Incorporating the Financial Variables Using Two Step DEA Efficiency Evaluation: Case Study of Slovak Gynaecology Departments

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Abstract: *One of the available approach to improve performance of healthcare facilities is Data envelopment analysis - DEA. This method with its variations and supplementary methods, such as regression models, is widely used in many countries of the world. Financial indicators are often included in DEA models. We excluded them from DEA analysis and we included them into second step of two step DEA. This has helped us to determine the impact of these financial indicators on efficiency of gynaecological departments in 8 regions of Slovak republic. We have selected following financial variables: Material costs, Operational Costs and Total revenues. Two step DEA analysis, using truncated regression, shows that these indicators are not suitable to determine efficiency of selected departments.*

Key words: DEA, departments, efficiency, truncated regression, two step DE

JEL codess: H43, C52, G17

1. Introduction

The healthcare system consists of a comprehensive set of entities, activities and processes and covers a wide range of participants, where each of them brings different set of needs, priorities and evaluation criteria. On the issue of efficiency evaluation is paid attention mainly in profit sector. The closer look from the side of public hospitals shows the less use of financial indicators in the process of efficiency evaluation. Public hospitals don´t strive for profit achievement, but it does exist other aspects within those they have an interest for efficiency evaluation. Yusefzadeh and Ghaderi (2013) maintain, that the efficiency and budgeting of public hospitals is dependent on their ability to measure and economic efficiency. Villalobos et al. (2016) performed the study in 193 public hospitals in Chile and they found that the main motivator for measurement economic efficiency in these organizations was the pressure and requirements from the side of stakeholders. Effort to obtain additional financial resources with aim to improve

provision of services was also important motivator. Similar study performed also Li and Dong, S., (2015).

They presented the set of measuring and benchmarking efficiency of public hospitals in Tianjin. One of the reasons was the possibility to influence the attitude of society, what is linked with the fact that measurement efficiency can serve as effective marketing tool. Ineveld et al. (2015) described the usefulness of measurement efficiency mainly in period of restructuralization. With the aim of improvement and retention of services quality can be measurement effective tool. The question is what should be measured? Indicators of economic efficiency are inputs, outputs and influence variables. These indicators are derived from private sector, but they are usable also in conditions of public hospitals.

2. Methodology

If we want to quantify the influence of selected financial measures we first need to choose proper methods for this purpose.

2.1. Methods

To check if there is influence of financial variables on efficiency of selected departments we have to first compute the efficiency scores using CCR output oriented DEA model according to following Cooper´s et al. (2007) input oriented model just as a reciprocal value 1/ θ.

$$\max_{u,v} \theta = \frac{u_1 y_{1o} + u_2 y_{2o} + \cdots + u_s y_{so}}{v_1 x_{1o} + v_2 x_{2o} + \cdots + v_m x_{mo}} \tag{1}$$

$$\text{while } \frac{u_1 y_{1j} + \cdots + u_s y_{sj}}{v_1 x_{1j} + \cdots + v_m x_{mj}} \leq 1 \quad j = 1,2, \dots, n$$

$$v_1, v_2, \dots, v_m \geq 0$$

$$u_1, u_2, \dots, u_s \geq 0.$$

For better understanding of this method see Cooper et al. (2007).

Then we need to use regression to check the influence of explanatory variables on computed efficiency. For this purpose is often used (see Flokou et al. (2016); Gholami et al. (2015); Li and Dong (2015); Araújo et al. (2013); Kounetas a Papathanassopoulos (2013); Mitropoulos et al. (2012); Varabyova and Shreyogg (2013); Chaabouni a Abednnadher (2012); Blank a Hulst (2010); Blank and Valdmanis (2010)) truncated regression. To get consistent estimates of regression model we need to use method/algorithm proposes by Simar and Wilson (2007) which by using the double bootstrap mechanism provides bias corrected DEA efficiencies suitable for using in regression models. As we mentioned, we will use truncated regression model which has form:

$$\delta_i = z_i \beta + \varepsilon_i, i = 1, \dots, n \tag{2}$$

where δ_i is DEA efficiency score of selected DMU, z_i is set of explanatory variables, β are regressors and ε_i is standard error. If we use algorithm proposed by Simar a Wilson (2007) truncated regression model will have following form:

$$\widehat{\delta_i}^{BC} \approx z_i\beta + \varepsilon_i, i = 1, \dots, n, \text{ where } \varepsilon_i \geq 1 - z_i\beta \quad (3)$$
$$\text{and } \varepsilon_i \sim N(0, \sigma_\varepsilon^2)$$

where $\widehat{\delta_i}^{BC}$ is bias corrected efficiency using the second algorithm proposed by Simar and Wilson (2007).

