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Efficiency Assessment of Bosnia-Herzegovina Water Companies

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Abstract

This paper is aimed at addressing the issue of municipal water companies in Bosnia-Herzegovina. It demonstrates that data envelopment analysis (DEA) could be a useful tool in assessing the relative efficiencies of water supply systems. The results obtained by applying DEA are additionally compared with the resultants achieved by employing corrected ordinary least squares (COLS).

The principal aim of this paper is to show that is worth assessing the efficiency improvements that could result from the better use of all inputs. Despite the severe scarcity of data for the BiH water sector, collected data allowed us to develop a DEA model with a set of inputs (number of connections, number of workers, and other costs) and outputs (water billed) as required in the water sector empirical literature.

As a first step in the efficiency analysis in BiH the research could serve as a benchmark against which future analysis of water utilities can be measured. Additionally, it could provide policy-makers with comparable quantitative evidence on the effectiveness of water utilities with the aim of focusing them in rebuilding the water sector infrastructure, beginning with the most inefficient municipalities to minimize huge water losses.

Keywords

Water, Efficiency, Benchmarking, Bosnia-Herzegovina

1. Introduction

The initial World Bank estimates of bringing the BiH water services in line with the service level of EU Member Countries was around 1 billion USD through the year 2030. Estimates of the Office of the High Representative and EU Special Representative reveal that the total investment sum in the water supply and sanitation sector will be much larger than the World Bank estimate amounting to around 6.9 billion USD for achieving full compliance with all relevant EU standards.

On its EU way, BiH will be obliged to follow the Directive 2000/60/EC stating that all costs incurred by the water utility should be covered by revenues and estimates of relevant investment including forecasts of such investments. This principle of cost recovery for water supply is not understood adequately in BiH and neither included into the legislation for local public authorities.

This paper is intended to deal with the issue of how to improve the efficiency of the BiH water industry in BiH through a better regulation based on an efficiency assessment of the water utilities. Additionally, it will provide policy-makers and financial institutions with comparable quantitative evidence on the effectiveness of water utilities with the aim of focusing them in rebuilding the water sector infrastructure components, beginning with the most inefficient municipalities in order to minimize huge water losses.

The paper is organised as follows. The second part presents the institutional and regulatory background and simple ratio analysis. The third part deals with mathematical and statistical modelling, putting emphasis on COLS and DEA. The fourth part applies DEA and COLS to recent data from the B-H water industry and discuss some striking differences in their efficiency results. Summary and concluding comments are provided in the fifth part.

2. Institutional and regulatory background

In BiH, responsibility for water service provision is decentralised and rests with municipalities. There are some 130 municipal water companies in BiH serving the needs of 3.8 million of inhabitants.

The municipally owned water companies operate as formally autonomous organisations, separated administratively and financially from the municipal government. However, devolution of responsibility to company level is substantially very weak. They are not empowered and enabled to function as efficient service providers. By being obliged on overemployment, artificially depressed tariffs, following political rather than economic criteria in signing up contracts and undertaking investments etc. they spiral costs, accrue losses and weaken quality of service.

Due to lack of financial resources for investment and maintenance and inefficient water management in most of water companies, water coverage and service quality are unsatisfactory. The water service quality has been deteriorating markedly for at least the last twenty years. More than 15 years after the Dayton Peace Agreement, access to water services has been unacceptably low or unreliable.

Water loss levels in the South East Europe are highest in Europe ranging from 48 to 63 percent, except for Croatia (where they reach 19) (see Figure 1). High level of the water losses of 61 % for 2007 BiH indicates worn-out water pipe network and poor system management.

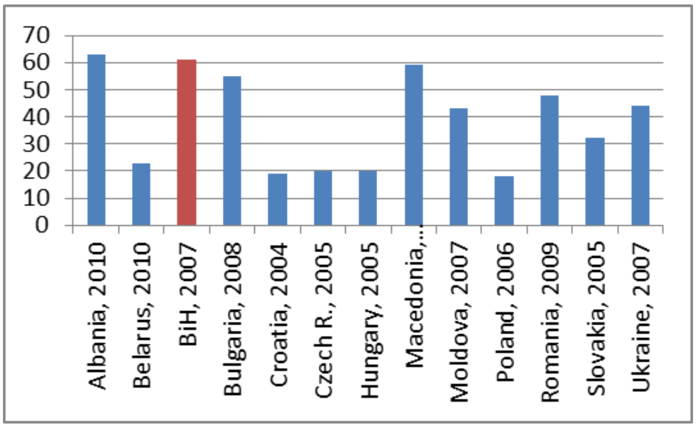

Figure 1: Water losses (in %), selected
European transition countries

The simplest way to perform comparisons across countries is to use some overall performance indicators e.g. to use indicators such as number of employees per connection (see Figure 2).

