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Discussion Papers

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Efficiency Analysis of East European Electricity Distribution in Transition: Legacy of the Past ?

Berlin, February 2006

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IMPRESSUM

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ISSN print edition 1433-0210
ISSN electronic edition 1619-4535

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Abstract

This paper provides a cross-country efficiency analysis of electricity distribution companies in East European transition countries (Poland, Czech Republic, Slovakia and Hungary). We compare the relative technical efficiency of East European regional distribution companies (RDCs) among themselves, as well as with German RDCs. We use the nonparametric DEA, and also apply bootstrapping techniques and the FDH-estimator; in addition, we carry out parametric analyses, mainly SFA (stochastic frontier analysis) and COLS (corrected ordinary least squares). The results suggest that the Polish distribution companies are still inefficiently small. The Czech Republic and Slovakia feature the highest efficiency.

Keywords: Efficiency analysis, econometric methods, electricity distribution, transition, Eastern Europe

JEL Classification: L51, P31, C14, C67

Abstract

In dieser Studie wird ein internationaler Effizienzvergleich der Stromverteilung in osteuropäischen Transformationsländern durchgeführt. Wir beziehen uns hierbei auf Polen, die Tschechische Republik, die Slowakei sowie Ungarn, und vergleichen die relative technische Effizienz der Regionalverteiler untereinander. Zum anderen wird die Effizienz mit denen der deutschen Regionalverteiler verglichen, um Rückschlusse der Marktorientierung auf die Effizienz der Unternehmen ziehen zu können. Es werden übliche nichtparametrische Benchmarkingmethoden, die *Data Envelopment Analysis* (DEA) sowie der *Free Disposal Hull* Schätzer, angewandt deren Sensitivität anhand der Bootstrap Methode überprüft wird. Zur Validierung der Ergebnisse werden zusätzlich parametrische Verfahren, die *Stochastic Frontier Analysis* (SFA) sowie die Methode der *Corrected Ordinary Least Squares* (COLS) verwendet. Die Ergebnisse weisen darauf hin, dass die polnischen Verteilungsunternehmen im Vergleich zu den europäischen Nachbarn signifikante Skalenineffizienzen aufweisen. Die Slowakische und Tschechische Republik erreichen die höchsten Effizienzwerte unter den osteuropäischen Transformationsländern. Im Vergleich zu Deutschland erscheinen alle Unternehmen technisch ineffizienter.

Keywords: Effizienanalyse, Ökonometrische Methoden, Stromverteilung, Osteuropa

JEL Classification: L51, P31, C14, C67

Inhaltsverzeichnis

1 Introduction

After decades of socialist planning, the energy sector in the East European transition countries underwent substantial market-oriented reform during the last decade. As a key sector for economic development, but also as a socially sensitive activity, energy sector reform has been particularly difficult, especially when it came to mergers between companies and downscaling of employment. Subsequently, the last decade was characterized by a very tough transition process from socialist structures towards market economies. The price system had to be changed from “social tariffs” to cost-covering and yet efficient prices. The vertically integrated monopolies had to be unbundled. Even regional units had to be disintegrated due to new political borders (in Czechoslovakia, Yugoslavia, and the Soviet Union). Parts of the unbundled monopolists were privatized. Regulation authorities were established and environmental standards as well as renewable-promotion schemes were implemented. In brief, the transition countries experienced 50 years of gradual reforms of the West European power sector in only 15 years.[1] Little is known, however, about the competitiveness of the electricity sector, and whether differences between East and West European companies prevail.

Efficiency analysis has emerged as a powerful tool to assess the structure of electricity sectors, and to help companies and regulators to understand the drivers of productivity. As the transition countries are moving forward with reforms and some of them recently joining the European Union, there is also an increasing need for comparative efficiency analysis at the international level. However, literature is rare: Kocenda and Cabelka (1999) studied the liberalization of the energy sector in the transition countries with respect to its effect on transition and growth. The only quantitative study to date is Fillipini, Hrovatin and Zoric (2003), who analyze the efficiency of electricity distribution companies in Slovenia, using a stochastic frontier analysis. International comparisons outside the transition countries have been carried out by Jamasb and Pollit (2003), evaluating the performance of national utilities within a larger context of six West European countries. The study has been updated and a quality parameter has been integrated in Growitsch, Jamasb, and Pollit (2005). Agrell, Bogetoft and Tind (2005) have worked on Scandinavia, and Estache et al. (2004) argue in favor of international coordination of electricity regulation in South America. Zhang and Bartels (1998) compare the efficiency of electricity distribution in Australia, Sweden and New Zealand; Hattori (2002) concludes in a study of the relative performance of U.S. and Japanese electricity distribution companies that Japanese electricity distribution companies are on average more efficient.