Data will be truncated left to point 1, because output efficiencies are in interval 1 to infinity. The main idea of this regression is that both, explanatory and dependent variables under this boundary are latent.

3. Data and variables

For the purpose of our study we chose as the object of research gynaecology departments of secondary health care providers. According to the data provided by the National centre for health care information (NCHI) we chose to evaluate the efficiency between 8 regions in Slovakia according to NUTS 3 classification. Data were provided for 6 years (2009 till 2014). We selected Window approach, which means that department in selected year will be handled as unique DMU. As input variables for DEA CCR model we chose according to the most used variables presented in Hadji et al. (2014) and according to the availability of variables provided by NCHI following variables: *Number of Beds* – average value in selected year, *Average Length of Stay, Number of Doctors, Number of Nurses* – both average numbers in selected year. As output variables we chose *Number of Inpatients* and *Bed Occupancy Rate* in %. As explanatory variables we selected following financial variables: *Material Costs, Operational Costs* and *Total Revenues.* Then we constructed panel with 48 DMUs.

4. Results

If we want to analyse efficiency in gynaecological departments we need to prepare data for purpose of this analysis. Table no. 1 shows the basic descriptive statistical indicators of input and output variables of DEA CCR output model. Data were provided by National centre for health care information. We do not have permission to show whole dataset so we chose this data presentation.

Table 1: Descriptive statistics of inputs and outputs of model DEA

Statistic	Number of Beds	ALOS	Number of Doctors	Number of Nurses	Number of Inpatients	Bed Occupancy
N	48	48	48	48	48	48
Mean	326.81	4.69	54.05	174.05	15,613.38	62.81
St. dev.	64.45	0.45	14.74	38.87	3,209.50	5.42
Min	242	4.00	33.43	107.09	10,895	49.10
Max	451	5.50	81.90	262.50	22,056	71.50

Source: Own processing according to data provided by NCHI

During selected period, there were in average 327 beds. In case of gynaecological department belongs to one doctor an average of 6 beds. The average number of nurses were almost three times higher than that of the number of doctors. Average length of stay was about four and a half days, with a minimum value recorded during each year in these regions has been four days and a maximum of 5.5 days. Bed occupancy, in average, was at nearly 63%. Bed occupancy minimum value was recorded in the Banska Bystrica region, there remained unused every other bed. On the contrary, the highest values were recorded in the Bratislava region. Table no. 2 shows the descriptive statistics of explanatory variables.

Table 2: Descriptive statistics - explanatory variables

Statistic	Material Costs	Operational costs	Total Revenues
N	48	48	48
Mean	905,332.50	447,592.70	7,799,875.00
St. Dev.	435,543.20	201,680.50	3,314,163.00
Min	408,992.00	193,114.00	3,752,557.00
Max	1,973,676.00	958,932.20	15,896,758.00

Source: Own processing according to data provided by NCHI

Material and operational costs were highest in the Bratislava region, by contrast, they were lowest in the Banska Bystrica region. Sales of individual departments were on average about € 7.8 million. The highest sales were recorded in Bratislava region, the lowest in Banska Bystrica region. In the table no. 3, there are results of efficiency evaluation.

Table 3: Results of efficiency evaluation

DMU	CCR_OUT	CCR_OUT_DB	CI_LB	CI_HB
BA14	1.0645	1.0855	1.0499	1.1062
BA13	1.1035	1.1254	1.0907	1.1456
BA12	1.0735	1.0909	1.0600	1.1063
BA11	1.1180	1.1402	1.1051	1.1571
BA10	1.0891	1.1172	1.0904	1.1373
BA09	1.0728	1.1049	1.0695	1.1363
TT14	1.1666	1.2003	1.1624	1.2337
TT13	1.1043	1.1289	1.0993	1.1513
TT12	1.0714	1.1018	1.0568	1.1308
TT11	1.0593	1.1041	1.0382	1.1439
TT10	1.0039	1.0437	0.9785	1.0808
TT09	1.0000	1.0870	0.9565	1.1726
TN14	1.0785	1.1119	1.0746	1.1401
TN13	1.0717	1.1080	1.0597	1.1431
TN12	1.2392	1.2847	1.2346	1.3229
TN11	1.2338	1.2814	1.2350	1.3262
TN10	1.1548	1.2002	1.1572	1.2387
TN09	1.0547	1.1010	1.0555	1.1449
NR14	1.0303	1.0587	1.0042	1.0869
NR13	1.0396	1.0697	1.0133	1.0989
NR12	1.0334	1.0646	1.0069	1.0953

