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EFFICIENCY EVALUATION OF HOSPITALS IN THE ENVIRONMENT OF THE CZECH AND SLOVAK REPUBLIC

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Abstract

SENDEK STANISLAV, SVITÁLKOVÁ ZUZANA, ANGELOVIČOVÁ KATARÍNA. 2015. Efficiency Evaluation of Hospitals in the Environment of the Czech and Slovak Republic. *Acta Universitatis Agriculturae et Silviculturae Mendelianae Brunensis,* 63(6): 2109–2118.

The paper applies the Data Envelopment Analysis as a deterministic non-parametric method based on the linear programming, to measure the efficiency of Czech and Slovak hospitals based on input and output performance. Managing physician or hospital practice patterns is an important tool to reduce health care costs. State-run hospitals, as decision-making units working in an operating healthcare system, might have some excess resources in the process of providing care. Ehealth tools are expected to contribute to the cost containment in them, enhancing finally the quality of patient care in the overall assessment.

Keywords: Data Envelopment Analysis, radial BCC model, e-health, input-output analysis, hospital efficiency assessment, decreasing returns to scale

INTRODUCTION

Efficiency measurement of decision-making units (DMUs) with identification of inefficiencies of the sources being examined is a key prerequisite for performance improvements in a competitive setting. A DMU might be generally understood as a unit producing any inputs or outputs. The point of view can be micro- or macroeconomic, depending on the level of approach and level of aggregation of our inputs, outputs or DMUs.

Evaluating the performance of institutions of public sector such as a hospital is a task which has been of great interest to health care managers, administrators and government, even though measuring efficiency of the banking sector is a dominant area in the literature (Jablonský, Dlouhý, 2004). It is not only in the wake of the recent financial crisis and associated budgetary constraints but a general pressure on cost containment and resource constraints in the health care sector and hospital network in the recent decade which does contribute to ever-increasing drive for optimal resource utilization. These measurements and findings have direct policy implications aiming at re-allocation of sources or rationalization of working capacity or even disappearance of hospitals subsequently to be merged into bigger health care institutions both in rural and urban areas (WHO, 2005).

It is especially the WHO report (WHO, 2000) with its first ever indicator-based "Health system performance" ranking of all member countries, which in turn has obviously had spin-offs in the area of efficiency observation of health care sectors and health systems as a whole ever since.

This paper presents a basic Data Envelopment Analysis (DEA) measuring only the technical selected input-output efficiency, i.e. not the financial or overall efficiency, on selected acute care university hospitals and other hospitals in the Czech and Slovak Republic. Data have been used from public and non-public statistical databases (NCZI, 2014).

At the same time, authors are simulating potential positive shift in efficiency performance of inefficient hospitals based on empirical results from other studies on electronic healthcare, e-health (Garnter, 2009; Empririca *et al.*, 2009). An increasing amount of medical and/or clinical errors resulting from the lack of information often leads to harming the patient, or endangering his life in the worst scenario. With e-health tools like electronic prescriptions, electronic health records, supported by knowledge-based data mining processes, to name the most important, are expected to contribute to the optimization or resources, reduction of medical errors and duplicities and even deaths and increasing efficiency in the process of health care provision (For more, refer also to the European Commission, 2004).

METHODOLOGY OF ELABORATION

Modelling and the comparative method have been applied. Based on the common technique applied in similar underlying studies (Bitran *et al.*, 1987; Harrison *et al.*, 2004, and recently by Barnum *et al.*, 2011). We have identified basic inputs and outputs for selected acute care hospitals in Slovakia and the Czech Republic in order to carry out the Data Envelopment Analysis (DEA). Some indicators to be observed needed to be derived and recounted from the statistical database of the National Health Information Center Slovak Republic (NCZI) and of the Institute of Health Information and Statistics of the Czech Republic (ÚZIS ČR) for Czech hospitals.

