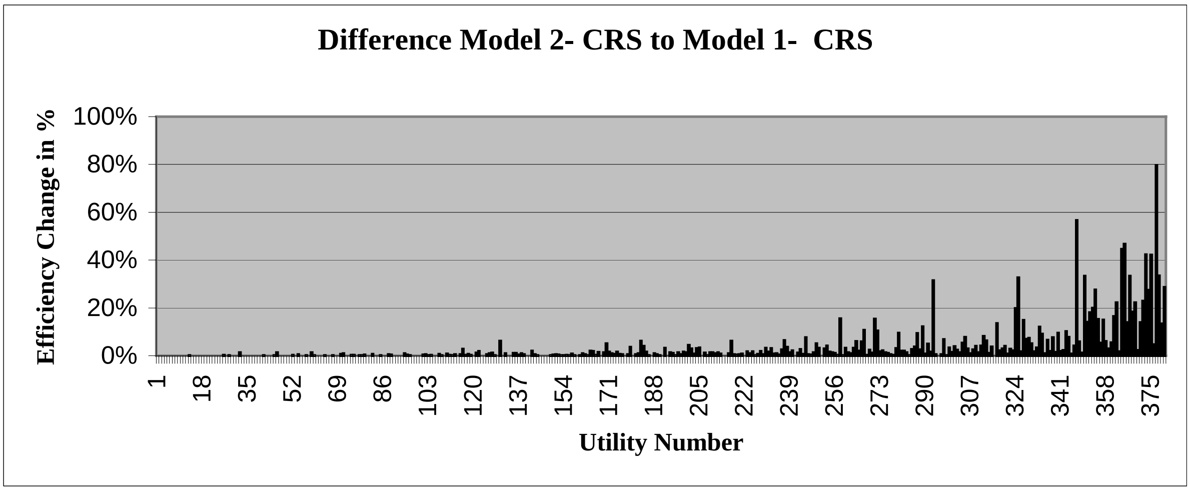

Figure 5: Differences for each utility between measures of model 2 and model 1.

4.2.3. Analysis of Differences between East and West Germany

The model also permits an analysis of structural differences in efficiency among West and East German distribution utilities. In fact, the association agreement includes a structural variable "East-West", implying that East German utilities have on average higher costs than their West German counterparts. This is supposedly due to the structural legacy inherited from socialist times, as well as to the dramatic drop in electricity consumption given almost constant network sizes. In order to test the East-West hypothesis, we split up the sample into 320 West German utilities, and 60 East German ones. Figure 6 and Figure 7 show the rather astonishing result: the average efficiency in East Germany seems to be higher than in West Germany. Taken from the same DEA analysis, East German utilities feature an average efficiency of 75.6%, against a West German average of 65.1%.

This result may suggest that investment efforts of the last decade have led to an accelerated modernisation process in East Germany, and thus a more efficient use of resources. Electricity production and distribution can now revert to a modernised power station park and distribution system. The results tend in the same direction as those of Frontier Economics and Consentec (2003, p. 19), which find some East German utilities have among the higher efficiency scores.[10]

