ACTA UNIVERSITATIS AGRICULTURAE ET SILVICULTURAE MENDELIANAE BRUNENSIS

Volume 62 73 Number 4, 2014

http://dx.doi.org/10.11118/actaun201462040697

EFFICIENCY EVALUATION OF HOSPITALS IN THE ENVIRONMENT OF THE SLOVAK REPUBLIC

Stanislav Sendek[1]

[1] Faculty of Business and Economics, Mendel University in Brno, Zemědělská 1, 613 00 Brno, Czech Republic

Abstract

SENDEK STANISLAV. 2014. Efficiency Evaluation of Hospitals in the Environment of the Slovak Republic. *Acta Universitatis Agriculturae et Silviculturae Mendelianae Brunensis,* 62(4): 697–706.

The paper applies the Data Envelopment Analysis as a deterministic non-parametric method based on the linear programming, to measure the efficiency of 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 of the country, might have some excess resources in the process of providing care. It is also e-health tools which might 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, be it in private or public sector, along with identification of inefficiencies of the sources being examined is a key prerequisite for performance improvements in a competitive setting. A decision-making unit (DMU) might be generally understood as a unit producing any inputs or outputs, i.e. an automotive company, bank as well as public accounts, school or a hospital. 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 efficiency of banking sector is a dominant area of research of efficiency based on the DEA in the literature (JABLONSKÝ, DLOUHÝ, 2004). It is not only in the wake of the recent financial crisis and associated budgetary constraints which do contribute to ever-increasing drive for optimal resource utilization, but it is primarily a general pressure on cost containment and resource constraints in the health care sector and hospital network in the recent decade. 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.

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 DEA analysis on selected acute care university hospitals and other hospitals in the Slovak Republic. Data of most recent selected years from 2006 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 selected hospitals based on empirical results from other studies on electronic healthcare, e-health. A great deal of influence in implementation of electronic healthcare is attributable to the ineffective and inefficient clinical procedures, still done as paperwork. (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. e-Health tools, when fully implemented, have the potential for increasing efficiency in the process of health care provision. (For more, refer also to the European Commission, 2004).

METHODOLOGY OF ELABORATION

In relation to the goals of the paper the methodology comprising the logical methods, the method of 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; BARNUM *et al.*, 2011). We have identified basic inputs and outputs for selected acute care hospitals in Slovakia 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 of the Slovak Republic (NCZI) for the years of 2006 and 2009–2012.

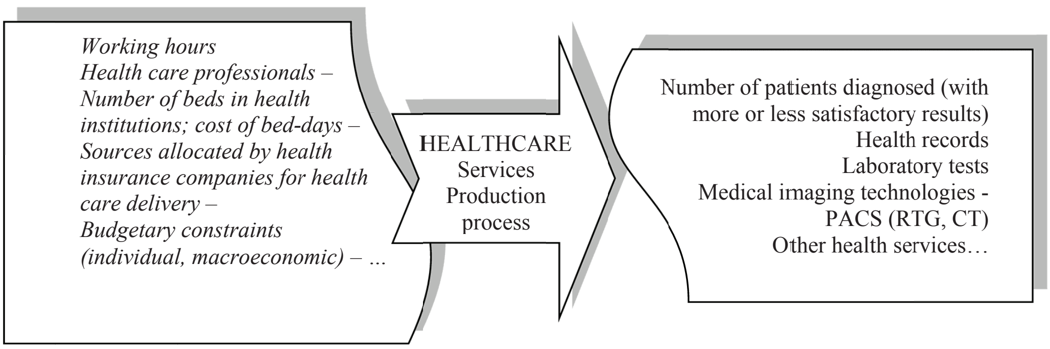
Data inputs have been calculated in 2012 prices. Subsequently, the efficient scores using the variable Banker–Charnes–Cooper (BCC) model designed by Banker. (BANKER *et al.*, 1984). The basic CCR model by Charnes, Cooper and Rhodes (CHARNES *et al.*, 1978) was not used since, understandably, we are generally not assuming constant economies of scale in hospitals in terms of a linear increase of outputs when increasing the inputs and vice versa (JABLONSKÝ, DLOUHÝ, 2004). Simultaneously, we have identified potential savings when selected e-health tools are fully implemented in 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. In doing so, with regard to the complexity and extent of the issue, it was necessary to apply abstraction in certain aspects pertaining to the absence of a detailed impact-study of full deployment of e-health in 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, KG *et al.*, 2001). For the purpose of this study, we derived some selected assumptions in e-health savings in hospital environments since real data for Slovak hospitals will be available post the implementation in Slovakia, which will be the case not earlier than in late 2017 or 2018 provided that the current implementation model of fundamental e-health applications[2] is seamlessly implemented with no other postponements. Finally, we summarize the observation, designing a set of recommendations.