Data inputs have been calculated in 2012 prices. Subsequently, the efficient scores using the variable BCC model (first applied by Banker *et al.*, 1984) are counted to design a 'CZ-SK model' using decreasing returns to scale (the variable BCC DEA model) which is better adjusted for healthcare sector (Jablonský, Dlouhý, 2004). Simultaneously, we have identified potential savings, based on Gartner (2009) and Empirica *et al.* (2005), if selected e-health tools were hypothetically fully implemented in two years 2009 and 2012 in the Czech and Slovak hospitals.[1]

Afterwards, selected hospitals with these new optimized inputs and outputs through electronization of processes were added as new separate DMUs to simulate the potential of efficiency improvement of these hospitals. The method of induction had to be applied as our e-health savings are derived from outcomes of various independent clinical trials on e-health around the world (Gartner, 2009; Shekelle *et al.*, 2013; Shojania *et al.*, 2001). We also compared the results with the 'old' 6 models[2] of 48 Slovak hospitals presented in Sendek (2014), filling thus one of the previous limits of the 2014 study where the efficiency of Slovak hospitals was compared in the pool of Slovak hospitals only. Finally, we summarize the observation, designing a set of recommendations.

DATA AND METHODOLOGY

Measuring efficiency or performance of a DMU is possible through several partial methods such as productivity, average return on equity, profitability. Within the evaluation presented in this paper, we are applying the data envelopment analysis. With DEA we are producing the empirical production function. The DEA as a method for measuring efficiency is based on methods of linear programming which came into use in the 1970s (Bitran, Valor-Sebatier, 1987). It is Farell who is considered to be the first pioneer of a convex envelopment curve. This new measure of efficiency was based on the calculation of two components of the overall efficiency, the technical and price/allocation efficiency.

The technical efficiency, on which the variable input-ouput BCC model is based and which is employed in this paper, is defined as an ability of a decision-making unit to produce the maximum output with the inputs available. This can be represented by the equation:

$$TE_i = \frac{0Q}{0P} = \frac{1-QP}{0P}, \tag{1}$$

TE ....input-output oriented technical efficiency,
Q ....DMU in the point of Q is technically efficient, lying on the isoquant curve.

Allocation efficiency is the ability of a DMU to combine the outputs in such combinations so as to be optimal in relation to the inputs. Similarly, the range of scores of the allocation efficiency is also within the interval <0; 1>.

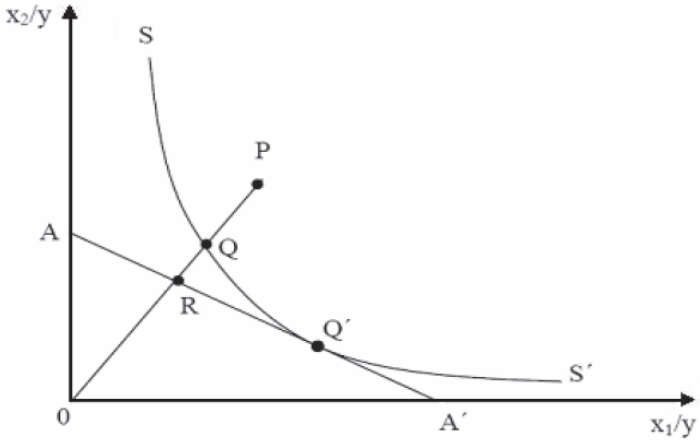
$$AE_i = \frac{0R}{0Q}, \tag{2}$$

RQ ......is a point representing the reduction of the production costs which are attainable at the point Q which is efficient in allocation and technical redistribution.

Economic (overall) efficiency – is a measure comprising both the technical and allocation efficiency in the relation of multiplication. According to which goal a DMU is aiming at, it is referred to as the cost efficiency (in the cost minimisation efficiency approach) or revenue efficiency (in case of the maximisation of returns). It is a measure

1 Electronic healthcare is being implemented under the Programme of Implementation of e-health (PIeH) in the Slovak Republic in the period of 2008–2018. For more, refer to URL: <http://www.ezdravotnictvo.sk/en/Pages/default.aspx>. The e-health implementation was underway most notably through the IZIP project (implementing an integrated electronic health record with other ehealth tools) until 2012 when it was stopped. Subsequently, new national strategy for ehealth in the Czech Republic was developed.

2 Hereinafter referred to as the 'old model' or 'SK-model' whereas the CZ-SK model is the 'new model'.



1: *Input-oriented measure of technical and allocation efficiency*
Source: Coelli *et al.*, 2005; Chilingerian, Sherman, 1990

representing both technical and allocation efficiency.

$$EE_i = \frac{0R}{0P} = TE_i \times AE_i = \left(\frac{0Q}{0P}\right) \times \left(\frac{0R}{0Q}\right), \tag{3}$$

RP ....distance representing the cost reduction.