This paper provides a cross-country efficiency analysis of regional electricity distribution companies (RDCs) in four East European transition countries: Poland, Czech Republic, Slovakia and Hungary. We compare the relative efficiency of East European regional distribution companies (RDCs) among themselves as well as with German (RDCs), using common benchmarking methods (DEA, including FDH estimator and bootstrapping, parametric SFA and COLS). We estimate single output production functions in form of a translog production function as well as multi-output functions in form of distance functions. After a description of the state of reforms in the transition countries (Section 2), Section 3 defines models for a comparative efficiency analysis, and describes the data. Section 4 presents the empirical results. We find significant differences between the efficiency scores. Polish distribution companies seem to be inefficiently small, whereas Czech and Slovak companies feature the highest efficiency. When compared to the German companies, the companies in all transition countries seem to be inefficient; however, this effect is softened when we correct for different consumer densities. In Section 5, we derive conclusions and identify future research topics.

2 Reform of the Electricity Sector in East European Transition Countries

Together with high-voltage transport and low voltage distribution of electricity, regional electricity distribution has the typical characteristics of a natural monopoly (subadditive cost function) and therefore has to be regulated. Over the last decade, all East European transition countries have made attempts to modernize and privatize their electricity sectors, with different degrees of success (see EBRD, 2004, Chapter 4 for a detailed survey). The transition in Eastern Europe has implied substantial restructuring of the electricity distribution utilities, from centrally planned execution units to more independent, market-orientated decision units.

[1] See Newbery (1994), Stern (1998), Kocenda and Cabelka (1999) and Hirschhausen (2002, Chapter 9) for a general presentation of the transition process in the electricity sector.

Electricity distribution is perhaps the most complicated element in the energy chain to restructure: demand has collapsed in the industrial sector whereas it is rising in the residential sector. The capital stock had not been renewed for quite some time. Also, electricity distribution is in the most focus of politics, directly related with sensitive pricing issues and security of electricity supply to industry and household users.

In general, it is fair to say that the East European transition countries had a difficult point of inception for electricity sector reforms. Poland is by far the largest electricity producer and distributor in the region, and it also had the hardest time to restructure its energy sector. In socialist times, the country had set up one distribution company per region (voivody). These were a total of 33 distribution companies, which is a large number for the distribution of only about 100 TWh of electricity. However, the corporate structures were hardly modified in the transition period, as one would have expected. Also, privatization has been largely unsuccessful thus far, with only 3 of the 33 companies being bought by (foreign) private investors. Recently, plans to reorganize the 33 existing regional structures into 7 new, larger distribution companies have been discussed intensively, but not yet completely implemented.

The Czech Republic and Hungary are structurally quite alike, with an electricity distribution capacity of around 10 GW, and eight and six regional distribution companies, respectively. The Czech Republic has pursued a conservative policy, keeping a state owned generation company (CEZ) as the dominant owner of five RDCs; foreign investors now hold majority stakes in the remaining three RDCs. Since the early 1990s, most RDCs have massively invested in the renovation of their distribution facilities, so that by today the technical state is said to be satisfying. Hungary has certainly pursued the most consequent strategy of divestiture and privatization: all of the six RDCs were sold to foreign investors already in the mid 1990s. Slovakia is the smallest country in the region by size and by number of RDCs (only 3), but its electricity generation and distribution (about 30 TWh) reaches the level of its neighbor Hungary. This is due to the relatively high electricity intensity of the country's industry and rising household demand. Reforms of the three RDCs were delayed for quite some time: the companies were separated from their generation facilities and transformed into state-owned corporations only in 2001. Privatization began in 2002, with 49% of each RDC put up for tender, and majority stakes at a later point in time.

3 Methodology and Data

3.1 Methodology

In order to measure the efficiency of the East European RDCs, we apply the standard quantitative methodologies that have proven to be very useful in a number of different sectors and applications: the nonparametric and deterministic data envelopment analysis (DEA), the deterministic corrected ordinary least squares (COLS) method, as well as stochastic frontier analysis (SFA).