DMU	CCR_OUT	CCR_OUT_DB	CI_LB	CI_HB
NR11	1.0501	1.0876	1.0421	1.1236
NR10	1.0062	1.0327	0.9805	1.0587
NR09	1.1065	1.1575	1.0683	1.2067
ZA14	1.1070	1.1463	1.1105	1.1844
ZA13	1.0269	1.0658	1.0224	1.1037
ZA12	1.0000	1.0623	1.0098	1.1213
ZA11	1.0000	1.0921	0.9325	1.1794
ZA10	1.0542	1.0938	1.0392	1.1323
ZA09	1.0000	1.0510	1.0008	1.1002
BB14	1.0674	1.0975	1.0711	1.1231
BB13	1.1743	1.2148	1.1607	1.2456
BB12	1.3290	1.3716	1.3203	1.4060
BB11	1.2657	1.3120	1.2637	1.3524
BB10	1.2468	1.2920	1.2233	1.3336
BB09	1.0000	1.0932	1.0404	1.1763
PO14	1.2584	1.2930	1.2568	1.3259
PO13	1.3071	1.3441	1.3064	1.3723
PO12	1.3706	1.4156	1.3497	1.4540
PO11	1.3814	1.4436	1.3698	1.5008
PO10	1.2852	1.3450	1.2792	1.3949
PO09	1.2264	1.2983	1.2270	1.3636
KE14	1.0000	1.0115	0.9895	1.0227
KE13	1.0181	1.0290	1.0043	1.0393
KE12	1.0000	1.0203	0.9681	1.0405
KE11	1.0368	1.0506	1.0297	1.0642
KE10	1.0302	1.0411	1.0083	1.0517
KE09	1.0711	1.0910	1.0483	1.1106

Source: Authors

Notes: BA – Bratislava region, TT – Trnava region, TN – Trencin region, NR – Nitra region, ZA- Zilina region, BB – Banska Bystrica region, PO- Presov region, KE, Kosice region; CCR_OUT – output oriented efficiency according to CCR DEA model, CCR_OUT_DB – efficiencies after second loop of S&W (2007) algorithm, CI_LB – confidence interval of bootstrapped efficiencies lower boundary, CI_UB – conf. interval upper boundary, $\alpha = 0.01$. 1st loop - 100 iterations, 2nd loop - 2000 iterations.

It should be mentioned, that only efficient DMUs are these with efficiency 1, other are inefficient, the higher number of efficiency score, the worse efficiency. This because of output orientation. Only 7 DMUs were efficient. Zilina region appears to be the most efficient region since it was efficient 3 times. Kosice region was efficient 2 times. In the second column, there are double bootstrapped efficiencies. As one can see, no DMU is efficient, this is because the values of original efficiencies were adjusted by stochastic error, so the efficiency worsened. Columns number 3 and 4 shows confidence intervals for these bootstrapped efficiencies at 0.01 significance level. This can help to check if there were for example significant increase or decrease of efficiency – there is no interject of intervals between selected years. This can be observed for example in case of Trencin region (TN09 – TN10) between years 2009 and 2010, the efficiency significantly worsened. Table no. 4 shows the results of truncated regression.

Table 4 on the next page.

Table 4: Regression model

		Dependent variable:
		CCR_OUT_DB
Intercept		1.3811 ***
		(0.0837)
Material Costs		1.7046e-07
		2.8807e-07
Operational Costs		-1.4255e-06 ***
		4.3696e-07
Total Revenues		2.0559e-08
		3.6691e-08
Sigma		0.1204 ***
		0.0210
Log Likelihood		58.412
R-Squared		0.286
Note:		*p<0,1,**p<0,05,***p<0,01

Source: Own Calculation

As can be observed, the only statistical significant variable are operational costs. In fact there is problem with mathematical sign of this regressor. It means that by increasing the value of operational costs, the efficiency score will decrease, and in fact, the efficiency will be better. The R-squared value is quite low. Model describes only 30% of variability of dependent variable.

5. Discussion, limitations and conclusions

Material costs, operational costs and total revenues are frequently used financial measures used in DEA efficiency evaluation (Hadji et al., 2014; O´Neill, 2008). We exclude these financial variables from DEA analysis because we wanted to find out if they are suitable for use of purposes of selected departments in terms of Slovak Republic health care. These variables could be used by evaluation of economic efficiency, which is different from technical efficiency computed by DEA. Our results showed that according to human resources and health care indicators there are only 7 of DMU efficient. Results of regression models showed, that use of financial indicators is not suitable to explain efficiency of gynaecological departments in terms of Slovak Republic. This can be caused by non-for profit orientation of Slovak departments in secondary health care hospitals. However, in other departments, these indicators could perform better. There is a wide gap of research in this filed in Slovak Republic. More departments, hospitals and other health care facilities can be evaluated, only limitation is in availability of data and in cooperation of Ministry of Health with research subjects.