At the same time, the DEA is based on the measure in which a DMU (a hospital) is able to realize too few inputs or too many outputs. This is why the positive values represent the measure in which a variable contributes to the overall score of efficiency. Thus Ozcan *et al.* (1992) interpreted the measure which finds out which factor (input or output) is to be considered when seeking to increase the efficiency (Bannick and Ozcan, 1995; Ozcan *et al.*, 1992). Algebraically expressed:

$$Eff(u,v) = \frac{\sum_{i=1}^{\neq outputy} v_i y_i}{\sum_{j=1}^{\neq inputy} u_i x_i} = \frac{\sum_{i=1}^{n} v^T y_i}{\sum_{j=1}^{m} u^T x_i} \le 1, \tag{4}$$

Eff(u, v) .... efficiency of a DMU,
y .... outputs (e.g. number of hospitalizations, number of clinical tests, etc.),
x .... inputs (e.g. number of staff working hours, salaries, cost of medicines used, etc.),
$v = (v_1, \ldots, v_n)^T$ .....pricing of inputs through vectors,
$u = (u_1, \ldots, u_m)^T$ ...pricing of outputs through vectors.

MaxDea Basic 6.3 software, beta version, was used for estimation of the efficiency.[3] For a more detailed concept on the theoretical and graphical representation compare Coelli *et al.* (2005); or an earlier study by Chilingerian, Sherman (1990).

e-Health Benefits Assumptions

To simulate the potential of e-health implementation in hospitals we are drawing on results from clinical studies of Gartner (2009), Shojania *et al.* (2001), and its revised version by Shekelle *et al.* (2013), and on random samples and data mining-based analyses of all the three Slovak insurance companies[4] to make some estimations aimed at the potential of ehealth tools destined to improve the hospital's technical efficiency in decreasing selected inputs and increasing outputs. Only conservative estimations have been applied in this paper.[5]

Preventable Bed-days, Length of Hospitalizations

There are several e-health tools which are intimately linked with the reduction of the length of stay in the hospital such as electronic health records, hospital business-intelligence systems, electronic prescriptions and other computer-backed systems. We do refer to the most important ones, incorporating them into our e-health models.

Based on several studies, primarily on observations of the American Thoracic Society Documents (2005) and Healthcare Informatics

3 http://www.maxdea.cn/.
4 A complex non-public cost-benefit analysis had to be assembled, some data of which cited in this paper are based on data inputs from three Slovak health insurance companies. The whole CBA is available to the authors of the paper. The analysis is being continuously updated during the life cycle of the project from the start of the e-health implementation in Slovakia in 2009. Partially, some pieces of aggregated data and summary information are available on the Slovak official e-health information portal on URL: <http://www.ezdravotnictvo.sk/Documents/NZIS.pdf> or on the portal of the Ministry of Finance of the Slovak Republic on URL: <http://informatizacia.sk/index/open_file.php?ext_dok=13237>.
5 It means that if a study proved e.g. a direct reduction of hospital-acquired infections between 5–10% of all admissions the lower conservative value of 5% was applied for our calculations.

(2007), we made an estimation that 5% of all admissions are associated later with hospital-acquired infections. One admission is unnecessarily extended for 5 average bed-days. With data-mining and business intelligence-backed e-health tools introduced, 3.1% of incidents are reduced (Gartner, 2009).

Unnecessary bed-days may also be prevented if the patient has the optimal medication. If a physician prescribes a medicine *F* to a patient, not knowing that the patient is already taking medicines *A-E*, an adverse drug event (ADE) may occur with serious unfavourable health consequences for the patient (Bates *et al*., 1997; Aahern *et al*., 2006; Babeľa *et al*., 2008). ADEs occurring during hospitalization are common (Shekelle *et al*., 2013). Using computerised physician/provider order entry (CPOE) and clinical decision support system (CDS) by means of a database on medicinal products. Reported studies refer to the 55% decrease of medication errors and 17% decrease in preventable (Shojania *et al*., 2001; Bates, 1995). Another study by Smith (2004, found out that 1.8% of all admissions (hospitalizations) are due to or associated with ADEs. The average number of bed-days per ADE is 4 to 11 days (Gartner, 2009). We opted for a conservative number of 5 bed-days. Therefore, we estimated that a total number of (1.8 × 5) bed-days may be reduced if CDS and CPOE are introduced and applied together.