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 either within a constant return to scale (CRS) approach or a less restrictive variable returns to scale (VRS) approach. The efficiency score of the *i*-th firm in a sample of N firms is determined by linear programming methods.[2] In order to analyze the sensitivity of our empirical estimators we implement the bootstrapping procedure especially tailored to DEA by Simar and Wilson (1998). Further we apply another nonparametric estimator, the Deprins et al. (1984) FDH model, in order to assess the robustness of our results. Within this specification one releases the convexity requirements and retains only the assumption of free disposability of inputs and outputs. The FDH estimator is based on the idea of a smallest free disposal set covering the observation sample of firms.[3]

In addition, to determine the impact of the respective input factors on the efficiency, we introduce deterministic as well as stochastic parametric methodologies: COLS and SFA. COLS supposes that the distance to the efficient frontier is entirely interpreted as inefficiency. For SFA, in contrast, the underlying assumption to measure the efficiency relative to an efficient production frontier consists of splitting the error term into a stochastic residuum (noise) and an inefficiency-term. Thus, SFA accounts for noise and the effect of outliers in the data. We specify single output production functions where aggregate output measures are formed, as well as multi-output distance functions which have the advantage to accommodate both, multiple inputs and multiple outputs.

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2 Comprehensive reviews of the methodology are presented by Coelli (1998) and Jamasb and Pollit (2003).

Within the single output production function, without imposing restrictions upon returns to scale or substitution possibilities, we decide to specify a translog functional form and to run model variations with a single output index. The stochastic model to be estimated is defined by:

$$\ln y_i = \beta_0 + \sum_{j=1}^{2} \beta_j \ln x_{ji} + \sum_{j \le k}^{2} \sum_{k=1}^{2} \beta_{jk} \ln x_{ji} \ln x_{ki} + v_i - u_i \qquad (1)$$

where Y_i is the output of the *i*-th firm, x_i is a $k*1$ vector of input quantities of the *i*-th firm, β is a vector of parameters to be estimated, v_i are random variables which are assumed to be iid, N(0,σ_V ^{2}), and independent of u_i; u_i are non-negative random variables usually assumed to be half normal (iid. |N(0,$\sigma_U{}^2$)|), or truncated normally distributed; thereby accounting for individual technical inefficiency.

The basic idea of a distance function is that in the case of a given production possibility frontier, for every producer the distance from the production frontier is a function of the vector of inputs used, X and the level of outputs produced, Y. The estimated form of the translog input distance function, after having imposed the restrictions of homogeneity and symmetry, in its normalized parametric form with $M(m=1,2,...,M)$ outputs, $K(k=1,2,...K)$ inputs and $I(i=1,...,I)$ firms, can be expressed by (Coelli, 2000):

$$-\ln\left(x_{Ki}\right) = \alpha_0 + \sum_{m=1}^{M} \gamma_m \ln y_{mi} + \frac{1}{2} \sum_{m=1}^{M} \sum_{n=1}^{M} \gamma_{mn} \ln y_{mi} \ln y_{ni} + \sum_{k=1}^{K-1} \beta_k \ln\left(\frac{x_{ki}}{x_{Ki}}\right)$$
$$+ \frac{1}{2} \sum_{k=1}^{K-1} \sum_{l=1}^{K-1} \beta_{kl} \ln\left(\frac{x_{ki}}{x_{Ki}}\right) \ln\left(\frac{x_{li}}{x_{Ki}}\right) + \sum_{k=1}^{K-1} \sum_{m=1}^{M} \beta_{km} \ln\left(\frac{x_{ki}}{x_{Ki}}\right) \ln y_{mi} + v_i - u_i$$

3.2 Model Specification, Choice of Variables and Data

The literature is rather heterogeneous with respect to the variables to be used as inputs and outputs; the choice of variables is also constrained by data availability, (see survey by Jamasb and Pollit (2001)). We have three criteria for constructing among different models:

[3] By construction the FDH estimator is an inward-biased estimator of its theoretical correspondent, see Badin and Simar (2004). Based on order statistics they propose a new bias corrected estimator for the efficient frontier and scores.

- scope of countries: in the base model, we compare the efficiency of the four East European transition countries among themselves. In addition, we add a comparison between these countries and Germany, a traditional electricity market economy that has not gone through the socialist period and 15 years of transition;
- choice of input and output parameters: in the base model, we adopt the traditional choice of parameters: the number of employees (labor), estimated by the number of workers, and the length of the electricity grid (capital)[4], are taken as inputs; as outputs we define total sales (in GWh) and the number of customers. In the extended version of the model, we include a structural variable to account for differences among regions: the inverse density index, IDI, (measured in km2 per inhabitant);[5]
- the estimation method: we differentiate between parametric and nonparametric and deterministic and stochastic approaches.

We limit the presentation of our results to eleven models, as summarized in Table 1.