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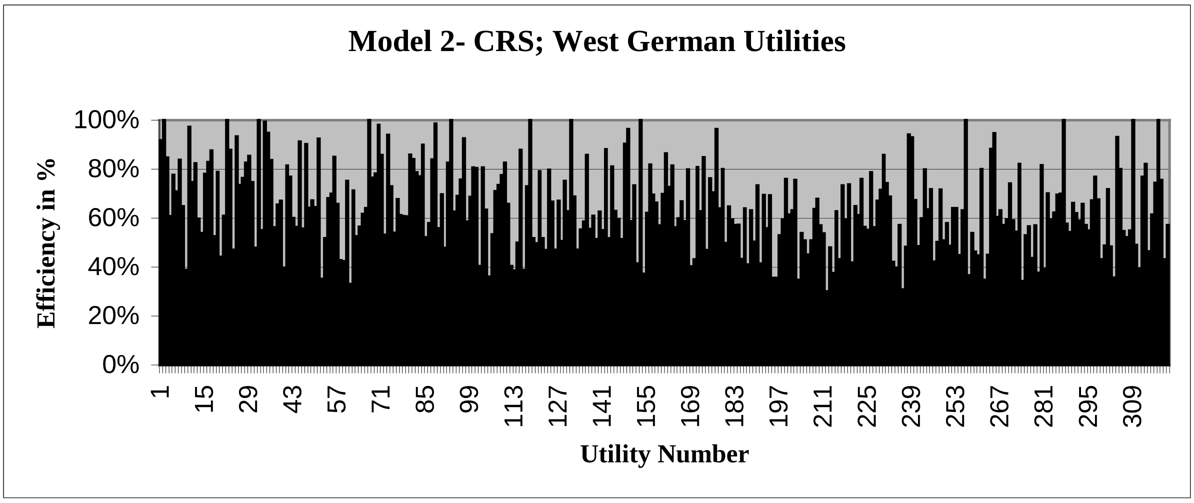
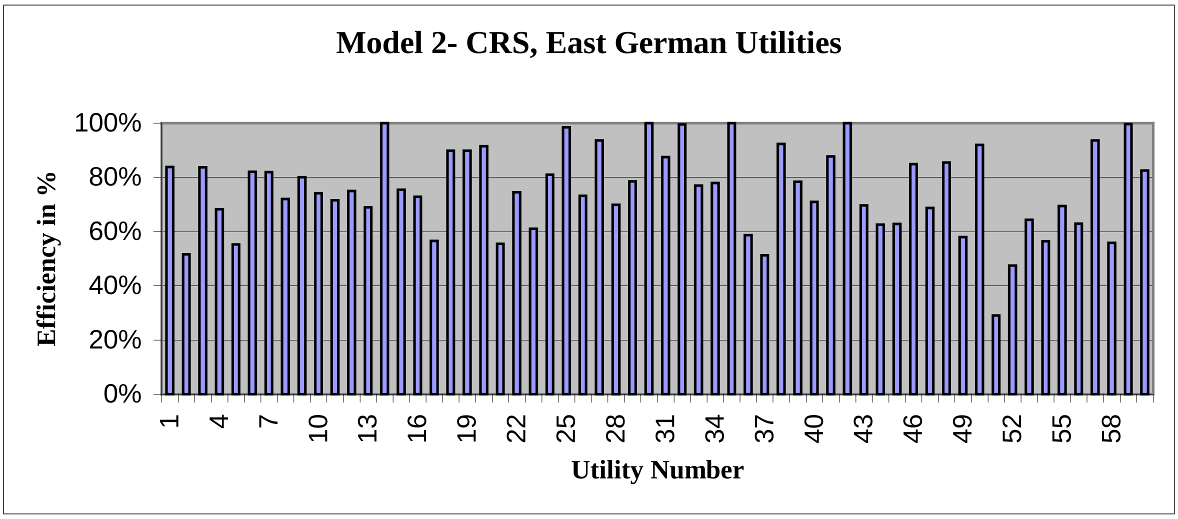
[10] Once again, more in-depth research and better data is required to base serious policy advice on that conclusion.



Average efficiency: 65.10%.
320 utilities.
Input: labour, grid size.
Output: customers, units sold, inverse density index.

Figure 6: DEA analysis; Model 2 with CRS, Results for West German utilities only.



Average efficiency: 75.60%.
60 utilities.
Input: labour, grid size.
Output: customers, units sold, inverse density index.

Figure 7: DEA analysis; Model 2 with CRS, Results for East German utilities only.

4.2.4. Effect of Grid Composition

A third structural variable that may have an impact on efficiency scores is the composition of the grid, i.e. the relation of aerial lines to cable lines. The idea behind this reasoning is that cable lines are on average more expensive than aerial lines. However, regional utilities are often not free in choosing the most appropriate grid type. This is particularly true in densely settled areas where national law prohibits aerial lines.

We approach the issue in the traditional way: we define a downturn factor of 0.75 for each km of cable line, and thereby indirectly consider higher prices for cables. This favours those utilities that are forced to maintain a high proportion of cable lines.[11]

The first noticeable result is that average efficiency remains almost unchanged; it increases slightly to 66.0% compared to the 63.1% in the original specification (Model 1). The number of efficient utilities increases by one to 14. The modest changes in efficiency is not surprising: some utilities use a grid with a higher proportion of cable lines, others with more aerial lines. These two tendencies compensate each other, while the change of the average productivity remains almost the same. The efficiency of single utilities, in contrast, changes more significantly: utilities with a higher share of cables benefit from this transformation. Differences between Model 2 with cable factor 0.75 and without are presented in Figure 8. All in all, the grid composition does not add much to the interpretation of results, a finding also suggested by Frontier Economics and Consentec (2003, p. vii) who doubt that grid composition is a significant cost driver.