Every tenth hospitalisation is associated with a cardiovascular chronic diseases (NUSCH, 2003) which might be prevented through better prevention, in which telemedicine and home health monitoring of the patient plays an important role. Cardiovascular chronic diseases represent around 50% of all chronic diseases. Darkins *et al*. (2008), does also confirm that at least 25% of bed-days due to chronic conditions could be reduced through better systems of tele-monitoring.

Full Time Equivalents (FTEs)

A study by Black *et al*. (2011), found out that with the electronic health record of a patient, a total amount of ca. 22% in clinical staff productivity (measured as FTEs) may be saved through reduced time in searching, retrieving and capturing information about the patient's medical history.

Cost of Medicines Prescribed

There are several studies looking into the potential of electronic prescription and medication (Gartner, 2009). Even though some studies prove higher numbers, we estimated that at least 10% of medicines prescribed[6] during a hospitalization or within the outpatient care in a hospital (clinic) might be saved.

RESULTS

We collected data from Czech and Slovak acute care hospitals (n = 38), out of which 23 are state university or teaching hospitals and 15 other hospitals or specialized hospitals (NCZI, 2014).

Input measures: The input measures used in this study were number of beds (*Beds* (*n*)), full time equivalents representing working hours and overtime hours of physicians and nurses (*FTEs* (*h*)), bed-days (*B-Day* (*n*)), cost of medicines and medicinal products in EUR (*MMD* (€)). In general, number of beds of a hospital is considered a measure of a hospital's size. Bed days are counted as days during which a patient received all services which are provided by the institution. The medicines and medicinal products are being prescribed and administered to patients during their stay in the hospital.

Output measures: In our models, the output measures are represented by the number of hospitalizations (*Hosp* (*n*)) and outpatient visits (*OutVis* (*n*)) in hospitals. All hospitals do also offer outpatient one-day services without a need for hospitalisation.

DEA Models: Technical efficiency of the hospitals in this study was examined using decreasing returns to scale (BCC model) since we assume that in general an increase in bed capacities or of any other input does not necessarily lead to a higher number of hospitalization. Hospitalizations and outpatient services are considered to be stable in a region. It is the inputs which are expected to be optimized in the process of the provision of health care.

In two years, 2009 and 2012, we hypothetically assumed that e-health tools, as described above, are implemented in those of 19 hospitals for 2009 and 18 hospitals for 2012 which did not reach efficiency scores of 1. These two models are referred to as *e-2009* and *e-2012* respectively. The Tab. I represents development of efficiency scores in our four input/two output BCC model.

In Tab. I, we see that in 2009 through 2012 in all 6 models, there are altogether efficient Czech and Slovak hospitals in the number of 18 (11 CZ, 7 SK), 29 (15, 14), 22 (11, 11), 21 (11, 10), 20 (12, 8) and 27 (15, 12) respectively. If we run similar 6 models with 48 Slovak hospitals only in the old model (Tab. II), we find a lower number of efficient Slovak hospitals, namely 7, 12, 8, 9, 8 and 8 respectively. Compare Sendek (2014). This is attributable to the change of weights in the models since there are no Czech hospitals incorporated in the old model. The efficiency of Slovak hospitals is compared in the pool of 48 Slovak hospitals only. These obviously perform worse in an international comparison.[7]

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6 Based on estimations of three Slovak health insurance companies within the CBA.

7 There was a slight difference in this old model though (Tab. II), the ehealth tools in "e-2009" and "e-2012" were implemented only in the previously inefficient university hospitals in the "2009" and "2012" models, not in all inefficient hospitals (out of 48) as in this new research of CZ-SK model.