Tabelle 1
Modell Specification

The data used includes information on the regional electricity distribution companies (RDCs) in Poland (33), the Czech Republic (7), Hungary (4) and Slovakia (3), for the year 2003.[6] In addition, we use data for 37 German RDCs.[7] For DEA Models 1 and 2 we have 47 observations. For DEA Models 3 and 4 as well as the SFA and COLS Models 1 and 2, we dispose of 84 observations.[8]

4 Capital input is approximated by the length of the existing electricity cables. We differentiate between voltage levels (high, medium and low voltage) by introducing a cost factor for each type of line (factor 5 for high voltage, 1.6 for medium voltage and 1 for low voltage cables).

5 Utilities with a dense customer structure have a natural cost advantage over those with a weak customer density. When taken as output, the IDI improves the performance of sparsely inhabited distribution areas.

6 One Czech and two Hungarian companies are not included due to missing data availability (number of customers lacking). In some cases, data is for 2002.

7 German distribution companies for which no IDI was available, or which had an output of less than 10 GWh or less than 10 customers were sorted out. In addition, Mitteldeutsche Energieversorgung AG was sorted out because of its abnormally high IDI.

8 The data for Eastern Europe was collected from company reports and national statistics, the data for Germany was taken from VDEW (Verband Deutscher Elektrizitätswirtschaft).

4 Results and Interpretation

Our principle aim is on the one hand, to compare and discuss the results obtained from different benchmarking methodologies, and, on the other hand, to reflect certain trends. First we discuss the nonparametric DEA Models 1-4. DEA Model 4 includes an analysis of robustness for sampling error, (bootstrapping) and for different production assumptions (FDH estimator). In a further step we discuss stochastic and deterministic parametric models. All discussion involves physical quantities and technical relationships; this is due to the limited data availability of input factor prices and costs. With respect to the DEA analysis we insist mainly on the constant returns to scale approach,[9] because when looking at the different market concentrations in the countries considered, we indeed suspect the East European RDCs to be searching adaptation towards an optimal firm size. We also check the correlations and rank-correlations to test for the consistency of the results. Technical efficiency scores across all model specifications are presented in Table 2.

Table 2
Summary of technical efficiency scores

4.1 Results from the Nonparametric Models

DEA Model 1 (Figure 1) is compared to the extended DEA Model 2, where we include the structural variable, the inverse density index (IDI), in order to correct for regional differences of the customer density. Including the IDI significantly changes the efficiency rank of the individual firms within each country. Companies which operate in a less favorable environment gain efficiency. But the rank between the countries does not change, so that we limit our interpretation to DEA Model 2. The CRS estimates indicate that the Czech RDCs are by far the most efficient, with an average of 90%, and four (out of 7) RDCs are on the efficiency frontier. Hungary (74%) and Slovakia (69%) follow closely. Poland obtains the lowest average efficiency score (65%), even though, contrary to Hungary and Slovakia, it has one com-

9 It assumes that companies are flexible to adjust their size to the one optimal firm size. However, we also calculate the VRS model in order to report scale efficiency information.

pany on the efficiency line. Apparently the Slovak and the Hungarian companies are rather homogenous, whereas the Czech and, in particular, the Polish RDCs are characterized by a large heterogeneity.

The VRS efficiency values reveal that the inefficiency of the Polish RDCs mainly roots in their size which is visualized for Model 1 in Figure 2 by means of a trend line for the estimated scale efficiency scores. This is confirmed by an additional DEA estimation with non increasing returns to scale (NIRS).[10] The difference of efficiency, between the CRS and VRS approach is even more marked for Slovakia (69% to 95%, respectively), even though Slovakia is the smallest of the analyzed countries, there are only three distribution companies. This leads us to assume that Slovak firms operate in an area of decreasing returns to scale. The output sales in GWh confirm this assumption. Running an additional NIRS DEA confirms this result.[11]

Figure 1 Results DEA Model 1, CRS

Figure 2: Scale efficiency of East European transition countries, DEA Model 1

We now enlarge the scope of countries beyond Eastern Europe, and compare the efficiency of these countries with RDCs from Germany. As explained above, we consider Germany to be representative for a traditional market-economy country (even though the East Germany part underwent rapid restructuring in the early 1990s as well).[12] In the CRS-specification, one clearly observes a difference between the average efficiency in Germany (64%) and in the East European countries (between 54% for the Czech Republic and 37% for Poland). Considering Eastern Europe apart in the general estimation, the CRS results are consistent with

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10 To determine the nature of scale inefficiencies the DEA model has to be altered. We have to ensure that the i^{th} firm will be benchmarked against firms smaller than it. For the Polish companies this was consistently the case. For more details see Coelli (1998).

