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A DEA-BASED TOOL FOR TRACKING BEST PRACTICE EXEMPLARS: THE CASE OF TELECOMMUNICATIONS IN EBRD COUNTRIES

ABSTRACT: *Benchmarking is a strategic management tool that can help to gain competitive advantage, but the question is how to decide the relevant practice exemplars to be used as role models. Data Envelopment Analysis (DEA) is a very helpful method for tracking corresponding benchmarks, but the question remains of how to record them when performance is fluctuating and unstable, as is the case in a transition period to an open market. To address this issue a new DEA-based tool is proposed, the Corresponding Benchmark Matrix (CBM), which helps to reveal 'leader' countries and the most suitable benchmarks for less successful countries. The approach is illustrated for telecommunications in 22 European Bank for Reconstruction and Development (EBRD) countries.*

KEY WORDS: *benchmarking, DEA, corresponding benchmark matrix, telecommunications policy.*

JEL CLASSIFICATION: P52, L96, C44

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1. INTRODUCTION

Benchmarking (BM) is a strategic management tool with broad application. Although first used in the private sector (Xerox company: Camp 1989) in the late 1970s, it very soon found its way into the public sector. In modern academic literature, benchmarking serves as a conceptual framework in studies in various areas, such as expert and decision-making systems (Estrada et al., 2009; Petrović et al., 2014), reengineering (Thor & Jarrett 1999; Jain et al. 2010), Total Quality Management (Prajogo & Sohal 2006), and strategy and policy (Bauer 2012; Petrović et al. 2012a, 2018). Public policy benchmarking occupies a prominent place in benchmarking literature (see Petrović et al. (2018) for details). From a policy perspective the aim of benchmarking is to identify the best policy practice and to establish a framework for policy transfer and cross-national learning (Hong 2012). The European Union gave what is perhaps the biggest endorsement of benchmarking by promoting it as an alternative policy tool to regulatory pressure in order to encourage the sharing of experiences and ideas between countries. The recently established Sustainable Development Goals for 2030 follow the same path. Other international organisations such as the Organisation for Economic Co-operation and Development (OECD) and the European Bank for Reconstruction and Development (EBRD) promote benchmarking studies in order to help lagging countries 'learn' from their more successful counterparts.

The two main goals of benchmarking are to compare and to learn. The terms 'benchmarking' and 'benchmark' need to be distinguished. While the first is related to the systematic process of comparing the performance of peer units, the latter refers to the reference point, the target, the 'best in class', and the role model. In the field of policy-making, international benchmarking is used to encourage policy transfer through cross-national learning (Rose 1991; Dolowitz & Marsh 2000, Lundvall & Tomlinson 2002; Evans 2009; Hong 2012). There are many challenges associated with gaining competitive advantage based on policy benchmarking results, in both the conceptual and the methodological sense (for detailed discussion see Lundvall & Tomlinson 2002; Bauer 2010; Petrović et al. 2012a, 2014). While some authors criticize the idea of cross-national learning in a policy context (Dolowitz & Marsh 2000, Evans 2009) there are also studies that favour this idea (Rose 1991; Petrović et al. 2013). One of the most discussed and analysed issues is the question of the benchmark itself. The core of the benchmark's complexity is its prevailing quantitative nature or the 'role model' issue, where policymakers and practitioners have to find the right BM metrics to steer development strategy.

Benchmarking has been widely implemented in telecommunications, from benchmarking equipment and service components (Sim 2003) to cross-country benchmarking in the policy domain (Petrović et al. 2012a). The widespread use of the benchmarking approach has led scholars in different research fields to pursue improved and innovative analytical tools. This is an especially challenging task when it comes to cross-country analysis in constantly changing sectors such as telecommunications. The dynamism of the sector, the variety of support services and technologies, and the growing number of application domains all point to the importance of an adequate BM metric. In telecommunications, composite indicators (CI) are the common BM metric (Mitrović 2015). Although widely used, in terms of benchmarking CIs have been criticised due to the compensatory effect (Petrović et al. 2012a; Stamenković et al. 2016), double-counting, and their inability to point to corresponding benchmarks, i.e., relevant practice exemplars. Therefore, researchers have looked for alternative benchmarking solutions.

Data Envelopment Analysis (DEA) is a very helpful method for revealing corresponding benchmarks, i.e., role models. It is useful for developing countries, since setting targets according to the performance of the best can be unrealistic. Instead, the goal should be to find the way to improve efficiency gradually. In other words, policymakers should consider pursuing relevant practice exemplars or a sequence of intermediate benchmarks (so-called stepwise benchmarking, see Petrović et al. 2014, 2018) instead of the common best practice approach.

However, DEA is a method for measuring efficiency, so the benchmarking exercise should be in this context. Since one of the main characteristics of the sector-level analysis pertains to its multi-output nature, DEA can be considered a benchmarking method that properly addresses the sector's efficiency yet is flexible in terms of data requirements (Resende 2008). Nevertheless, when deciding on corresponding benchmarks the stability of a country's performance is very important, especially when analysing developing countries that are transiting to an open market economy (as is the case of the EBRD countries between 1998 and 2007, which are the subject of our study). Some countries may be relatively efficient in one year but inefficient in the next. In that case one line of research shifts to Total Factor Productivity analysis (TFP), based on the DEA-like Malmquist Index. The sources of output change over time, whether from efficiency or technological changes, and TFP evaluation using the DEA Malmquist Index associates TFP with regulatory change. For example, Petrović et al. (2012b) exploit the DEA Malmquist index to obtain TFP for the telecommunications sector and to link it to the regulatory index of selected transition countries.