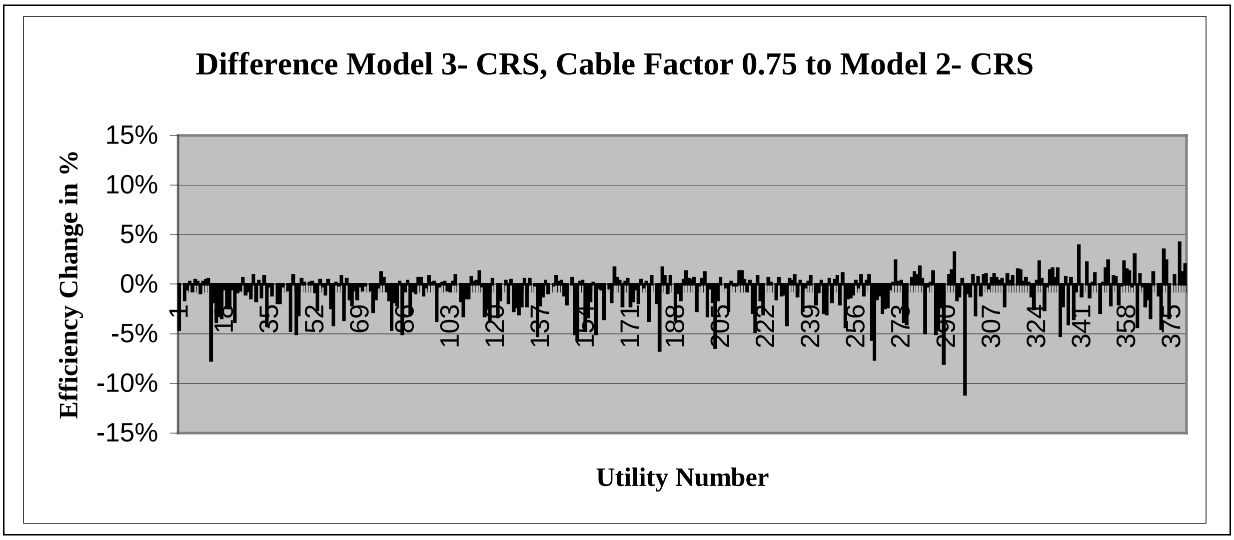


Figure 8: Differences between Model 2-CRS with cable factor 0.75 and Model 2 –CRS.

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[11] Note that this approach is the opposite of the one chosen by Auer (2002), who would disadvantage cable-intensive utilities by charging them with a factor of 1.25-1.5. On the other hand, the association agreement in Germany considers the cable grid the same way that we do.

4.2.5. Peak Load as an Input Variable

In addition to the traditional inputs, grid line and labour, one could consider peak load (as a proxy for transformer capacity, for which no data is available) to be a separate cost factor. Model 4, containing three input and three output variables, is estimated with a reduced sample size of 308 utilities.

Model 4 with peak load leads to higher efficiency scores averaging 73.4%. Figure 9 shows the difference between Model 4, including peak load, and model 2.[12] There seems to be no structural correlation between the size of a utility and its peak load as a structural variable affecting efficiency. In the case of lacking cost data, it may therefore make sense to work with two different variables accounting for capital costs.

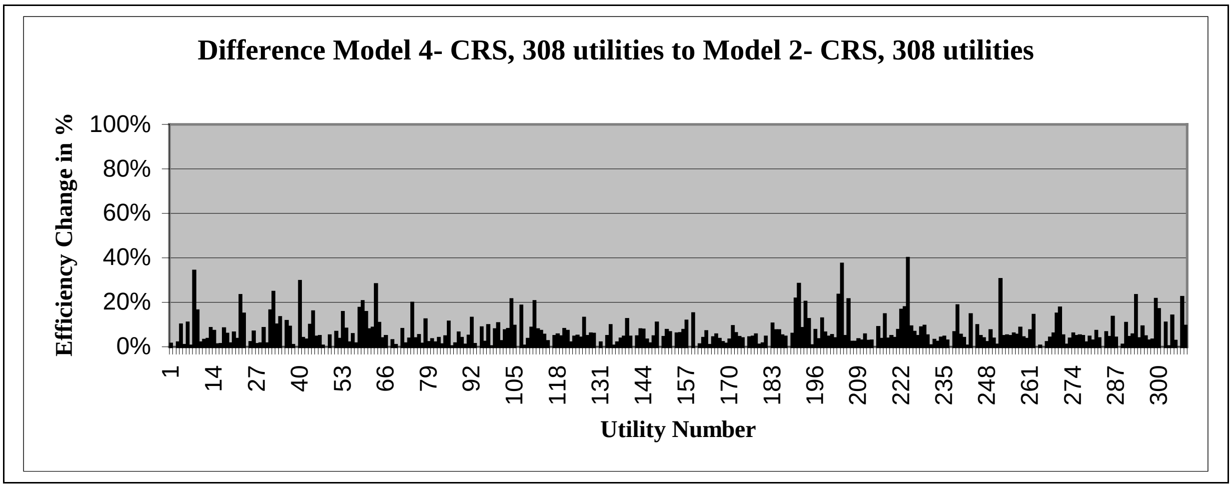

Figure 9: Difference between Model 4 and Model 2 for Sample with 308 Utilities.