11 However to draw the conclusion that the Slovakian electricity distribution companies are too big to be efficient would be drawn to fast. One has to take the special structure of the Slovakian electricity sector into account. Since Slovakia exports a lot of energy and assuming the distribution companies bear at least some of the brunt, some of their input factors serve solving this task, without generating output according to the used model. That would be one possible explanation for their inefficiency in the DEA-CRS model in relation to the electricity distribution of the other countries.

12 For efficiency analysis of German electricity distribution, including a comparison between East and West Germany, see Hirschhausen, Cullmann and Kappeler (2005).

those obtained in the DEA Models 1 and 2. It seems as if the East European transition economies suffer from a structural lack of efficiency when compared to its Western neighbor. Reasons for this might be the more consistent development of the grid infrastructure in Germany; the drop of industrial electricity demand in Eastern Europe, leading to over dimensioned distribution companies, and an inappropriate territorial structure of most East European RDCs, mainly the Polish ones. Note however, that the VRS efficiency results modify the ranking of the countries averages: the Czech Republic now features the highest average (76%), even before Germany (72%), the rest of the ranks staying in line. This indicates that, when compared to Germany, the Czech utilities feature higher scale inefficiency. The Polish companies hardly gain in efficiency.

DEA Model 4 includes the IDI to count for structural differences between the countries. Here we find that among the East European countries, Poland and the Slovak Republic gain due to their lower population density. But one can see that this effect is particularly strong in the case of Germany which is a surprising result. The overall trend remains valid, however: the Polish companies still are less efficient than the companies of the other countries. Considering the pure technical efficiency, the companies of the Czech Republic do best among the analyzed new member states, followed by Hungary. Hence, we find a high potential in these two countries to improve productivity by exploiting scale efficiencies. The same holds for Poland.

For DEA Model 4 we apply the Simar and Wilson (1998) bootstrap procedure[13] in order to assess the sensitivity to sample variation and to quantify the reliability of the results. This is useful because DEA results are based on a very small static cross-country data set. After 10000 replications, we noticed that the technical efficiency estimates are highly sensitive to sampling variation, which might pose an important problem.[14] Further research has to include dynamic data in the comparative efficiency analysis across countries and/or a wider range of countries in order to get more reliable non parametric results which could then be used by regulatory authorities.

In addition, we want to report the sensitivity of the results to a different production assumption, estimating the technical efficiencies using the Deprins et al (1984) FDH model. The re-

[13] All technical efficiency scores as well as the bootstrapping confidence intervals were estimated with FEAR 0.913 by Paul W. Wilson.

[14] We found that the efficiency estimates for all companies have on average a bias of 30 percent points and a standard deviation of 3.

sults suggest that within the FDH estimation 82 companies out of the sample are classified as fully efficient. This might again be due to the fact that our data sample is too small. The findings also suggest that the DEA results are not robust with respect to changes in the maintained production assumption. This means that a more detailed analysis concerning the consideration of noise and outliers in the data as well as the production assumptions is necessary.

4.2 Results from the Parametric Models

The SFA Model 1 calculates the efficiency for all countries (including Germany) and all variables (including the IDI). The outputs are aggregated to create a joint index for total sales and the number of customers.[15] We calculate the predicted technical efficiency according to Coelli (1996).[16] The results of this approach lead to smaller gaps between the firms of each country. This can be explained econometrically: in contrast to the nonparametric DEA approach, stochastic frontiers do not assume that all deviations from the frontier are due to inefficiency. The differences between the average of Poland and the other countries are smaller than in the DEA results.[17]

A similar approach, with different weights, is used in SFA Model 2 (number of customers: 70%, total sales: 30%).[18] The "small" East European countries Slovakia: 75%, Czech Republic: 74% and Hungary: 73% still have a clearly efficiency advantage over the large one Poland: 65%. Germany (74%) is now located on the same rank as the Czech Republic. The average efficiency values of the countries, especially without considering Poland, tend to differ less than in the previous SFA Model 1. However, the values for single firms tend to differ more strongly. Slovakia, the Czech Republic, Hungary and Germany all vary around an average efficiency of 74%, therefore can be considered as featuring the same technical efficiency in the electricity distribution, which is a surprising result. Contrary to the DEA results,

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15 For the first SFA run the outputs were logged and weighted fifty percent each.

16 We applied the Battese and Coelli (1995) Specification, who propose a stochastic frontier model in which the inefficiency effects are expressed as an explicit function of a vector of firm specific variables, in our case the IDI, and a random error. See Coelli (1996) p. 5 for more detail.

17 Note, however, that some of the parameters lack statistical significance.

18 The explanation for this approach is that the number of connections determines the need for input factors more than the demanded energy. Within certain limits the maintenance for a customer is quite cheap by using thicker wires and cables for example without increasing costs significantly. This has led to the Model 2 to weight the number of customers more than the total sales in GWh.