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7. References

Araújo, C., Barros, C. P., & Wanke, P. (2014). Efficiency determinants and capacity issues in Brazilian for-profit hospitals. Health Care Management Science, 17(2), 126–138. https://doi.org/10.1007/s10729-013-9249-8

Blank, J. L. T., & Valdmanis, V. G. (2010). Environmental Factors and Productivity on Dutch Hospitals: A Semi-parametric Approach. Health Care Management Science, 13(1), 27–34. https://doi.org/http://link.springer.com/journal/volumesAndIssues/10729

Blank, J., & van Hulst, B. (2011). Governance and Performance: The Performance of Dutch Hospitals Explained by Governance Characteristics. JOURNAL OF MEDICAL SYSTEMS, 35(5), 991–999.

Chaabouni, S., & Abednnadher, C. (2012). Efficiency of public hospitals in Tunisia: a DEA with bootstrap application. International Journal of Behavioural and Healthcare Research, 3(3–4), 198–211. https://doi.org/10.1504/IJBHR.2012.051380

Cooper, W. W., Seiford, L. M., & Tone, K. (2007). Data envelopment analysis : a comprehensive text with models, applications, references and DEA-solver software. New York : Springer, c2007.

Flokou, A. (1), Aletras, V. (1, 2), & Niakas, D. (1). (2016). Decomposition of potential efficiency gains from hospital mergers in Greece. Health Care Management Science, 1–18. https://doi.org/10.1007/s10729-016-9365-3

Gholami, R., Añón Higón, D., & Emrouznejad, A. (2015). Hospital performance: Efficiency or quality? Can we have both with IT? Expert Systems With Applications, 42, 5390–5400. https://doi.org/10.1016/j.eswa.2014.12.019

Hadji, B. (1, 2), Melikeche, S. (1), Degoulet, P. (1, 4,5), Meyer, R. (3), & Escalon, S. (5). (2014). Assessing the Relationships Between Hospital Resources and Activities: A Systematic Review. Journal of Medical Systems, 38(10). https://doi.org/10.1007/s10916-014-0127-9

Kounetas, K. (1), & Papathanassopoulos, F. (2). (2012). How efficient are Greek hospitals? A case study using a double bootstrap DEA approach. European Journal of Health Economics, 1–16. https://doi.org/10.1007/s10198-012-0446-z

Li, H., & Dong, S. (2015). Measuring and Benchmarking Technical Efficiency of Public Hospitals in Tianjin, China: A Bootstrap-Data Envelopment Analysis Approach. Inquiry: A Journal Of Medical Care Organization, Provision And Financing, 52. https://doi.org/10.1177/0046958015605487

Mitropoulos, P. (1), Mitropoulos, I. (1), & Sissouras, A. (2). (2012). Managing for efficiency in health care: the case of Greek public hospitals. European Journal of Health Economics, 1–10. https://doi.org/10.1007/s10198-012-0437-0

O'Neill, L., Rauner, M., Heidenberger, K., & Kraus, M. (2008). A cross-national comparison and taxonomy of DEA-based hospital efficiency studies. Socio-Economic Planning Sciences, 42, 158–189. https://doi.org/10.1016/j.seps.2007.03.001

Simar, L., & Wilson, P. W. (2007). Estimation and inference in two-stage, semi-parametric models of production processes. Journal of Econometrics, 136, 31–64. https://doi.org/10.1016/j.jeconom.2005.07.009

van Ineveld, M. (1), van Oostrum, J. (1), Steenhoek, A. (1), van de Klundert, J. (1), & Vermeulen, R. (2). (2016). Productivity and quality of Dutch hospitals during system reform. Health Care Management Science, 19(3), 279–290. https://doi.org/10.1007/s10729-015-9321-7

Varabyova, Y., & Schreyögg, J. (2013). International comparisons of the technical efficiency of the hospital sector: Panel data analysis of OECD countries using parametric and non-parametric approaches. Health Policy, 112(1–2), 70–79. https://doi.org/10.1016/j.healthpol.2013.03.003

Villalobos-Cid, M., Chacón, M., Zitko, P., & Instroza-Ponta, M. (2016). A New Strategy to Evaluate Technical Efficiency in Hospitals Using Homogeneous Groups of Casemix. Journal of medical systems, 40(4), 1-12.

Yusefzadeh, H. (1), Ghaderi, H. (1), Bagherzade, R. (2), & Barouni, M. (3). (2013). The efficiency and budgeting of public hospitals: Case study of Iran. Iranian Red Crescent Medical Journal, 15(5), 393–399. https://doi.org/10.5812/ircmj.4742