5. CORRELATION ANALYSIS AND VERIFICATION THROUGH SFA

In this section we check the robustness of our results by conducting a correlation analysis for the respective model specifications. In addition, we present a stochastic frontier analysis (SFA) for the case of one output and multiple input factors in order to generally verify the DEA results discussed in Section 4.

Table 2 shows the correlation analysis for models 1 (CRS and VRS), Model 2, and Model 3. Overall, the correlation among the models is high; all are above 75%. The highest

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[12] We recalculated Model 2 with the inverse density index for the new sample. Average productivity then amounts to 66.82%, almost identical with the results of Model 2 for the sample of 380 utilities (66.76%). A further confirmation that the new sample is representative is provided by a DEA based on Model 1, using only the 308 observations; results do not change.

correlation is observed between Model 3 (cable factor 0.75) and Model 1 (VRS). Table 3 presents the correlation for Models 2 and 4 (peak load) for the limited sample of 308 utilities. Once again, correlation is very high. Thus, we can conclude that the obtained DEA efficiency measures can generally be assumed to be robust.

	Model 1- CRS	**Model 1- VRS**	**Model 2- CRS**	**Model 3- CRS**
Model 1- CRS	1	0,846	0,891	0,769
Model 1- VRS		1	0,902	0,954
Model 2- CRS			1	0,919
Model 3- CRS				1

Table 2: Correlation analysis for Models 1 to 3; sample size 380

	Model 2- CRS	**Model 4- CRS**
Model 2- CRS	1	0,925
Model 4- CRS		1

Table 3: Correlation analysis for Model 4 specification; sample size 308

Last but not least, we estimate a model taking a stochastic approach in order to harden the evidence obtained through DEA. To this end, we specify a one-output-multiple-input Model 5, where units sold is the output, whereas labour, grid size, and peak load are the inputs. We run the model both using an SFA, and a DEA with constant and with variable returns to scale.

Stochastic Frontier Analysis (SFA) is a parametric method requiring the definition of an explicit production or cost function. Based on the usual OLS regression a parallel shift of the original production function yields the efficiency frontier. This is caused by an underlying assumption splitting the error term into a stochastic residuum and an inefficiency-term, where the random variables are assumed to be iid $N(0,\sigma)$, and independent of the individual technical inefficiencies u_i which are non-negative random variables and assumed to account for technical inefficiency in production. Usually, to account for stochastic errors a half normal distribution is assumed.

Graphically, SFA shifts the classical regression line downwards corresponding to the inefficiency index. All companies on or under the shifted regression line are then defined as 100 % efficient, all companies beyond the line proportionally inefficient, as is depicted in Figure 10 for the case of one input and one output.

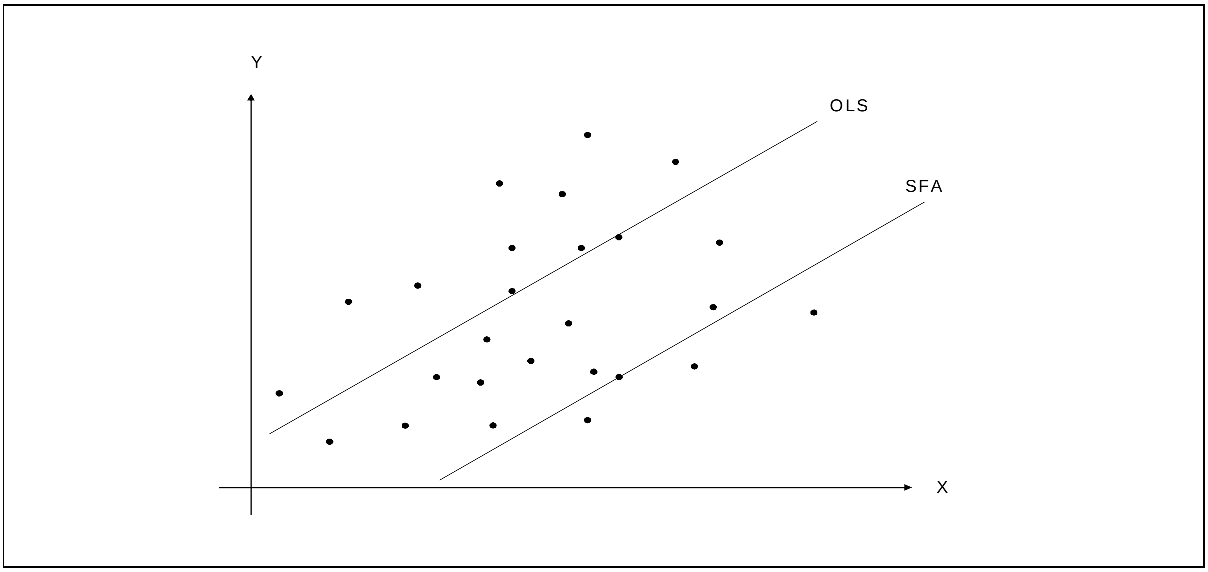

Figure 10: OLS and SFA efficiency frontiers
Source: Auer (2002, 34).