I: *Efficiency scores development of Czech (No. 1–19) and Slovak (No. 20–38) hospitals in 2009–2012 without and with some e-health tools hypothetically implemented in all previously inefficient DMU's in 2009 and 2012. The university hospitals (UH) are marked in grey*

No.	SK-CZ HOSPITALS (n = 38)/YEAR	2009	e-2009	2010	2011	2012	e-2012
1	UH_FN Praha	1	**1**	1	1	1	**1**
2	UH_FN Královské Vinohrady	0.93	**1**	0.95	0.92	1	**1**
3	UH and Clinics_FN Thomayerova	1	**1**	1	1	1	**1**
4	UH_FN Motol	1	**1**	1	1	1	**1**
5	UH_FN Na Bulovce	1	**1**	1	1	1	**1**
6	UH_FN Olomouc	0.87	**1**	0.87	0.90	0.77	**0.95**
7	UH_FN u sv.Anny	0.95	**1**	0.94	0.96	0.84	**1**
8	UH_FN Hradec Kralove	0.72	**0.788**	0.72	0.70	0.97	**1**
9	UH_FN Plzen	1	**1**	1	1	1	**1**
10	UH_FN Ostrava	0.94	**1**	0.96	0.93	0.91	**1**
11	MH_Ústřední vojenská nemocnice Praha	0.84	**0.91**	0.89	0.86	1	**0.95**
12	Institute of clinical and experimental medicine	0.73	**0.95**	0.73	0.80	0.73	**0.93**
13	Institute for the Care of Mother and Child	1	**1**	1	1	1	**1**
14	Institute of Rheumatology	1	**1**	1	1	1	**1**
15	Institute of Hematology and Blood Transfusion	1	**1**	1	1	1	**1**
16	Prague Psychiatrical center	1	**1**	1	1	1	**1**
17	H_ Nemocnice Na Homolce	1	**1**	1	1	1	**1**
18	Centrum kardiovas. and transp. surgery	0.74	**0.98**	0.73	0.75	0.67	**0.87**
19	Masaryk cancer institute	1	**1**	1	1	0.93	**1**
20	UH_UN Bratislava	1	**1**	1	1	1	**1**
21	UH_UN L.Pasteura Košice	0.97	**1**	0.97	1	0.95	**1**
22	UH_UN Martin	0.81	**0.97**	0.77	0.64	0.60	**0.76**
23	Children's UH and Clinics_DFNsP Košice	0.69	**0.88**	0.72	0.68	0.74	**0.98**
24	Children's UH and Clinics_FNsP Banská Bystrica	1	**1**	1	1	1	**1**
25	Children's UH and Clinics_FNsP Bratislava-Nové mesto	0.84	**1**	1	0.83	0.77	**1**
26	UH_FN Nitra	1	**1**	1	1	1	**1**
27	UH and Clinics_FNsP F.D.Roosevelta Banská Bystrica	0.89	**1**	1	1	1	**1**
28	UH and Clinics_FNsP J. A. Reimana Prešov	0.90	**1**	0.73	0.87	0.63	**0.79**
29	H and Clinics_NsP Skalica	1	**1**	1	0.77	0.75	**1**
30	UH and Clinics_FNsP Žilina	0.84	**0.93**	0.71	0.63	0.56	**0.66**
31	UH and Clinics_FNsP Nové Zámky	0.83	**0.98**	0.75	0.67	0.61	**0.78**
32	UH and Clinics_FNsP Trenčín	0.74	**0.972**	0.739	0.663	0.614	**0.78**
33	UH and Clinics_FNsP Trnava, so sídlom Andreja Žarnova 11	0.90	**1**	0.83	0.67	0.60	**0.79**
34	H and Clinics_NsP Spišská Nová Ves	1	**1**	1	1	1	**1**
35	H and Clinics_NsP sv. Barbory Rožňava	1	**1**	1	1	0.98	**1**
36	H and Clinics_NsP Sv. Jakuba Bardejov	0.79	**1**	1	1	1	**1**
37	Specialized H for Ortopedic Protetics_ŠNOP Bratislava	1	**1**	1	1	1	**1**
38	National Institute of Cardiovascular Diseases_NÚSCH	0.95	**1**	1	1	1	**1**

The average inputs of technically efficient hospitals are higher than those of inefficient hospitals. These hospitals do count higher number of hospitalizations too. This might prove that the concentration of healthcare occurs in bigger hospitals in urban areas. This is primarily attributable to the economies of scale.