In this study our aim is not to track the sources of an output change but rather to illuminate fluctuations in efficiency over time, as our focus is tracking best practice exemplars. This leads to the question of whether 'one-time efficient countries' are appropriate as best practice exemplars.

The aim of this study is to develop a tool that will help decision-makers in an unstable environment where performance fluctuates, using benchmarking as the conceptual basis and DEA as the operational basis of their evaluation and practice. The paper focuses on selection of a corresponding benchmark in subsequent time cut analysis. For this purpose, we introduce the Corresponding Benchmark Matrix (CBM). The approach is applied to the field of telecommunications in 22 EBRD countries during the transition period of 1998–2007, before the financial crisis.

The paper is organised as follows. In the next section we briefly address DEA in the context of benchmarking. We continue with the introduction of the Corresponding Benchmark Matrix in Section 3 and apply it to benchmarking telecommunications in EBRD countries in Section 4. The paper ends with concluding remarks and future research directions.

2. DEA AND BENCHMARKING

DEA is widely used for benchmarking efficiency and productivity in telecommunications (some representative studies are: Lien & Peng 2001; Lam & Shiu 2008; Giokas & Pentzaropoulos 2008; Azadeh et al. 2007, 2010; Petrović et al. 2011; Ceccobelli et al. 2012). Public policy issues are addressed in the same manner (Chan & Karim 2012).

DEA uses mathematical programming techniques and models to evaluate the performance of peer units (Decision-Making Units or DMUs) in terms of the multiple inputs used and multiple outputs produced. DEA evaluates each decision-making unit individually and detects those units in the sample that exhibit the best practice. These 'best practice' units constitute an exemplar (frontier) to which the remaining units in the sample are compared. The two most prominent types of DEA model depend on the envelopment surface. The first, called CCR, was proposed by Charnes, Cooper, and Rhodes (1978) in their seminal paper and uses a constant returns-to-scale (CRS) surface. The second uses a variable returns-to-scale (VRS) surface and was developed by Banker, Charnes, and Cooper (1984). The assumption of CRS (that the underlying production function is linear) is appropriate only when all DMUs operate at an optimal scale, with optimal production. Both types of models can be applied to an input- or output-orientation model. In an output-orientation model, efficiency is measured from the perspective of producing maximum output with the same amount of inputs. For each unit the DEA calculates a relative efficiency score. In the input-oriented model a value of 1 indicates efficiency and a value smaller than 1 indicates the level by which the relevant inputs should be decreased in order for an inefficient DMU to become relatively efficient. In the output-oriented model a value of 1 indicates relative efficiency and a value greater than 1 indicates the level by which the relevant outputs need to be increased in order for an inefficient DMU to be deemed relatively efficient. A detailed description of DEA models with CRS and VRS can be found in Liu et al. (2013) and Emrouznejad & Yang (2017).

DEA provides each inefficient unit with an efficiency reference set (ERS) or peer group, defined by a (small) subset of the efficient units closest to the unit under evaluation (with a similar mix of inputs and outputs). In this context, each inefficient country is compared to its corresponding benchmark set, containing countries drawn from the list of efficient countries.

ERS also provides the linear programme (LP) duals of the corresponding benchmarks (denoted as λ_i). These duals demonstrate how significant the particular corresponding benchmarks in each reference set are, and therefore which successful unit will be most useful to the inefficient unit in constructing strategies leading to optimal efficiency (Forker & Mandez 2001).

DEA can be regarded as a benchmarking tool because the identified frontier can be used as an empirical standard of excellence (benchmark). Many authors have evaluated DEA from the benchmarking perspective (see, for example, Sharma & Yu 2009; Forker & Mendez 2001; Lim et al. 2011; Petrović et al. 2013). However, if we return to the question of substantial benchmarking ranking and relevant practice determination, the benefits of DEA are elusive.

DEA can be inconclusive in terms of relative performance and ranking because all units found to be efficient are assigned the same value (1.00). Although extensively elaborated in the literature, the question of ranking in DEA is still not fully resolved. For example, a ranking solution named super-efficiency DEA (proposed by Andersen & Petersen 1993) was later found to be unworkable (see Banker & Chang 2006) However, it was further investigated; for example, Chen (2004) propose an approach to correct the unfeasibility of the super-efficiency model. Adler et al. (2002) comprehensively review ranking methods in the DEA context but also point out that "none of proposed approaches can be regarded as a complete solution to the efficiency ranking problem". Many other approaches to ranking have been devised; for example, the fully inefficient frontier (Jahanshahloo & Afzalinejad 2006) and changing the reference set (Jahanshahloo et al. 2007). Chen & Deng (2011) devise a cross-dependence-based ranking system where the changes in efficient and inefficient units are evaluated through the removal of units from the efficiency reference set.

Possibly the most used method for ranking efficient units is based on frequency of occurrence in the efficiency reference set (ERS), an idea first developed in Charnes et al. (1985). Torgersen et al. (1996) carried out a seminal study using this approach. The main idea is that an efficient unit is highly ranked if it appears frequently in the reference sets of inefficient DMUs; i.e., if it is chosen as a useful target by many inefficient units. However, a complete ranking cannot be guaranteed since several DMUs could obtain the same ranking score. Examples of its application in a benchmarking context can be found in Gikoas & Pentzaropoulos (2000, 2008).