A relatively common approach to define the production function is a translog specification as defined in the following equation for the two-input-one-output case:

$$\ln(Q)= b_0 + b_1\ln(K_i)+b_2(\ln L_i)+b_3*\ln(Ki)^2 + b_4\ln(L_i)^2+b_5*\ln(K_i)*\ln(L_i)+ (V_i-U_i)^{13}.$$

where Q represents output, K and L are capital and labour input, respectively, V_i and U_i are the random terms, and the bs are coefficients.

Generally, SFA is more complex than DEA. Its particular assumptions on two-part residuals is criticised as it is difficult to determine these two effects separately in reality. Econometricians usually have problems in identifying stochastic errors and technical inefficiencies. Approximations run the risk of regarding inefficiency wrongly as noise. On the other hand, with an increasing data sample, outliers do not have a large effect on the results and stochastic tests can be applied for specification and significance.

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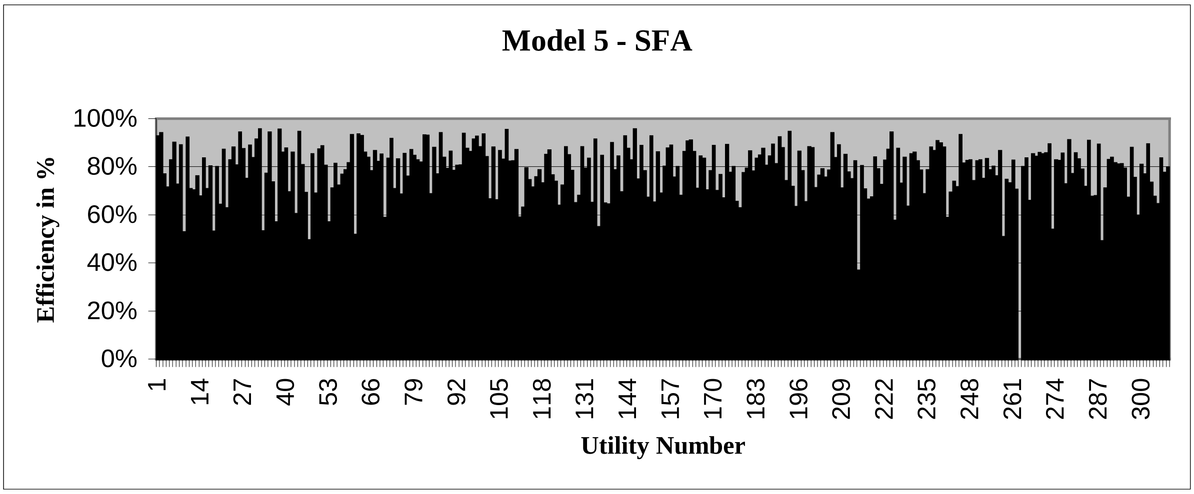
[13] See for a detailled presentation Coelli; et al. (1998, Chapter 8).

Figure 11 presents the SFA results for Model 5. The average efficiency is 79.1% (compared to an efficiency of 69% for the DEA-VRS). Although we did not consider our structural variable, there seems to be no significant correlation between the efficiency and the size of a given utility.[14] Table 4 shows the correlations between the DEA and the SFA approaches for Model 5. All correlations are above 70%, and thus – once again – significant. In general, we can conclude that the standard DEA approach yields robust, verifiable results.



Average efficiency: 79.00%.
308 utilities.
Input: labour, grid size, peak load.
Output: units sold.

Figure 11: Model 5 with SFA.

Sample size 308	Model 5 SFA	Model 5 DEA CRS	Model 5 DEA VRS
Model 5 SFA	1	0,707	0,719
Model 5 DEA CRS		1	0,708
Model 5 DEA VRS			1

Table 4: Correlation analysis of results for Model 5 with different estimation methods.

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[14] Note that not a single utility is on the production frontier (100% efficient); in fact, SFA "recognizes that some of the distance from the frontier is due to random events or statistical noise in the data. Therefore it is common not to have efficent organizations in a sample" (Carrington, Roger; Coelli, Tim and Groom, Eric (2002): International Benchmarking for Monopoly Price Regulation: The Case of Australian Gas Distribution, Journal of Regulatory Economics; No. 21, 24).