Germany does not have an overall leader position. But the results for Poland are again similar to earlier results. Slovak Republic, as the smallest new member state, features the highest efficiency score in both parametric SFA. We notice that the parametric results differ from the nonparametric results which is akin to various earlier benchmarking studies, due to the fact that DEA models have no restriction on the form of the production function. The efficiency rank of the countries across both stochastic models can be confirmed by a COLS estimation of the single-output production function with both aggregation weights.

When we calculate the technical efficiency results of the companies by estimating the multi-output distance function (DF) using COLS (COLS DF) and SFA (SFA DF), the rank of the countries differs from our previous models, whereas the Slovak RDCs again obtain the highest efficiency scores. The performance of the Polish utilities no longer remains clear: there is no evidence for a large technical efficiency distance to its East European neighbors and Germany. Surprisingly, in contrast to our nonparametric results, the Czech Republic features now very low efficiency scores.[19]

5 Conclusions

In this paper, we have compared the technical efficiency of regional distribution companies (RDCs) in the transition countries of Eastern Europe. The reform process in this sector is influenced by the legacy of several decades of socialist energy policy, and by attempts to modernize the sector in the wake of EU-accession. Our results indicate marked differences in the efficiency scores, both within the countries and between the countries, and between different model specifications. The Polish RDCs seem to suffer from a lack of scale efficiency. Recent discussions of merging the 33 companies into 7 may therefore be well founded. Companies in the Czech Republic regularly come up with the highest efficiency scores within our nonparametric approaches, which can be explained by the substantial restructuring efforts

19 The disparity of the technical efficiency rankings obtained from multi-output distance functions induces a doubt on the reliability of the single aggregated output models. With regard to the individual rankings, a Kruskall Wallis Rank Sum test was carried out. The null hypotheses had to be rejected at a significance level of 1% in the case of all methods. This indicates that the efficiency levels are not consistent across our parametric and non parametric methods selected. This confirms earlier results, such as Estache et al. (2004), warning against the direct use of these parameters for regulatory purposes. Rather these efficiency scores have to serve as basis for discussion in more detail between firms and regulator, for consistency condition in more detail see Bauer at al. (1998).

undertaken in the mid 1990s. When comparing the East European RDCs with their German counterparts, most of the CRS models indicate lower efficiency values in Eastern Europe. We have tried to explain this phenomenon with the more coherent network development in a market economy, and it can also be due to structural variables, such as the population density. The difference in efficiency diminishes when using VRS, SFA and COLS models, within the single output production technology as well as applying the distance function approach; in fact, German RDCs are no longer leading in several models.

From a methodological perspective, our study reconfirms the fact that the results from different models should be interpreted carefully. Whereas the DEA results are quite clear cut, the results from the parametric approaches indicate less difference of efficiency scores. The Kruskal-Wallis test on rank correlation also suggests that different models yield quite different results. Further research should focus on a dynamic comparative analysis of efficiency measures in the region, e.g. time series analysis from 1995-2004. The use of monetized cost data would also allow more reliable conclusions with regard to scale efficiencies (e.g. Farsi and Filippini 2004); it might also inverse the efficiency relation between Eastern Europe and Germany, as Germany has by far higher labor costs.

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Table 1
Model Specification

Model	Countries included	Variables	Description
DEA Model 1	Only East European Countries	All variables included without IDI	Input orientation CRS, VRS, TE
DEA Model 2	Only East European Countries	All Variables with IDI	Input orientation CRS, VRS, TE
DEA Model 3	All Countries	All Variables without IDI	Input orientation CRS, VRS, TE
DEA Model 4	All Countries	All Variables with IDI	Input orientation CRS, VRS, TE
FDH Model 4	All Countries	All Variables with IDI	Input orientation CRS, VRS, TE
SFA Model 1	All Countries	All Variables included	Translog Output weighted 50/50
SFA Model 2	All Countries	All Variables included	Translog Output weighted, customers 0,7/ sales 0,3
COLS Model 1	All Countries	All Variables included	Translog Output weighted, customers 0,5/ sales 0,5
COLS Model 2	All Countries	All Variables included	Translog Output weighted, customers 0,7/ sales 0,3
COLS DF	All Countries	All Variables included	Translog
SFA DF	All Countries	All Variables included	Translog