In our study we also use frequency of occurrence to arrive at the final ranking and final choice of corresponding benchmarks – the two main outcomes of a benchmarking exercise. As we are dealing with countries (benchmarking partners) undergoing a period of intensive transformation and efficiency fluctuation, instead of ERS we rely on a specific framework, the corresponding benchmarks matrix (CBM), described in the following section.

3. THE CBM MATRIX – A NEW TOOL FOR DYNAMIC BENCHMARKING

An Efficiency Reference Set (ERS) is in fact a Corresponding Benchmarks (CB) set because it contains the decision-making units to which each inefficient country has been most directly compared in Data Envelopment Analysis efficiency estimations. Therefore, our approach starts with efficiency reference set analysis and uses several steps to create a matrix that is the core of a framework for dynamic benchmarking (Figure 1). Since the matrix offers additional information on CBs it is named Corresponding Benchmarks Matrix (CBM).

Step 1: For each less successful country we analyse the ERS and select benchmark countries with the highest measure of benchmark share – the highest Linear Programming (LP) duals (the contribution of an efficient DMU to the potential input or output improvement of an inefficient DMU). These DMUs are the benchmarks with the highest correspondence.

Step 2: We repeat step 1 for each year of observation. The longer the analysed period the greater the amount of reliable information on CBs that can be gathered.

Step 3: Based on the gathered information the CBM is mathematically formulated as follows:

$$CBM = \lfloor n_{ij} \rfloor,\ i = \overline{1,n}$$

where n_{ij} represents the number of times DMU_j (country j) appears as a corresponding benchmark (CB) with the highest linear programming dual ($\lambda_{DMU}=\lambda_{max}$) for DMU_i (country i), and n is the number of analysed DMUs (here seen as countries).

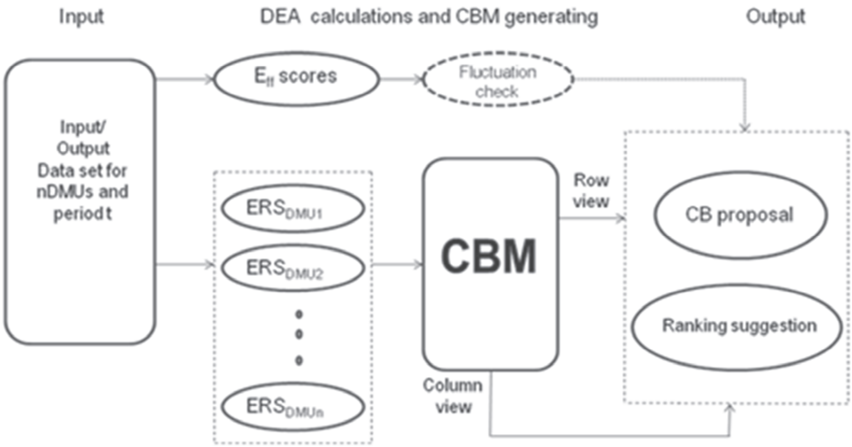
The Corresponding Benchmarks Matrix offers the following information about countries' performance in the analysed period:

- Looking across the rows – *Which is my best practice exemplar?* (Which countries appeared as my Corresponding Benchmarks and to what extent, or, technically, how many times did an efficient country appear in my Efficiency Reference Set?)
- Looking down the columns - *Can I serve as the practice exemplar?* (How many times did I appear as a Corresponding Benchmark and to what extent (technically, how many times did a country appear as a CB with a high contribution to the ERS of other countries?)
- Looking along the diagonal – *How many times was a country found to be efficient?*

The main contribution of CBM to the benchmarking process is that it provides a framework for meaningful and reliable CB selection. From among the potential CBs it distinguishes the efficient countries with good, stable performance that are relevant practice exemplars. It can also help to further rank countries found to be efficient by pointing to those that most frequently occur as CBs.

Here it is important to note that all implications drawn from the CBM are in terms of relative assessment (i.e., are affected by the selection of BM partners). Success according to the CBM does not reflect the overall achievement of a unit, but how it stands relative to other BM partners in the sample. This is why it is very important for decision-makers to choose benchmarking partners that have institutional support for exchanging knowledge and experience, such as EBRD countries.

Figure 1. CBM framework



4. CBM APPLIED TO TELECOMMUNICATIONS IN EBRD COUNTRIES

The described benchmarking procedure is applied to EBRD countries in the most intensive transition period, 1998–2007, before the world economic crisis. Although many EBRD countries, especially those that had recently joined the European Union (EU), made significant advances in development during this period (Falcetti et al. 2006), the transformation process in some of them was slow (e.g., Commonwealth of Independent States (CIS), formerly the USSR) (Markova 2009; Petrović et al. 2012a, 2014). For these less successful countries it is very important to find a way to accelerate the transition process and to adopt best policy practice. EBRD countries can be considered as benchmarking partners since they share the same policy goals (under the framework of the EU electronic communications policy) and have the EBRD as institutional support for achieving them, which is an important premise for 'policy-learning' through international benchmarking (for a more detailed discussion of this issue see Petrović et al. 2012a, 2013). However, the disparities between them and their unstable development trends bring issues to the benchmarking process regarding both countries' relative position and determining benchmarks. It is difficult to capture trends in regions with turbulent and unstable markets and which are still in the process of moving from command to market economies (transition countries) and experience both progress and regressions in efficiency (Kumar & Russel 2002; Petrović et al. 2011). The 2008 EBRD regulatory assessment report shows that policy trends differ across the region and less successful countries should find a way to adopt the experiences of their more successful counterparts (EBRD 2008). We consider the pre-crisis period in order to pinpoint the effectiveness of this method. A similar approach and focus can be found in Gligorić (2014).