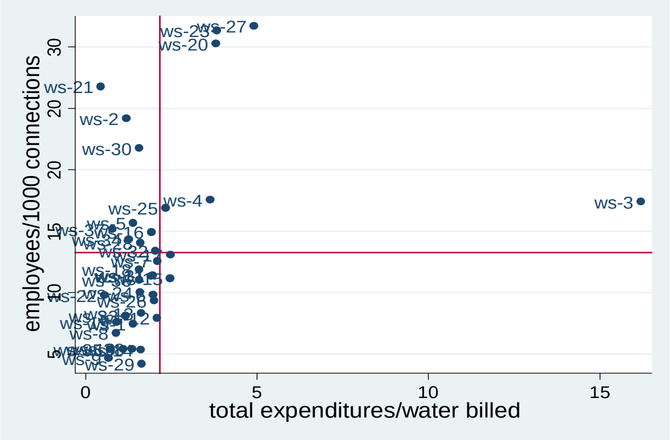

Figure 2: BiH Water Suppliers: Total expenditures, connections, employees, and water billed, 2000-09

A ratio of 2-3 employees per 1000 water connections is found in an efficient water supplier. A ratio of 6.6 and 3.3 workers per 1000 connections is found in Central America and Latin America respectively (Corton and Berg, 2009). At the same time, the ratio for the BiH water suppliers equals 13.4.

Salary expenses of the BiH water suppliers represent 37.7 % of total costs which is in line with for instance Peru's water supply industry (Corton, 2003), but it is almost twice as Germany's water supply industry (20.6 %). It is obvious that excess staff contribute to the low productivity of the BiH water suppliers (see Figure 3).

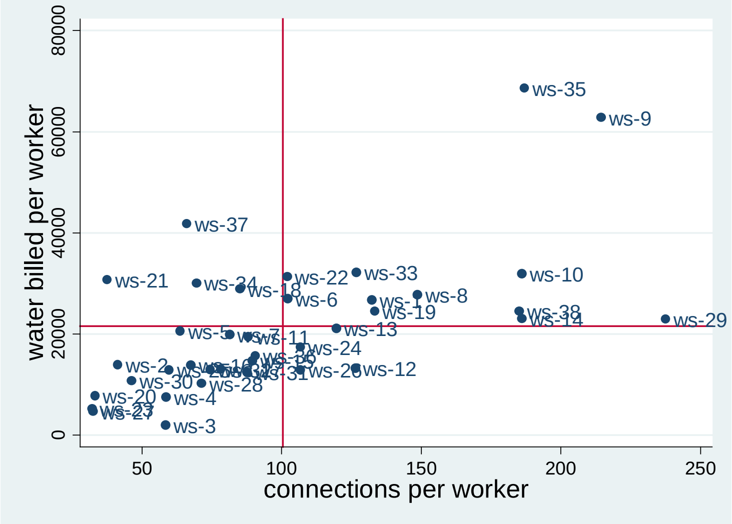

Figure 3: BiH Water Suppliers: Water billed and connections per employees, 2000-09

However, core indicators can often be insufficient in the case of countries comparison or even misleading in comparing various firms within a country. To assess properly the relative efficiency of a water supplier, a benchmark or an efficiency frontier is required to put it into appropriate efficiency groups. When setting a target for efficiency improvements and input reductions, it is necessary to analyse the joint effect of all inputs rather than the effects of a specific input.

3. Conceptual Framework and Methodology

3.1. Data envelopment analysis (DEA)

Data envelopment analysis (DEA) has the advantage that it can accommodate multiple inputs and multiple outputs, and produce information on peer utilities for each of the inefficient utilities. This research employs an input oriented DEA model. It is common practice to use an input orientation in analyses of water supply utilities because the firms are generally required to supply services to a fixed geographical area, and hence the output vector is essentially fixed. The question is how to minimize inputs relative to a given output. The model can be briefly described as follows (Coelli and Perelman, 1999).