6. CONCLUSIONS

This paper provides additional evidence on the determinants of efficiency in electricity distribution. We have addressed the general issue of optimal utility size, and specific issues related to the ”Balkanisation” of the German electricity distribution industry. The results suggest that returns to scale play only a minor role: only very small utilities have a significant cost disadvantage. Low customer density is found to affect the efficiency score significantly in the lower third of the sample. The grid composition does not produce systematic effects. Surprisingly, East German utilities show a higher average efficiency than their West German counterparts. Peak load as a structural input variable does not seem to be an important determinant of efficiency, when compared to the base model without peak load. The correlation tests, as well as a verification through SFA, show that the results are highly coherent. Further research using real cost data and a deeper differentiation of the models should be carried out to verify (or falsify) these results.

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Nr.	Utility	Nr.	Utility	Nr.	Utility
1	Hamburgische E-Werke AG	56	GSW Kamen - Bönen - B.	111	SW Verden GmbH
2	GEW Köln AG	57	Wilhelmshaven GmbH	112	SW Dreieich GmbH
3	SW München GmbH	58	SW Aalen	113	SW Stade GmbH
4	SW Hannover AG	59	Kreis-EV Schleiden	114	SW Rendsburg GmbH
5	SW Düsseldorf AG	60	Vereinigte Wertach- EW	115	SW Lindau (Bodensee)
6	HEAG -DARMSTADT	61	SW Landshut	116	SW Neustadt GmbH
7	Mainova Aktiengesellschaft	62	SW Norderstedt	117	SW Tuttlingen GmbH
8	PESAG AG (Paderborn)	63	Zwickauer EV GmbH	118	SW Borken/Westf. GmbH
9	Minden-Ravensberg GmbH	64	SW Rastatt	119	Energieversorgung Gifhorn
10	EWAG NÜRNBERG	65	TW Friedrichshafen	120	SW Weimar
11	Dortmunder E. u. W. vers.	66	SW Schwäbisch Gmünd	121	SW Dillingen-Lauingen
12	SW Duisburg AG	67	SW Passau GmbH	122	EV Lohr-Karlstadt
13	Koblenzer E-Werke AG	68	SW Peine GmbH	123	SW Langen GmbH
14	SW Bielefeld GmbH	69	Energieversorgung Gera	124	SW Garbsen GmbH
15	EV Offenbach AG	70	Lister- und Lennekraftw.	125	SW Werl GmbH
16	DREWAG - SW Dresden	71	Freisinger SW	126	EV SYLT GmbH
17	Wuppertaler SW AG	72	SW Gronau GmbH	127	SW Dülmen GmbH
18	SW Leipzig GmbH	73	SW Konstanz GmbH	128	SW Nürtingen
19	SW Karlsruhe GmbH	74	SW Pirmasens	129	Neustadt a.d. Weinstr.
20	EW Rheinhessen AG	75	SW Baden-Baden	130	Wittingen GmbH
21	STAWAG SW Aachen AG	76	SW Frankenthal GmbH	131	SW Brühl
22	EW Mittelbaden	77	GGEW Bergstraße AG	132	SW Wernigerode
23	REWAG AG & Co KG	78	SW Speyer GmbH	133	Energiev. Nordhausen
24	SWK Energie GmbH	79	SW Brandenburg a. d. H.	134	Westharzer Kraftwerke
25	SW Kiel AG	80	SW Bietigheim-Bissingen	135	SW Deggendorf
26	SVO Energie GmbH (Celle)	81	SW Kleve GmbH	136	SW Balingen
27	SW Osnabrück AG	82	Bruchsal GmbH	137	SW Völklingen
28	SW Ingolstadt Energie	83	SW V.-Schwenningen	138	Rheinhessische EW
29	E. u. W. Bonn/Rhein-Sieg	84	SW Rosenheim	139	SW Buxtehude
30	SW Würzburg AG	85	ENRW Rottweil	140	SW Weinheim
31	Städtische W. AG, Kassel	86	Dessauer Stromv.	141	SW Wolfenbüttel GmbH
32	Städtische W. Magdeburg	87	SW St. Ingbert	142	SW Haltern GmbH
33	SW Solingen GmbH	88	SW Willich GmbH	143	SW Geesthacht GmbH
34	SW Chemnitz AG	89	SW Heidenheim AG	144	EW Reinbek-Wentorf
35	Energie und Wasser Lübeck	90	SW Ansbach GmbH	145	SW Dachau
36	SWE Strom und Fernwärme	91	SW Marburg GmbH	146	SW Halberstadt GmbH
37	SW Schweinfurt GmbH	92	Hertener SW GmbH	147	SW Lutherstadt W.
38	SW Gießen	93	SW Dinslaken GmbH	148	Fischereihafen-GmbH.
39	EV Halle GmbH	94	SW Bühl GmbH	149	SW Menden GmbH
40	SW Bamberg GmbH	95	SW Itzehoe GmbH	150	Meißener SW GmbH
41	EWR Remscheid GmbH	96	SW Bad Salzuflen GmbH	151	SW Riesa GmbH
42	TW Ludwigshafen a. Rhein	97	SW Amberg GmbH	152	SW Schwabach GmbH
43	Albwerk GmbH & Co. KG	98	SW Neuwied GmbH	153	SW Achim AG
44	Erlanger SW AG	99	SW Crailsheim GmbH	154	SW Gaggenau
45	KEW Neukirchen	100	SEV Stralsund	155	FREITALER S+G
46	Waldeck- Frankenberg	101	SW Straubing GmbH	156	TW Delitzsch GmbH
47	TW Kaiserslautern GmbH	102	EV Limburg GmbH	157	StWL a.d. Pegnitz
48	infra fürth gmbh	103	SW Gotha GmbH	158	SW Dillingen/Saar
49	SW Gütersloh GmbH	104	SW Neumarkt i. d. OPf.	159	SW Pinneberg GmbH
50	SW Flensburg GmbH	105	SW Neu-Isenburg GmbH	160	SW Haldensleben
51	SW Hanau GmbH	106	SW Merzig GmbH	161	Allgäuer Kraftwerke
52	Wdt. Licht- und Kraftwerke	107	SW Neuburg a. d. Donau	162	SW Oranienburg GmbH
53	Niederrheinwerke Viersen	108	SW Saarlouis GmbH	163	EW Schwandorf GmbH
54	SW Homburg GmbH	109	SW Waiblingen GmbH	164	EV Selb-Marktredwitz
55	EVP Potsdam GmbH	110	SW Forchheim	165	SW Weißenburg GmbH