4.1. Data

Our study research sample comprises panel data for 22 transition countries (here seen as DMUs) covering the period 1998–2007. In order to measure the productivity and efficiency of the telecommunications sector, data on sector outputs and inputs was selected. In line with many previous studies (for example, Lam & Shiu 2008, 2010; Giokas & Pentzaropoulos 2008; Lien & Peng 2001; Madden & Savage 1999; Sueyoshi 1994), total telecommunications services revenue (in US dollars) is used as a measure of output, while fixed telephone lines in operation (Direct Exchange Lines, measured in thousands), total full-time staff (measured in thousands), and annual telecommunications investment (also referred to as annual capital expenditure, measured in millions of US dollars) are selected as input measures. The correlations between inputs and outputs are positive, i.e., have an isotonic relationship, and thus are appropriate for inclusion in the model.

All the data is taken from the Yearbook of Statistics, Telecommunications Services Chronological Time Series 1998–2007 (International Telecommunications Union). The missing data was obtained from other sources (for example, OECD, World Bank, National Statistical Offices). Eight EBRD countries were excluded from the study due to lack of data and because

DEA is sensitive to measurement errors (Georgia, Kazakhstan, Latvia, Montenegro, Russian Federation, Slovak Republic, Tajikistan, Turkmenistan).

Since in the analysed period a general assessment of telecommunications market conditions is complicated by strong regional disparities between transition countries, in our empirical example we use both output-oriented DEA methods, VRS and CRS.

4.2. Results and discussion

In this section we first analyse the relative positions of countries according to their efficiency scores. Next, using the CBM approach, for the less successful countries we determine the most suitable benchmark country.

Table 1 in the Appendix summarises the efficiency scores obtained by the output-oriented DEA VRS (denoted by Evrs) and DEA CRS (denoted by Ecrs) for the 1998–2007 period.[1] Pearson and Spearman correlations between the two efficiency measures indicate a strong relationship between the two efficiency observations (above 0.9 for each year of observation), indicating low efficiency.

For the majority of countries, efficiency was found to vary over time. Only Hungary was found to be efficient by both measures throughout the observed period.[2] Estonia, Turkey, and Albania were found efficient in 15 or more observations and can also be considered successful, since their efficiency scores remained close to 100% with a standard deviation lower than 0.2. Poland and Mongolia were found to be efficient in 13 and 10 observations respectively (mainly in terms of VRS). Slovenia is an interesting case since its mean efficiency score is better that Poland's, but it was found to be efficient in only eight observations. The same goes for Croatia: there is less variation in its efficiency scores but it was only efficient in four years of observation.

Although countries' efficiency varied over time, on average the observed EU countries[3] were more efficient than the South East European (SEE) countries, while both proved more efficient then CIS countries (also known as early transition countries). This is in line with results obtained by the EBRD (2008)

1 All tables are given in the Appendix at the end of the paper.

2 With the exception of E_{crs} in 2004.

3 EU member countries are seen here as transition country members of the EU–25 (Estonia, Hungary, Lithuania, Poland, Slovak Republic, Slovenia.). Bulgaria and Romania are considered as SEE countries, as well as Croatia, which joined the EU in 2013.

on telecommunications sector performance in these countries. Albania and Mongolia are an interesting case since they showed better performance than some EU countries such as Poland. It can be argued that some developing countries – particularly transition economies – are likely to attain higher output-input ratios because they can deploy the latest technologies to develop their nationwide telecommunications networks. This concept is known as 'latecomers' advantage' (see Lam & Shiu 2010; Petrović et al. 2011).

To further evaluate corresponding benchmarks, the efficiency results can be utilised in a 'fluctuation check' (Figure 1). A country like Mongolia must be excluded as a CB candidate since its efficiency scores varied greatly over time, reaching scores of above 2.000 in CRS efficiency in 2006 and 2007.

Following the steps described in Section 3, we design a Corresponding Benchmark Matrix (CBM).

First, Corresponding Benchmarks (CBs) are extracted using the Efficiency Reference Set of each country in each year of observation. The example for Lithuania (in the case of DEA VRS) is given in Table 2. CBs with the highest LP dual are highlighted (Table 2) and selected for further observation. These are countries from which the 'best practice' can most appropriately be adopted since they have a similar combination of inputs and outputs. Following this procedure, CBs for all analysed countries and years of observation are presented in Table 3 (VRS results) and Table 4 (CRS results).

CBMs (Tables 5 and 6) are formed using the data from Tables 3 and 4. The numbers in the CBMs show how many times a country is found to have the most relevant practice – the CB in the ERS that contribute most to the efficiency target.

The CBM allows decision-makers to review the suitability of their country as a CB for their counterparts (column view) and, vice versa, the suitability of counterpart countries to be a CB for their country (row view).

A column view perspective offers the following information. As seen from the CBMs (Tables 5 and 6 in the Appendix), Albania, Estonia, Hungary, and Mongolia are the countries with the highest frequency of occurrence in terms of CRS that contribute most to efficiency targets, and therefore represent the group of best practice exemplars for the analysed countries: the EBRD telecommunications benchmarks. Turkey, earlier discussed as a benchmark country, is eliminated since it appeared as a CB only 4 and 2 times in terms of VRS and CRS respectively. At the same time Mongolia is added, since it appears frequently as a CB. Here, again, caution is necessary when analysing results: although Mongolia occurs frequently as a CB, as we already mentioned it is undermined by its unstable performance.