The input oriented production frontier may be defined on the input set, L(y), as

$$D_I\ (x, y) = \max\ \{r:(x/p) \in L(y)\},$$

where the input set L(y) represents the set of all input vectors, $x \in R^{k,}$ which can produce the output vector, $y \in R^k$. That is,

$$L(y) = \{x \in R^k : x \text{ can produce } y\},$$

D_I (x, y) is non-decreasing, positively linearly homogenous and concave in x, and increasing in y. The distance function D_I (x, y) will take a value ≥ 1 if the input vector, x, is an element of the feasible input set L(y), i.e. $D_I\ (x, y) \geq 1$ if $x \in L(y)$. The distance function will take a value of unity if x is located on the inner boundary of the input set.

The issue of what may be regarded as adequate indicators of outputs and inputs is a complicated exercise. The outcome of DEA analysis is sensitive to the selection of the variables for inputs and outputs and to the application of different DEA methods. DEA has been developed in a non-statistical framework, so hypothesis testing is problematic. It is accordingly decided to supplement DEA analysis with the COLS analysis.

3.2. Corrected ordinary least squares (COLS)

The production model can be written:

$$Y_i = bX_i + \upsilon_i$$

where Y_i is total production, X_i is a vector of output quantities and input quantities, b is a vector of unknown parameters to be estimated. The random component, υ_i represents factors outside the control of the firm (also called measurement error) and factors under the control of the firm (also called inefficiency).

Output is measured by the yearly water billed, and connections (a proxy for capital stock), labour expenses and other operational costs.

$$WB = a + b_{con}CON_{it} + b_{lb}LB_{it} + b_{oe}OE + \gamma T + e_{it}$$

where WB, CON, LB and OE represent the logarithms of the water delivered, the number of connections, the labour expenses and the other expenses; coefficients b_{con}, b_{lb}, b_{oe} are the output elasticities of inputs, and the sum of them gives us the elasticity of scale, which indicates the returns to scale. There is also the variable T added here to measure the Hicks-neutral technical change, i.e. to capture possible technology shifts explaining technological changes.

The composite error term, $e_{it,}$ captures all deviations from the production frontier, including factors under the control of the firm (inefficiency) (Estache and Kouassi, 2002).

Upon estimating the production function using ordinary least square (OLS), a procedure that allows to generate adjusted OLS scores that are confined with the (0-1) span is conducted. The water utility with highest residual is treated as having efficiency score of 1 and other utilities' predicted output calculated on the basis of this shifted equation, COLS. The OLS estimate of the intercept parameter is adjusted (by adding the largest OLS residual to it) so that the function no longer passes through the centre of the observed points but bounds them from above. The distance measure for the ith water supplier is then calculated as the exponent of the (corrected) OLS residual (Coelli and Perelman, 1999; Tupper and Resende, 2004; Cubbin and Tzanidakis, 1998).

$$Efficiency\ score = \frac{actual\ output - predicted\ output}{predicted\ output}$$

4. Results from the application of RA and DEA to the BiH water industry

4.1 Data

The data is collected from a survey of 130 water suppliers in BiH. The list of collected data comprises: amount of water billed (in m^3 per year), amount of water collected (in m^3 per year), amount of residential water billed (in m^3 per year), amount of water non-residential billed (in m^3 per year), number of connections, number of metered connections, number of residential metered connections, number of metered non-residential connections, length of mains (in km), length of network (in km), resident population, total number of staff, average number of staff (in the hours of work), labour expenses (in BAM), value of network (in BAM), energy expenditure (in BAM), chemical expenditure (in BAM) and total costs (total annual cost of financing and operating the firm, in BAM).

However, only a subset of variables could be used for the analysis because not all water utilities report all variables or all years. For instance, it was not possible to use the length of mains or network length as an indicator of capital since data was missing or was not reliable for many utilities. A number of observations was reduced to allow the data set to be comparable for all utilities. Further, since BiH has a huge problem with water loss due to various reasons, we used water billed as the output, not water delivered.

The following set of output and input indicators was set: amount of water billed (in m^3 per year), number of connections, total number of staff, labour expenses (in BAM), energy expenditure (in BAM), chemical expenditure (in BAM), total costs (total annual cost of financing and operating the firm, in BAM) and other costs (total costs minus labour expenses, energy expenditures and chemical expenditure in BAM).