Tab. III presents some basic statistical outputs for a semi-hypothetical model of 38 Czech and Slovak hospitals in 2012. In the total of 20 out of 38 hospitals, identified as inefficient (refer to the Tab. I) in the "2012" model, there were e-health tools theoretically introduced in the model to design the "e2012" model. EHealth was not implemented in the efficient hospitals, even though this would not be true in practice, in order not to affect the overall weights of the model used in computations by the software. The result scores of other hospitals are almost unaffected. Referring first to the Tab. I, we see that efficiency scores rose in these electronized

II: *Efficiency scores development of Slovak hospitals, only, in the old model in 2009–2012 without and with some e-health tools hypothetically implemented in all 14 university hospitals (UH, marked in grey) in 2009 and 2012*

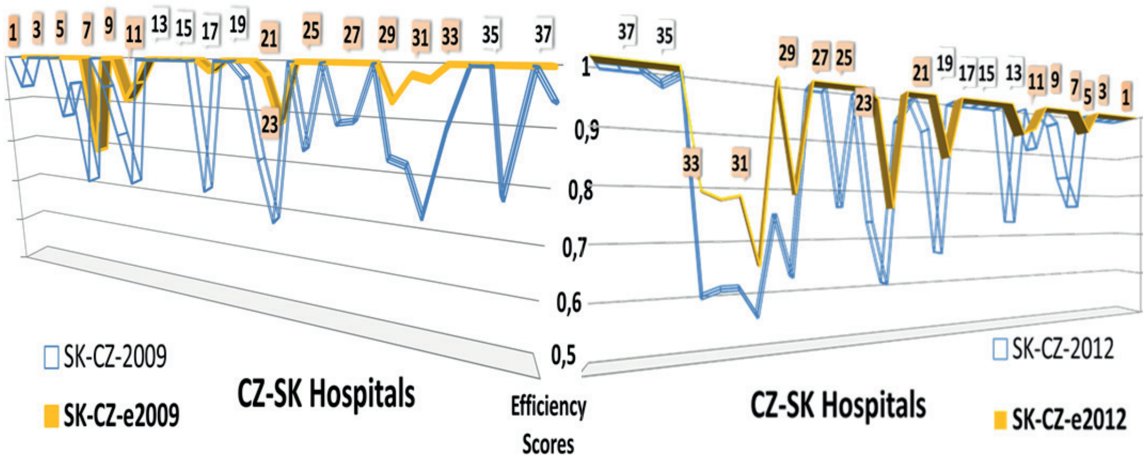
No	SK–HOSPITALS (n = 48)/YEAR	2009	e-2009	2010	2011	2012	e-2012
20	UH_UN Bratislava	1	1	1	1	1	1
21	UH_UN L.Pasteura Košice	0.97	1	1	1	1	1
22	UH_UN Martin	0.82	0.97	0.74	0.63	0.60	0.80
23	Children's UH and Clinics_DFNsP Košice	**0.72**	0.91	0.76	0.68	**0.74**	**0.98**
24	Children's UH and Clinics_FNsP Banská Bystrica	1	1	1	1	1	1
25	Children's UH and Clinics_FNsP Bratislava-Nové mesto	**0.83**	**1**	0.94	0.79	**0.73**	**0.99**
26	UH_FN Nitra	1	1	1	1	1	1
27	UH and Clinics_FNsP F.D.Roosevelta Banská Bystrica	**0.90**	**1**	0.96	1	1	1
28	UH and Clinics_FNsP J. A. Reimana Prešov	**0.90**	**1**	0.74	0.87	**0.63**	**0.85**
29	H and Clinics_NsP Skalica	1	1	1	0.76	0.74	0.74
30	UH and Clinics_FNsP Žilina	**0.85**	**0.93**	0.71	0.63	**0.56**	**0.69**
31	UH and Clinics_FNsP Nové Zámky	**0.84**	**0.98**	0.75	0.67	**0.61**	**0.82**
32	UH and Clinics_FNsP Trenčín	**0.74**	**0.97**	0.73	0.66	**0.61**	**0.82**
33	UH and Clinics_FNsP Trnava, so sídlom Andreja Žarnova	**0.92**	**1**	0.83	0.67	**0.60**	**0.82**
34	H and Clinics_NsP Spišská Nová Ves	1	1	1	1	1	1
35	H and Clinics_NsP sv. Barbory Rožňava	1	1	0.99	1	0.72	0.72
36	H and Clinics_NsP Sv. Jakuba Bardejov	0.75	0.75	1	1	1	1
37	Specialized H for Ortopedic Protetics_ŠNOP Bratislava	1	1	1	1	1	1
38	Central Slovak Institute of Cardiovascular Diseases_SÚSCH	0.93	0.93	0.90	0.96	0.84	0.84