166	SW Radolfzell GmbH	224	Osterholz-Scharmbeck	282	SW Mössingen
167	EW Landsberg	225	EZV Untermain	283	Städtische Werke Borna
168	SW Weißenfels GmbH	226	SW Aue GmbH	284	GW Halstenbek
169	SW Hockenheim	227	SW Waldshut-Tiengen	285	SW Clausthal-Zellerfeld
170	SW Bremervörde	228	Wendelin Maunz GmbH	286	GW Peißenberg
171	SW Ilmenau GmbH	229	SW Bogen GmbH	287	BEW
172	SW Bretten GmbH	230	SW Rhede GmbH	288	Gem.. Werke Hengersberg
173	SWS SW Schönebeck	231	VB Hann. Münden	289	Wennenmühle Schörger
174	SW Güstrow GmbH	232	HEWA GmbH	290	SW Vilsbiburg
175	SW Husum GmbH	233	SW Bad Pyrmont	291	Norderney GmbH
176	SW Viernheim GmbH	234	SW Meiningen GmbH	292	SW Treuchtlingen
177	GW Garmisch-PK	235	SW Bad Reichenhall	293	SW Neustadt an der Orla
178	SW Sulzbach/Saar	236	SW Eisenberg GmbH	294	SW Ludwigsfelde GmbH
179	SW Soltau GmbH	237	SW Buchen GmbH	295	SW Herborn GmbH
180	SWW - SW Wadern	238	SW Norden GmbH	296	Feuchter GW GmbH
181	SW Mühldorf am Inn	239	SW Korbach GmbH	297	GW Ebersdorf
182	SW Glauchau	240	SW Vilshofen GmbH	298	SW Bramsche GmbH
183	SW Neuruppin GmbH	241	SW Schneverdingen	299	SW Heilsbronn
184	SW Rotenburg GmbH	242	SW Bad Wörishofen	300	SW Bad Neustadt a.d. S.
185	SW Bad Harzburg	243	Neunburg vorm Wald	301	SW Ramstein-Miesenbach
186	Schleswiger SW GmbH	244	SW Schwarzenberg	302	SW Bad Bergzabern
187	Stromversorgung Pirna	245	Kirchheimbolanden	303	SW Schneeberg GmbH
188	SW Tönisvorst GmbH	246	Neustadt in Holstein	304	GW Kirkel GmbH
189	SW Quickborn	247	SW Torgau GmbH	305	SW Steinheim GmbH
190	SW Merseburg GmbH	248	SW Münchberg	306	EW Simbach GmbH
191	Hoyerswerda GmbH	249	SW Neustrelitz GmbH	307	SW Zwiesel
192	Bad Lauterberg im Harz	250	Spremberg (Lausitz)	308	SW Glückstadt
193	SW Feuchtwangen	251	Butzbach GmbH	309	SW Niebüll GmbH
194	SW Gunzenhausen	252	SW Finsterwalde	310	SW Gengenbach
195	SW Bad Nauheim	253	SW Landau a. d. Isar	311	SW Tirschenreuth
196	SW Bernburg GmbH	254	SW Trossingen	312	SW Mengen
197	SW Überlingen GmbH	255	SW Rottenburg	313	SW Altdorf
198	SW Heide GmbH	256	SW Pfarrkirchen	314	SW Trostberg GmbH
199	SW Traunstein GmbH	257	SW Zeitz GmbH	315	SW Barmstedt
200	SW Rinteln GmbH	258	Stromvers. Ruhpolding	316	Kronshagen GmbH
201	SW Pfullendorf	259	SW Blieskastel	317	Kraftwerk Bleckede
202	SWW Wunsiedel	260	SW Parchim GmbH	318	SW Uslar GmbH
203	EVGreiz GmbH	261	SW Schifferstadt	319	KBG Homberg eG
204	SW Bad Mergentheim	262	SW Crimmitschau	320	GW Leck GmbH
205	SW Roth	263	TWS Saarwellingen	321	SW Röthenbach GmbH
206	SW Zittau GmbH	264	SW Walldürn GmbH	322	GW Sinzheim
207	Bad Honnef AG	265	SW KELHEIM	323	KW Reutlingen-Kirchent.
208	SW Saalfeld GmbH	266	SW Wildbad	324	Wanfried v. Scharfenberg
209	SW Jülich GmbH	267	Weißachtalkraftwerke eG	325	EW Schweiger OHG
210	SW Arnstadt GmbH	268	EW Weißenhorn AG	326	VerbandsGW Eisenberg
211	SW Schwedt GmbH	269	SW Weilburg GmbH	327	Wendelsteinbahn GmbH
212	EGF Frankenberg mbH	270	SW Wasserburg a. Inn	328	Stromversorgung Sulz
213	SW Bad Säckingen	271	GW Baiersbronn	329	SW Bad Brückenau GmbH
214	SW Bad Dürkheim	272	SWB SW Biedenkopf	330	SW Neustadt a. d. Donau
215	SW Eckernförde GmbH	273	GW Wendelstein	331	SW Bad Sachsa GmbH
216	EW Goldbach-Hösbach	274	SW Schkeuditz GmbH	332	SW Nortorf
217	SW Eberbach	275	Energiewerke Zeulenroda	333	GW Schutterwald
218	EV Rudolstadt	276	SW Forst GmbH	334	EG Vogling & Angrenzer
219	SW Bad Aibling	277	GW Holzkirchen GmbH	335	GW Lilienthal GmbH
220	Luckenwalde GmbH	278	Eichsfelder E- u. W.	336	SW Kusel
221	SW Sangerhausen	279	SW Bebra GmbH	337	SW Altensteig
222	SW Leinefelde GmbH	280	SW Haiger	338	EW Bad Endorf J. Stern KG
223	SW Eichstätt	281	SW Neustadt a. d. Aisch	339	SW Furth i. Wald