We estimated the production frontier for a sample of 38 water suppliers covering the 2000-09 period. From a statistical viewpoint, it yields an unbalanced panel of water utilities as representative of the total of 130 water utilities in BiH. Two utilities are not included in this research since they are too big (Sarajevo) or too small (Ravno) in, say, terms of workers (1030 and 2, respectively). If included in the panel, the results would be distorted as the research methods applied are susceptible to the influence of outliers (Coelli and Perelman, 1999).

Table 1: Sample summary statistics

Variables	Obs	Mean	Std. Dev.	Min	Max
water billed (in m^3)	314	1128761	1541237	4120	8230000
number of connections	314	4623.484	4883.015	180	24485
number of employees	314	49.22299	47.39509	4	308
other costs (in BAM)	314	860822.6	1146393	36606	7660069

4.2. Results

In order to ensure comparability of the research methods the COLS was used to identify the variables for inclusion. It was started by regressing output on a number of potentially important explanatory factors or output drivers and tested the model aiming to arrive at a statistically valid and economically meaningful parsimonious specification. The names of the variables together with their roles in COLS and DEA are as shown in Table 2.

By dropping one by one the statistically insignificant variables whilst ensuring that the model passed a number of other diagnostic tests for panel data we got

$$\underset{(7.18)}{\mathrm{Ln(WB)} = 6.16} + \underset{(7.69)}{0.58 \ln(\mathrm{CON})} + \underset{(4.30)}{0.33\ln(\mathrm{LB})} + \underset{(3.07)}{0.10\ln(\mathrm{OC})} \quad (1)$$

where *t*-ratios are given in parentheses.

Table 2: Variables in COLS and DEA

Name	Description	Role in COLS	Role in DEA
WDEL	Volume of water billed (m^3 per year)	Dependent	Output
CONS	Number of water connections	Explanatory	Input
LB	Number of employees	Explanatory	Input
OC	Expenditures minus labour energy and chemical costs (in BAM)	Explanatory	Input

The dependent variable in this regression model is the volume of water billed (measured annually in m^3, WB), and the independent variables are the number of connections (CON), the number of employees, LB) and the other costs (total costs reduced for labour costs, energy costs and chemical costs in BAM (1EUR=2BAM; OC).

As described in 3.2. the aim was to include the time trend (T) as a proxy for technological changes and got this specification of a water production function:

$$\underset{(7.18)}{\mathrm{Ln(WDEL)} = 4.37} + \underset{(10.67)}{0.80 \ln(\mathrm{CON})} + \underset{(4.75)}{0.35\ln(\mathrm{LB})} + \underset{(3.44)}{0.10\ln(\mathrm{OC})} - \underset{(-3.89)}{0.01T} \quad (2)$$

The water industry is generally characterized by a slowly changing technology. As previously mentioned, the BiH water industry suffers from underinvestment. Accordingly, it is not surprising that the variable T in (2) is not of significant importance in explaining the production function.

The model (1) suggests that, at least for this data set, the main production driver (WB) is the number of water connections (CON) followed by the number of employees (LB).

The logarithmic specification is consistent with a standard multiplicative production function and enables the direct estimation of elasticities. The model appears to be a "good fit" with $R^2 = 0.833$. All the variables are statistically significant at 5% and they have their expected signs. The sum of the coefficients on the two output variables reflects, at a value of 1.01, i.e. the absence of scale economies.

The DEA specification was based on the regression model, using the same variables, except that, in accordance with normal practice, none of the variables was entered in a logarithmic form. The DEA was performed in "input shrinkage" mode, and two specifications were applied: standard DEA using constant returns (DEAcrs) to scale and a variable returns (DEAvrs) version.

The panel is treated as a single cross-section (each firm in each year is considered as an independent observation) and pool the observations. A single frontier is computed and the relative efficiency of each water supplier in each year is calculated by reference to this single frontier. In short, the DEA models are based on pooled data (Berg and Lin, 2008).

The Table 3 shows the average scores and rankings obtained from the COLS and the DEA under both constant and variable returns, ranked from most efficient (top row) to least efficient. The third and fourth columns of Table 3 show the DEA results. DEA scores take values from zero (least efficient) to one (most efficient). The last columns of Table 3 give the company rankings yielding almost the same rankings.