Table 2

Summary of technical efficiency scores

		DEA1 CRS	DEA1 VRS	DEA2 CRS	DEA2 VRS	DEA3 CRS	DEA3 VRS	DEA4 CRS	DEA4 VRS	SFA1	SFA2	COLS1	COLS2	COLS DF	SFA DF
Poland	1	0,76	1	0,78	1	0,67	1	0,67	1	0,8	0,71	0,73	0,68	0,41	0,76
	2	0,84	0,91	0,84	0,91	0,71	0,85	0,71	0,85	0,85	0,85	0,72	0,72	0,36	0,85
	3	0,65	0,69	0,65	0,77	0,44	0,68	0,44	0,77	0,71	0,74	0,46	0,46	0,45	0,81
	4	0,45	0,48	0,48	0,58	0,41	0,48	0,41	0,56	0,67	0,81	0,43	0,42	0,34	0,76
	5	0,61	0,74	0,67	0,74	0,52	0,53	0,52	0,53	0,71	0,89	0,49	0,47	0,34	0,8
	6	0,39	0,39	0,46	0,59	0,33	0,38	0,33	0,55	0,63	0,83	0,35	0,34	0,38	0,72
	7	0,48	0,49	0,55	0,61	0,35	0,41	0,36	0,56	0,61	0,71	0,36	0,35	0,41	0,78
	8	0,44	0,45	0,5	0,6	0,36	0,44	0,36	0,57	0,62	0,83	0,36	0,36	0,38	0,76
	9	0,48	0,56	0,55	0,56	0,44	0,44	0,44	0,5	0,55	0,83	0,4	0,41	0,38	0,81
	10	0,4	0,4	0,46	0,52	0,32	0,37	0,33	0,48	0,55	0,82	0,32	0,32	0,34	0,75
	11	0,58	0,97	0,98	1	0,54	0,55	0,55	0,62	0,61	0,82	0,38	0,32	0,47	0,76
	12	0,36	0,51	0,51	0,52	0,32	0,32	0,32	0,43	0,49	0,84	0,32	0,31	0,38	0,75
	13	0,41	0,54	0,53	0,54	0,32	0,32	0,32	0,44	0,5	0,17	0,31	0,3	0,36	0,76
	14	0,43	0,51	0,53	0,53	0,34	0,34	0,34	0,47	0,5	0,73	0,32	0,32	0,36	0,78
	15	0,35	0,5	0,47	0,5	0,29	0,29	0,29	0,38	0,47	0,83	0,29	0,28	0,32	0,73
	16	0,41	0,62	0,57	0,63	0,4	0,41	0,41	0,47	0,48	0,64	0,37	0,37	0,4	0,79
	17	0,48	0,49	0,63	1	0,34	0,44	0,34	1	0,52	0,44	0,3	0,32	0,51	0,82
	18	0,43	0,65	0,67	0,67	0,39	0,39	0,39	0,57	0,47	0,67	0,35	0,35	0,5	0,8
	19	0,41	0,62	0,53	0,62	0,39	0,39	0,39	0,41	0,69	0,39	0,35	0,36	0,34	0,78
	20	0,35	0,55	0,55	0,56	0,34	0,34	0,35	0,48	0,45	0,73	0,31	0,32	0,42	0,76
	21	0,62	0,83	0,67	0,83	0,52	0,58	0,52	0,6	0,65	0,76	0,44	0,47	0,3	0,82
	22	0,35	0,71	0,61	0,71	0,35	0,35	0,35	0,43	0,54	0,44	0,31	0,31	0,42	0,76
	23	0,3	0,49	0,48	0,5	0,24	0,24	0,24	0,37	0,38	0,75	0,22	0,22	0,3	0,7
	24	0,34	0,77	0,51	0,77	0,3	0,3	0,3	0,31	0,5	0,9	0,26	0,26	0,28	0,73
	25	0,37	0,48	0,52	0,55	0,27	0,27	0,27	0,45	0,39	0,82	0,23	0,24	0,34	0,8
	26	0,42	0,86	0,86	0,89	0,36	0,36	0,37	0,66	0,51	0,51	0,29	0,29	0,51	0,8
	27	0,41	0,75	0,8	0,84	0,29	0,29	0,3	0,58	0,36	0,7	0,24	0,24	0,42	0,78
	28	0,44	0,92	0,69	0,92	0,43	0,44	0,44	0,45	0,53	0,61	0,32	0,34	0,43	0,84