III: *Input and output data of efficient vs. inefficient hospitals for CZ-SK model "e-2012" and "2012" (in brackets). The MMD/Hosp ratio counted separately for Czech and Slovak hospitals (;)*

All facilities n = 38	Beds (n)	FTEs (h)	B-Day (n)	B-Day/Hosp (ratio)	MMD (€)	MMD/Hosp (ratio)	Hosp (n)	OutVis (n)
Real Mean	728 (728)	1 752 610 (1 945 548)	163 384 (191 088)	6.38 (7.40)	3 539 525 (3 735 019)	1.61;219 (1.67; 231)	27 364 (27 599)	518 728 (518 728)
Real SD	605 (605)	1 626 559 (1 675 142)	143 064 (157 987)	5.23 (5.10)	6 345 935 (6 523 273)	8.58; 372 (8.61; 371)	22 739 (22 885)	478 782 (478 782)
Mean with virtual inputs	676 (638)	1 659 625 (1 650 335)	156 800 (167 754)	6.05 (6.37)	3 070 193 (2 584 383)	1.59; 186 (1.55; 146)	27 364 (27 599)	599 407 (659 079)
Efficient n = 27 (18)								
Real Mean	744 (678)	1 896 801 (2 030 263)	175 221 (177 109)	6.50 (7.18)	3 346 031 (3 382 158)	1.42; 202 (1.57; 211)	29 416 (27 585)	617 631 (641 223)
Real SD	678 (651)	1 859 343 (2 039 918)	162 339 (171 782)	6.11 (6.85)	7 087 496 (7 672 953)	9.44; 460 (10.4; 549)	25 710 (25 271)	528 186 (601 340)
Inefficient n = 11 (20)								
Real Mean	689 (783)	1 398 689 (1 851 420)	134 329 (206 621)	6.09 (7.66)	4 014 466 (4 127 086)	2.62; 252 (1.85; 246)	22 327 (27 615)	275 965 (382 261)
Real SD	364 (543)	691 110 (1 132 928)	69 498 (139 451)	1.18 (1.55)	3 937 248 (4 911 870)	3.91; 95 (3.62; 110)	11 318 (19 901)	155 497 (216 677)

hospitals. After electronization, 9 hospitals out of 20 previously inefficient got the efficiency score 1.

By the results of the Tab. III we see that the average numbers of FTEs, bed days and MMD input measures, all of the inputs affected by the implementation of e-health tools decreased when compared to the "2012" model, which proves that electronic health care contributes to higher technical efficiencies of hospitals, as proved by many studies and clinical trials some of which are mentioned throughout this paper. Mean with virtual inputs is a projection computed by software, which denotes the desired amount of inputs needed to be realized in hospitals in order that each hospital may be identified as technically efficient and reach the efficiency frontier. Virtual inputs are projected values referred to as efficient targets. Comparing virtual inputs of all facilities in "2012" with real mean of all facilities in the e-health model "e-2012", we see that e-health tools lead to the optimization of resources in hospitals and higher levels of efficiencies are reached.



2: *Efficiency scores in Czech (No. 1–19) and Slovak (No. 20–38) hospitals (n = 38) in 2009 (left) and 2012 (right) with and without e-health tools implemented based on Tab. I. University hospitals highlighted red*
Source: Self-assembly

Fig. 2 illustrates a graphic representation of the efficiency scores in hospitals in 2009 and 2012 in Slovakia and the Czech Republic. Scores of efficiencies are clearly higher when clinical decision-making is supported by electronic transmission and computer-backed information. The average real efficiency score of university hospitals in the model "2009" is equal to 0.92 for all hospitals and 0.91 (0.93 CZ, 0.89 SK) for university hospitals only, whereas in the real model "2012" the value is equal to 0.89 for all hospitals and 0.85 (0.95 CZ, 0.77 SK) for university hospitals only. As for Slovakia, this is attributable to the reduced funding of state hospitals which finally led to the financial turmoil caused by ever-increasing debts and negative cash-flows in some hospitals which in turn had to be bailed-out by Slovak government in 2011, but it still did not stop their course. Refer to the Health Policy Institute (2013). By contrast, the Czech university hospitals performed better in 2012 than in 2009 which is to explain by structural reforms conducted continuously over time, affected i.a. by the decreasing long-term trend of the number of beds and, simultaneously, the increasing trend in net occupancy rates of bed places at the same time. The overall average length of stay decreased, too. Compare ÚZIS ČR (2012). The use of the to-be-more-just diagnosis-related group (DRG) payment mechanism in the Czech Rep., in contrast to Slovakia, most probably also weighs in. Compare ÚZIS ČR, 2012.