Looking along the diagonal, we can see how many times each country was found to be efficient. Hungary is a leader country in this sense also.

Based on frequency of occurrence in the ERS, the CBM detects the corresponding, most suitable benchmark countries for less successful countries. Taking Romania as a row view example, we can see that two countries appear most frequently in the CBMs: Hungary (in the case of VRS – Table 5) and Albania (in the case of CRS – Table 6). The difference in the CBM results is due to the frontier type (DEA VRS vs. DEA CRS model). It is up to the policymaker to decide whether to account scale efficiency.

From the perspective of lagging countries such as Serbia, the CBM points to three potential CBs: Albania, Estonia, and Hungary. Further analysis and the final selection of CBs require some additional discussion. Estonia can be ranked as a third choice since, unlike Albania and Hungary, it occurs less frequently in terms of VRS. However, the decision-maker may choose other criteria that favour Hungary in terms of exchanging experience.

In terms of possible leader EBRD countries, the CBM (column view) pinpoints Albania, Estonia, Mongolia, and Hungary. However, as indicated earlier, the decision-maker may decide to take efficiency results into consideration and exclude Mongolia due to fluctuations in its efficiency scores over time.

To summarize, although CBM results can help decision-makers manage assessment data and parameters, they are only an aid to decision-making. As Talluri (2000) points out, "DEA is primarily a diagnostic tool and does not prescribe any reengineering strategies". It is up to the policymaker to make the final choice of CB and find the way to emulate its performance.

6. CONCLUSION

This paper proposes an innovative, DEA-based procedure for setting public policy benchmarks. A Corresponding Benchmarks Matrix is introduced as a policy tool that can give policymakers insight into their countries' performance and provide best practice exemplars, especially in a dynamic situation.

The strength of a CBM is its ability to reveal relevant practice that can be used as a model and performance stability for successful countries. This is particularly important when analysing countries with imperfect competition where success in one year can disappear in the next, as was the case in EBRD countries during the period of intensive regulatory transformation studied in this paper (1998–2007).

The limitation of the proposed approach is that benchmark countries in the earlier years of observation are counted as equal to those with benchmark status in the last few years. This may be misleading in the current circumstances: if a country does not appear as a 'leader' in the more recent period, this can raise questions as to the accounting 'ten-year-old' success. This requires some modification of the CBM and could be the subject of future research. Another interesting approach would be a two-step DEA in order to determine the factors and drivers of DEA scores, including regulatory rules.

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APPENDIX

Table 1. DEA efficiency scores.

	1998		1999		2000		2001		2002		2003		2004		2005		2006		2007			
	Evrs	Ecrs	Evrs	Ecrs	Evrs	Ecrs	Evrs	Ecrs	Evrs	Ecrs	Evrs	Ecrs	Evrs	Ecrs	Evrs	Ecrs	Evrs	Ecrs	Evrs	Ecrs	mean	stdev σ
HUN	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.034	1.000	1.000	1.000	1.000	1.000	1.000	1.002	0.008
EST	1.152	1.179	1.000	1.000	1.000	1.224	1.000	1.154	1.000	1.000	1.000	1.081	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.040	0.074
TUR	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.192	1.000	1.310	1.000	1.166	1.000	1.131	1.040	0.088
ALB	1.000	1.000	1.000	1.000	1.097	1.806	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.262	1.000	1.000	1.000	1.000	1.000	1.000	1.058	0.186
SVN	1.000	1.000	1.000	1.017	1.247	1.621	1.154	1.318	1.000	1.177	1.000	1.000	1.000	1.000	1.104	1.112	1.091	1.109	1.452	1.481	1.144	0.187
POL	1.000	1.000	1.000	1.064	1.000	1.208	1.000	1.128	1.000	1.551	1.047	1.965	1.000	1.605	1.000	1.603	1.000	1.747	1.000	1.391	1.215	0.309
HRV	1.000	1.000	1.000	1.000	1.409	1.409	1.389	1.403	1.082	1.128	1.290	1.309	1.374	1.589	1.312	1.367	1.174	1.283	1.244	1.245	1.250	0.170
MNG	1.000	1.824	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.278	1.000	1.818	1.000	1.823	1.000	1.848	1.000	2.403	1.000	2.240	1.312	0.480
SVK	1.317	1.326	1.432	1.491	1.521	1.524	1.707	1.777	1.462	1.506	1.249	1.261	1.089	1.232	1.004	1.141	1.000	1.205	1.000	1.000	1.312	0.236
FYRM	1.693	1.738	1.436	1.438	1.468	1.735	1.472	1.620	1.000	1.230	1.000	1.413	1.000	1.442	1.000	1.375	1.000	1.191	1.000	1.315	1.328	0.263
BIH	1.000	1.000	1.000	1.000	1.000	1.214	1.934	1.954	2.260	2.395	1.822	1.887	1.966	2.175	2.293	2.515	2.184	2.532	1.459	1.614	1.760	0.556
LTU	2.888	2.893	2.665	2.673	2.991	3.287	2.295	2.506	1.490	1.588	1.415	1.515	1.395	1.412	1.415	1.420	1.160	1.267	1.061	1.222	1.928	0.743
ROM	2.606	2.874	2.253	2.568	3.771	3.807	2.430	2.723	1.516	1.788	2.211	2.538	1.743	2.330	1.546	2.082	1.256	1.877	1.252	1.611	2.239	0.717
BGR	2.103	2.600	1.964	2.143	1.847	2.018	2.420	2.566	2.585	2.973	2.691	2.702	2.338	2.754	2.151	2.591	1.893	2.559	1.838	2.134	2.343	0.343
UKR	1.832	2.392	2.490	2.887	2.992	3.338	2.943	3.238	2.982	3.360	2.805	3.798	2.263	3.587	2.158	3.968	1.912	3.451	1.914	3.195	2.875	0.641
SRB	2.235	2.265	2.766	2.805	3.677	3.680	2.824	2.843	2.767	2.877	3.074	3.110	4.783	4.964	3.234	3.401	2.729	2.774	2.499	2.510	3.091	0.725
AZE	1.943	2.676	3.570	3.980	3.823	3.991	4.419	4.478	2.111	3.743	2.510	4.588	2.028	2.434	2.040	2.278	3.085	3.832	2.662	2.743	3.147	0.907
KGZ	4.826	5.169	3.236	3.621	2.979	3.345	5.310	5.495	4.643	4.831	4.234	5.056	2.809	3.306	2.324	2.793	1.518	2.682	1.000	2.612	3.589	1.300
ARM	4.213	4.538	3.851	4.105	4.695	4.710	2.857	2.902	4.334	4.440	4.882	5.482	3.960	4.176	2.610	2.878	2.552	3.187	1.000	3.125	3.725	1.061
UZB	2.534	3.079	2.030	2.269	3.237	3.275	3.270	3.448	4.681	4.723	6.709	6.961	7.002	7.887	3.699	3.873	3.221	3.387	3.088	3.299	4.084	1.706
MDA	4.348	4.517	4.238	4.421	6.204	6.215	3.246	3.278	5.906	6.537	4.739	5.111	4.382	4.530	3.687	3.827	2.974	3.199	3.954	4.219	4.477	1.053
BLR	3.254	3.869	3.027	3.406	3.835	4.313	6.065	6.210	6.304	6.360	7.603	7.742	4.758	5.285	4.884	5.281	5.865	5.878	5.661	5.717	5.266	1.344
r**	0.979		0.996		0.992		0.998		0.980		0.970		0.984		0.943		0.927		0.878			
ρ***	0.959		0.944		0.964		0.993		0.936		0.934		0.913		0.879		0.887		0.705			