340	SW Bad Salzdetfurth	354	SW Bräunlingen	368	EG Wolkersdorf u. Umg.
341	strotög GmbH	355	GW Oberaudorf	369	Farchant A. Poettinger
342	Gundelfingen GmbH	356	SW Wilster	370	G. Haniel von Haimhausen
343	SW Bad Sooden-Allendorf	357	SV Neunkirchen GmbH	371	EG Nordhalben u. Umgeb.
344	SW Zeil a. Main	358	SW Baiersdorf	372	Bayerisch Gmain
345	P + M Rothmoser	359	SW Hemau	373	Heinrich N. Clausen
346	Bordesholm GmbH	360	SW Scheinfeld	374	Bauer GmbH & Co
347	EW Hindelang eG	361	Raiffeisenb. Greding-T.	375	GW Unterkirnach
348	SW Lambrecht (Pfalz)	362	F.X. Mittermaier & Söhne	376	SW St. Andreasberg
349	SW Braunlage	363	VBHelgoland GmbH	377	EW Ley
350	EG Tacherting-Feichten eG	364	GW Hohentengen	378	EG Karlstein eG
351	SW Bad Herrenalb	365	EG Schonstett	379	Karl Kuhn EW Markelsheim
352	Otto und Paul Schneider	366	C. Ensinger EW	380	GW Stammbach
353	Gebrüder Eirich EW	367	EG Rettenberg eG		

Table 5: Local electricity distribution utilities in the sample