As seen from the table 3, it was found that the rankings based on the COLS method are almost completely the same like the ones based on DEA method. However, it was also found that the DEA yields lower efficiency scores than RA does. For instance, the COLS average efficiency score of 90 % means that the water suppliers could decrease their inputs by about 10 %, while still maintaining their output levels.

Table 3: RA and DEA efficiency results, 2009-2000

Company shorthand	RA(COLS) score	DEA CRS score	DEA VRS score	RA ranking	DEA CRS ranking
1	2	3	4	5	6
ws-1	0.908714	0.471780	0.594739	14	14
ws-2	0.922646	0.431086	0.462391	10	15
ws-3	0.718872	0.048976	0.266714	38	38
ws-4	0.852793	0.194970	0.266068	35	35
ws-5	0.926297	0.526460	0.501943	9	10
ws-6	0.919704	0.520541	0.455895	11	11
ws-7	0.909540	0.427320	0.413352	13	16
ws-8	0.913629	0.580557	0.834370	12	9
ws-9	0.951313	0.913601	0.987598	4	4
ws-10	0.906367	0.481079	0.770032	16	13
ws-11	0.902771	0.404888	0.374191	17	18
ws-12	0.860655	0.250767	0.537939	34	34
ws-13	0.895461	0.374721	0.503373	18	20
ws-14	0.883026	0.363186	0.775284	26	21
ws-15	0.881865	0.307721	0.380454	27	27
ws-16	0.892650	0.337743	0.323527	20	24
ws-17	0.883079	0.303652	0.387617	25	28
ws-18	0.906611	0.496965	0.687225	15	12
ws-19	0.927677	0.609310	0.444946	8	8
ws-20	0.876766	0.265163	0.151851	29	30
ws-21	0.997752	0.993701	0.818328	1	1
ws-22	0.941545	0.783779	0.932988	6	5
ws-23	0.851343	0.186907	0.180218	36	36
ws-24	0.891539	0.348303	0.495811	21	22
ws-25	0.891273	0.324638	0.267452	23	25
ws-26	0.868791	0.257308	0.482486	33	32
ws-27	0.840599	0.165250	0.136860	37	37
ws-28	0.872700	0.255977	0.519583	31	33
ws-29	0.874993	0.376856	0.973316	30	19
ws-30	0.931454	0.658859	0.760124	7	7
ws-31	0.895053	0.314959	0.414899	19	26
ws-32	0.870526	0.264194	0.385208	32	31

ws-33	0.879367	0.298445	0.381943	28	29
ws-34	0.941984	0.701342	0.448200	5	6
ws-35	0.958104	0.985054	0.996844	3	3
ws-36	0.891337	0.343651	0.505652	22	23
ws-37	0.966260	0.992974	0.664905	2	2
ws-38	0.891240	0.426769	0.808195	24	17

Alternatively, the DEA average efficiency score of 45 % means that the water suppliers could decrease their inputs by about 55 %, while still maintain their output levels.

5. Conclusions

In spite of their deficiencies, partial productivity indicators clearly states that the BiH water supply system has much weaker performance than those in other countries at a similar stage of development. It is characterised by serious problems, including a high level of unaccounted-for water and excess staff.

The relative efficiency of water suppliers based on the DEA and COLS was considered. An inherent problem of COLS is that it requires specification of functional form and so risks inappropriate specification. One of disadvantages of both methods is that they attribute all deviation to inefficiency. Therefore, the results of this research provide preliminary evidence on the efficiency of the BiH water sector in terms of the performance of water companies.

Despite the topic's importance, only a few papers world wide examine the sensitivity of efficiency and rankings based on different methods (Berg and Lin, 2008). It is observed that the present paper is the first in B-H to investigate efficiency comparisons across service providers. A major contribution from this research could be pointing towards additional efforts and a higher level of coordination for improving data collection procedures in B-H. As additional data become available, analysts will be able to conduct much more thorough analyses of sector performance.

The research demonstrated that the BiH policy makers should focus on reforming the water system beginning with the most DEA/COLS inefficient municipalities in order to minimize water losses. A majority of the water supply utilities do not seem to be operating at the minimum level of resource input. It gave a contribution to awareness of making radical changes in water sector in having it closer to the EU acquis communitaire (the Water Framework Directive (WFD).

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