*Country abbreviations: ARM - Armenia; AZE - Azerbaijan; BLR - Belarus; BIH - Bosnia and Herzegovina; BGR - Bulgaria; HRV - Croatia; EST-Estonia; FYRM - FYR Macedonia; HUN - Hungary; KGZ - Kyrgyz Republic; LTU - Lithuania; MDA - Moldova; MNG - Mongolia; POL - Poland; ROM - Romania; SRB – Serbia; SVK - Slovak Republic; SVN - Slovenia; TUR - Turkey; UKR - Ukraine; UZB – Uzbekistan;

**Pearson product moment Correlation Coefficient

***Spearman rank correlation coefficient

Table 2. Efficiency reference set (corresponding benchmarks) for Lithuania from 1998 to 2007

Year	Evrs	ERS – i.e., Benchmark contribution to target formation							
1998	2.88783	0.320	ALB	0.138	BIH	0.516	HRV	0.026	POL
1999	2.66499	0.091	ALB	0.100	HRV	0.634	EST	0.174	HUN
2000	2.99076	0.158	BIH	0.683	EST	0.151	HUN	0.007	TUR
2001	2.29539	0.112	ALB	0.832	EST	0.022	HUN	0.033	TUR
2002	1.49050	0.190	EST	0.710	FYRM	0.095	HUN	0.005	TUR
2003	1.41467	0.907	EST	0.092	HUN	0.001	TUR		
2004	1.39458	0.855	EST	0.083	HUN	0.062	SLO		
2005	1.41467	0.879	EST	0.121	HUN				
2006	1.15952	0.407	EST	0.483	FYRM	0.111	HUN		
2007	1.06057	0.383	EST	0.515	FYRM	0.101	HUN		

Table 3. EBRD countries and their respective benchmarks from 1998 to 2007, based on DEA VRS results