	29	0,33	1	0,76	1	0,33	0,33	0,33	0,39	0,46	0,62	0,27	0,27	0,41	0,74
	30	0,3	0,89	0,99	1	0,28	0,29	0,29	0,83	0,43	0,82	0,24	0,24	0,51	0,71
	31	0,33	1	0,9	1	0,28	0,29	0,29	0,52	0,42	0,62	0,24	0,23	0,39	0,7
	32	0,31	0,82	0,85	0,86	0,26	0,26	0,27	0,67	0,39	0,57	0,21	0,21	0,42	0,71
	33	0,28	0,97	1	1	0,25	0,25	0,26	0,83	0,36	0,58	0,18	0,19	0,44	0,7
Mean		**0,44**	**0,68**	**0,65**	**0,74**	**0,37**	**0,41**	**0,38**	**0,57**	**0,54**	**0,7**	**0,34**	**0,34**	**0,39**	**0,77**
Slovak	34	0,74	0,92	0,74	0,92	0,52	0,92	0,53	0,92	0,77	0,75	0,6	0,56	0,51	0,81
Republic	35	0,49	0,56	0,68	1	0,45	0,52	0,46	0,77	0,7	0	0,49	0,46	0,68	0,77
	36	0,45	0,49	0,66	0,92	0,45	0,45	0,45	0,78	0,62	0,71	0,44	0,44	0,63	0,79
Mean		**0,56**	**0,66**	**0,69**	**0,95**	**0,47**	**0,63**	**0,48**	**0,83**	**0,7**	**0,49**	**0,51**	**0,49**	**0,61**	**0,79**
Czech	37	1	1	1	1	0,55	1	0,55	1	0,8	0,64	0,49	0,48	0,36	0,73
Republic	38	0,97	1	0,97	1	0,57	1	0,57	1	0,78	0,47	0,48	0,45	0,33	0,73
	39	1	1	1	1	0,56	0,88	0,56	0,96	0,74	0,91	0,45	0,43	0,37	0,78
	40	0,74	0,74	0,74	0,74	0,4	0,59	0,4	0,69	0,69	0,81	0,35	0,34	0,28	0,7
	41	1	1	1	1	1	1	1	1	0,84	0,66	0,58	0,56	0,38	0,87
	42	0,27	0,4	0,62	1	0,19	0,21	0,2	0,57	0,38	0,84	0,14	0,13	0,23	0,3
	43	1	1	1	1	0,52	0,68	0,52	1	0,61	0,76	0,38	0,4	0,42	0,81
Mean		**0,85**	**0,88**	**0,9**	**0,96**	**0,54**	**0,76**	**0,54**	**0,89**	**0,69**	**0,73**	**0,41**	**0,4**	**0,34**	**0,7**

Figure 1

Results DEA Model 1, CRS

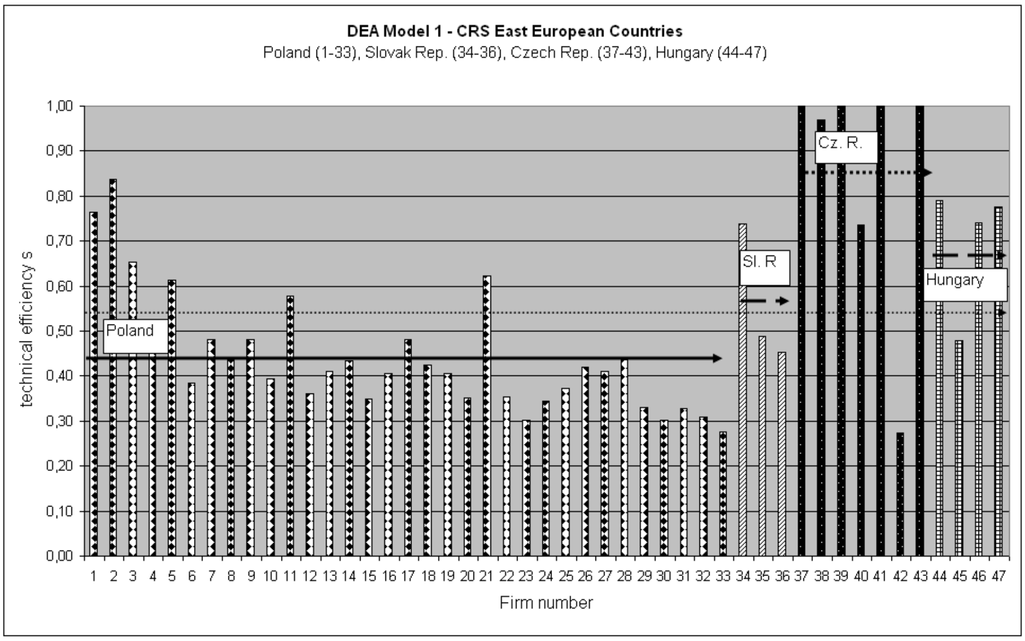

Figure 2:

Scale efficiency of East European transition countries, DEA Model 1