DISCUSSION

There are two most significant theoretical findings of our analysis in the environment of the Czech and Slovak Republic. The first is associated with generally accepted assumption pertaining to achieving returns to scale in larger hospitals with higher number of beds, providing more services, and concentrating highly-qualified working capacities. The second finding also proves the results of several studies that ehealth tools, when fully implemented, do contribute to higher efficiency performance and allocation of resources in hospitals in providing health care services.

EHealth, as a promising medium of computerization (paperless form of) processes in the healthcare sector is a relatively new means shaping the communication processes of healthcare sectors in developed countries today.

Improvements in availability of health care could also be increased thanks to the multiplier effect if resources released from the reduction of costs were reallocated to treat more patients, increase the throughput and reduce waiting time.

On the other hand, this paper does not deal with assessments of a more thorough analysis aiming at the DEA-super-efficiency of hospitals branded as efficient, or "weakly efficient", the concept elaborated by Farell, Paretto-Koopmans and in the research studies to follow (see Tone, Tsutsui, 2013). This could include the robust efficiency model being taken into account due to outliers which are caused by e.g. heterogeneity of DMUs or erroneous production assumptions. "Such outliers can reduce the goodness of the estimator for efficiency" (Kuosmanen, Post, 1999).

The presented paper, however, fills the gap of an international comparison as referred to in Sendek (2014), in incorporating 19 Czech hospitals in the combined Czech-Slovak model.

In addition, a windows DEA analysis on the efficiency separately in small, medium and large hospitals as presented by Kazley and Ozscan (2008), using the DEA analysis, is possible and could be examined in further studies. Efficiency of separate, and not all ehealth applications, is discussed in several studies, with significant positive effects (Korst, 2003; Terry, 2002) or with no statistically significant effects on the efficiency of hospitals (Kazley, Ozcan, 2008). Problems also do arise with exact identification when proving the causality between a diagnostic error, expected to be reduced by introducing e-health tools, and direct case-by-case clinical outcomes (Shekelle *et al.*, 2013, ch. 35). Only a holistic approach can bring about desired synergic effects expected from the implementation of e-health tools (Dansky *et al.*, 2009) and complex use of IT in providing healthcare (Devaraj, Kohli, 2003; ANAP, 2010, ch. 44; Croll *et al*, 2007).

CONCLUSION

Thirty-eight Czech and Slovak hospitals, out of which twenty-three are university hospitals, were analysed to measure the real yearly hospital technical efficiency in 2009–2012 and a hypothetical hospital technical efficiency with basic selected e-health tools implemented in 2009 and 2012. Smaller hospitals showed better efficiency scores in all models than larger university hospitals, which can be explained by several factors – cost-demanding diseases being treated in larger hospitals in catchment areas, higher number of patients compared to bed capacity, etc. Six DEA BCC models were run together to measure the economic efficiency. If all hospitals were electronized in 2009 by means of functioning EHRs, electronic prescription and medication, telemedicine, hospital business-intelligence and computer-backed systems, 29 hospitals would be efficient compared to 18 hospitals in 2009 with real historical efficiency. Out of 22 university hospitals, wherein most healthcare expenses are allocated, 9 (4 CZ, 5 SK) of them would obtain the efficiency frontier and the remaining ones would come nearer to it. With well-functioning electronic healthcare in 2012, 18 hospitals would be efficient equally as without e-health tools, but their individual performance scores would be significantly higher. It is to be noted that these hypothetical models assume the full implementation of key e-health applications rather than impacts induced by separate tools such as EHR (EMR), e-prescribing, telemedicine and other. Some differences in the development of the efficiency scores in both countries are also suggested and explained.

In 2012, the real hospital efficiency in providing health care was worse in Slovak hospitals than in 2009 which is primarily attributable to increased indebtedness of Slovak hospitals. Apart from more effective structural reform of Czech hospitals, it may also be the diagnosis-related group (DRG) payment mechanism implemented in the Czech Republic since 2003–2004, and which is supposed to be more efficient payment system for services. The DRG is still not implemented in Slovakia.

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