	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	
ALB	Eff*	Eff	MNG	Eff	Eff	Eff	Eff	Eff	Eff	Eff	**ALB**
ARM	ALB	ALB	MNG	MNG	ALB	MNG	EST	MNG	FYRM	Eff	**ARM**
AZE	ALB	MNG	MNG	ALB	MNG	MNG	MNG	MNG	EST	ALB	**AZE**
BLR	ALB	MNG	MNG	MNG	ALB	EST	EST	EST	HUN	HUN	**BLR**
BIH	Eff	Eff	Eff	ALB	ALB	EST	EST	EST	EST	ALB	**BIH**
BGR	ALB	MNG	MNG	ALB	HUN	HUN	HUN	HUN	HUN	HUN	**BGR**
HRV	Eff	Eff	MNG	ALB	ALB	EST	EST	EST	HUN	EST	**HRV**
EST	BIH	Eff	Eff	Eff	Eff	Eff	Eff	Eff	Eff	Eff	**EST**
FYRM	BIH	EST	EST	ALB	Eff	Eff	Eff	Eff	Eff	Eff	**FYRM**
HUN	Eff	Eff	Eff	Eff	Eff	Eff	Eff	Eff	Eff	Eff	**HUN**
KGZ	ALB	Eff	MNG	ALB	MNG	MNG	MNG	MNG	MNG	Eff	**KGZ**
LTU	HRV	EST	EST	EST	FYRM	EST	EST	EST	FYRM	FYRM	**LTU**
MDA	ALB	ALB	MNG	MNG	ALB	EST	EST	EST	FYRM	ALB	**MDA**
MNG	Eff	Eff	Eff	Eff	Eff	Eff	Eff	Eff	Eff	Eff	**MNG**
POL	Eff	Eff	Eff	Eff	Eff	TUR	Eff	Eff	Eff	Eff	**POL**
ROM	HRV	HRV	HUN	ALB	ALB	HUN	HUN	HUN	HUN	HUN	**ROM**
SRB	ALB	HRV	MNG	ALB	ALB	EST	HUN	HUN	FYRM	HUN	**SRB**
SVK	ALB	HRV	MNG	ALB	ALB	ALB	EST	EST	Eff	Eff	**SVK**
SVN	Eff	Eff	EST	EST	Eff	Eff	Eff	EST	EST	EST	**SVN**
TUR	Eff	Eff	Eff	Eff	Eff	Eff	Eff	Eff	Eff	Eff	**TUR**
UKR	TUR	MNG	MNG	TUR	HUN	HUN	TUR	POL	POL	POL	**UKR**
UZB	HRV	ALB	MNG	ALB	ALB	EST	EST	EST	FYRM	ALB	**UZB**

Eff - country was found to be efficient in observed year

Table 4. EBRD countries and their respective benchmarks from 1998 to 2007, based on DEA CRS results

	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	
ALB	Eff	Eff	MNG	Eff	Eff	Eff	EST	Eff	Eff	Eff	**ALB**
ARM	ALB	ALB	MNG	MNG	ALB	HUN	EST	EST	HUN	HUN	**ARM**
AZE	ALB	MNG	MNG	MNG	TUR	TUR	EST	EST	ALB	HUN	**AZE**
BLR	ALB	MNG	MNG	MNG	ALB	HUN	EST	EST	HUN	HUN	**BLR**
BIH	Eff	Eff	HUN	ALB	ALB	HUN	EST	EST	EST	HUN	**BIH**
BGR	ALB	MNG	MNG	ALB	ALB	HUN	EST	ALB	ALB	ALB	**BGR**
HRV	Eff	Eff	MNG	ALB	EST	HUN	EST	EST	EST	HUN	**HRV**
EST	HRV	Eff	MNG	HUN	Eff	HUN	Eff	Eff	Eff	Eff	**EST**
FYRM	HRV	EST	MNG	ALB	EST	HUN	EST	EST	HUN	HUN	**FYRM**
HUN	Eff	Eff	Eff	Eff	Eff	Eff	EST	Eff	Eff	Eff	**HUN**
KGZ	ALB	MNG	MNG	MNG	ALB	HUN	EST	EST	HUN	HUN	**KGZ**
LTU	HRV	EST	MNG	HUN	EST	HUN	EST	EST	EST	HUN	**LTU**
MDA	ALB	MNG	MNG	MNG	ALB	HUN	EST	EST	HUN	HUN	**MDA**
MNG	ALB	Eff	Eff	Eff	ALB	HUN	EST	EST	HUN	ALB	**MNG**
POL	Eff	HUN	MNG	ALB	ALB	HUN	EST	EST	EST	EST	**POL**
ROM	ALB	ALB	MNG	ALB	ALB	ALB	EST	ALB	ALB	ALB	**ROM**
SRB	ALB	ALB	MNG	ALB	EST	HUN	EST	EST	HUN	HUN	**SRB**
SVK	HUN	ALB	MNG	ALB	ALB	ALB	EST	ALB	ALB	Eff	**SVK**
SVN	Eff	BIH	HUN	HUN	HUN	Eff	Eff	EST	EST	SVK	**SVN**
TUR	Eff	Eff	Eff	Eff	Eff	Eff	EST	EST	HUN	HUN	**TUR**
UKR	ALB	MNG	MNG	MNG	ALB	HUN	EST	ALB	ALB	ALB	**UKR**
UZB	ALB	MNG	MNG	MNG	ALB	HUN	EST	EST	HUN	HUN	**UZB**

Eff - country was found to be efficient in observed year

Table 5. CB Matrix in the case of DEA with VRS

VRS	ALB	ARM	AZE	BLR	BIH	BGR	HRV	EST	FYRM	HUN	KGZ	LTU	MDA	MNG	POL	ROM	SRB	SVK	SVN	TUR	UKR	UZB	MAX	Final CB proposal
ALB	9	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	1	Eff
ARM	3	1	0	0	0	0	0	1	1	0	0	0	0	4	0	0	0	0	0	0	0	0	4	MNG
AZE	3	0	0	0	0	0	0	1	0	0	0	0	0	6	0	0	0	0	0	0	0	0	6	MNG
BLR	2	0	0	0	0	0	0	3	0	2	0	0	0	3	0	0	0	0	0	0	0	0	3	BLR/MNG
BIH	3	0	0	0	3	0	0	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4	EST
BGR	2	0	0	0	0	0	0	0	0	6	0	0	0	2	0	0	0	0	0	0	0	0	6	HUN
HRV	2	0	0	0	0	0	2	4	0	1	0	0	0	1	0	0	0	0	0	0	0	0	4	EST
EST	0	0	0	0	1	0	0	9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	9	Eff
FYRM	1	0	0	0	1	0	0	2	6	0	0	0	0	0	0	0	0	0	0	0	0	0	6	Eff
HUN	0	0	0	0	0	0	0	0	0	10	0	0	0	0	0	0	0	0	0	0	0	0	10	Eff
KGZ	2	0	0	0	0	0	0	0	0	0	2	0	0	6	0	0	0	0	0	0	0	0	6	MNG
LTU	0	0	0	0	0	0	1	6	3	0	0	0	0	0	0	0	0	0	0	0	0	0	6	EST
MDA	4	0	0	0	0	0	0	3	1	0	0	0	0	2	0	0	0	0	0	0	0	0	4	ALB
MNG	0	0	0	0	0	0	0	0	0	0	0	0	0	10	0	0	0	0	0	0	0	0	10	Eff
POL	0	0	0	0	0	0	0	0	0	0	0	0	0	0	9	0	0	0	0	1	0	0	9	Eff
ROM	2	0	0	0	0	0	2	0	0	6	0	0	0	0	0	0	0	0	0	0	0	0	6	HUN
SRB	3	0	0	0	0	0	1	1	1	3	0	0	0	1	0	0	0	0	0	0	0	0	3	ALB/HUN
SVK	4	0	0	0	0	0	1	2	0	0	0	0	0	1	0	0	0	1	0	0	0	0	4	ALB
SVN	0	0	0	0	0	0	0	5	0	0	0	0	0	0	0	0	0	0	5	0	0	0	5	EST
TUR	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	10	0	0	10	Eff
UKR	0	0	0	0	0	0	0	0	0	2	0	0	0	2	3	0	0	0	0	3	0	0	3	POL/TUR
UZB	4	0	0	0	0	0	1	3	1	0	0	0	0	1	0	0	0	0	0	0	0	0	4	ALB
SUM	35	0	0	0	2	0	6	35	0	20	0	0	0	30	0	0	0	0	0	4	0	0		
Rank	1				6		4	1		3				2						5				

Table 6. CB Matrix in the case of DEA with CRS

CRS	ALB	ARM	AZE	BLR	BIH	BGR	HRV	EST	FYRM	HUN	KGZ	LTU	MDA	MNG	POL	ROM	SRB	SVK	SVN	TUR	UKR	UZB	MAX	Final CB proposal
ALB	8	0	0	0	0	0	0	1	0	0	0	0	0	1	0	0	0	0	0	0	0	0	8	Eff
ARM	3	0	0	0	0	0	0	2	0	3	0	0	0	2	0	0	0	0	0	0	0	0	3	ALB/HUN
AZE	2	0	0	0	0	0	0	2	0	1	0	0	0	3	0	0	0	0	0	2	0	0	3	MNG
BLR	2	0	0	0	0	0	0	2	0	3	0	0	0	3	0	0	0	0	0	0	0	0	3	HUN/MNG
BIH	2	0	0	0	2	0	0	3	0	3	0	0	0	0	0	0	0	0	0	0	0	0	3	EST/HUN
BGR	6	0	0	0	0	0	0	1	0	1	0	0	0	2	0	0	0	0	0	0	0	0	6	ALB
HRV	1	0	0	0	0	0	2	4	0	2	0	0	0	1	0	0	0	0	0	0	0	0	4	EST
EST	0	0	0	0	0	0	1	6	0	2	0	0	0	1	0	0	0	0	0	0	0	0	6	Eff
FYRM	1	0	0	0	0	0	1	4	0	3	0	0	0	1	0	0	0	0	0	0	0	0	4	EST
HUN	0	0	0	0	0	0	0	1	0	9	0	0	0	0	0	0	0	0	0	0	0	0	9	Eff
KGZ	2	0	0	0	0	0	0	2	0	3	0	0	0	3	0	0	0	0	0	0	0	0	3	HUN/MNG
LTU	0	0	0	0	0	0	1	5	0	3	0	0	0	1	0	0	0	0	0	0	0	0	5	EST
MDA	2	0	0	0	0	0	0	2	0	3	0	0	0	3	0	0	0	0	0	0	0	0	3	MNG
MNG	3	0	0	0	0	0	0	2	0	2	0	0	0	3	0	0	0	0	0	0	0	0	3	ALB
POL	2	0	0	0	0	0	0	4	0	2	0	0	0	1	1	0	0	0	0	0	0	0	4	EST
ROM	8	0	0	0	0	0	0	1	0	0	0	0	0	1	0	0	0	0	0	0	0	0	8	ALB
SRB	3	0	0	0	0	0	0	3	0	3	0	0	0	1	0	0	0	0	0	0	0	0	3	ALB/EST/HUN
SVK	6	0	0	0	0	0	0	1	0	1	0	0	0	1	0	0	0	1	0	0	0	0	6	ALB
SVN	0	0	0	0	1	0	0	2	0	3	0	0	0	0	0	0	0	1	3	0	0	0	3	HUN
TUR	0	0	0	0	0	0	0	2	0	2	0	0	0	0	0	0	0	0	0	6	0	0	6	Eff
UKR	5	0	0	0	0	0	0	1	0	1	0	0	0	3	0	0	0	0	0	0	0	0	5	ALB
UZB	2	0	0	0	0	0	0	2	0	3	0	0	0	3	0	0	0	0	0	0	0	0	3	HUN/MNG
SUM	50	0	0	0	1	0	3	47	0	44	0	0	0	31	0	0	0	0	0	2	0	0		
Rank	1				7		5	2		3				4						6				