Health Flows

The health care services and provision involves incorporating together a large number of resource inputs to deliver an extraordinary array of different service outputs. Few manufacturing processes, if any, match the variety and the rate of change of production possibilities like those processes being taken place in the healthcare sector.

In order to understand the flows which are realized in the healthcare sector, all the more to analyse them, it is crucial to identify basic factors intrinsic to every health care setting, i.e. key inputs



1: *Health Flows. Self-assembly*
Source: BANNICK, 1995 and EMPIRICA *et al.*, 2005

1 Electronic healthcare is being implemented under the e-Health Implementation Programme (PIeH) in the Slovak Republic in the period of 2008–2018. For more, refer to <http://www.ezdravotnictvo.sk/en/Pages/default.aspx>.

2 As stipulated by the Act No. 153/2013 Coll. on the National Health Information System as amended, with effect from June 30, 2014.

and outputs. There is no unchanging position on either side of the health care production process for these items. Each of them might be found on the opposite side to each other depending on the methodology we use or point of view we apply. (CHILINGERIAN, J. A., 1990; CROLL *et al.*, 2007; EMPIRICA *et al.*, 2005).

Some basic inputs and outputs within the health care production process are presented in the Fig. 1.

DATA AND METHODOLOGY

Measuring efficiency or performance of a decision-making unit (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 which is based on the behaviour of indicators, ratios. 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, G. R., VALOR-SEBATIER, J., 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:

$$TE_i = \frac{0Q}{0P} = 1 - \frac{QP}{0P}, \quad (1)$$

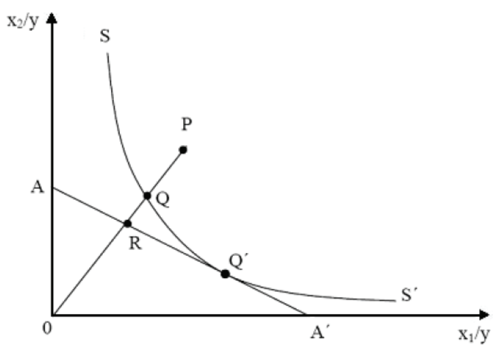
TE .... input-output oriented technical efficiency,
Q ...... DMU in the point of Q is technically efficient, lying on the isoquant curve.

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>.

$$AE_i = \frac{0R}{0Q}, \quad (2)$$

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 representing both technical and allocation efficiency.



2: *Input-oriented measure of technical and allocation efficiency*
Source: CHILINGERIAN, J. A., SHERMAN, H. D., 1990

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

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 tell of the measure in which a variable contributes to the overall score of efficiency. Thus Ozcan, *et al.* (OZCAN, Y. A. *et al.*, 1992) interpret the measure which finds out which factor (input or output) is to be considered when seeking to increase the efficiency. (BANNICK, R. R. and OZCAN, Y. A., 1995; OZCAN, Y. A. *et al.*, 1992). Algebraically expressed:

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

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.

The technical efficiency in this paper is assessed on the data flows of the sample of Slovak hospitals in the MaxDea Basic 6.1 software, using the radial model of the DEA input-oriented BCC analysis.[3]

3 http://www.maxdea.cn /

e-Health Benefits Assumptions

To simulate the potential of e-health implementation in hospitals, we are drawing on the 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]. 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 (2007), we made an estimation that 5% of all admissions are associated later with hospital-acquired infections (HAI). 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 due to HAI are reduced (GARTNER, 2009).

Unnecessary bed-days may also be prevented if the patient has the optimal medication, i.e. if he or she takes the right medicines. If a physician prescribes a medicine *F* to a patient, not knowing that the patient is already taking medicines *A-E*, or even he knows he does not notice for any reasons that the substance *X1* of the medicine *F* may be in the interaction with the substance *X32* of the medicine *E*, an adverse drug event (ADE) may occur with serious unfavourable health consequences for the patient. ADEs occur in the wake of consumption of drugs which should not have been prescribed on account of an interaction(s) with another medicine (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.[6] Half of medication errors occur when a medicine is being prescribed. Reported studies refer to the 55% decrease of medication errors and 17% decrease in preventable ADEs as a secondary outcome. (SHOJANIA, K. G. *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. Each input of bed-days has been reduced in hospitals in our models respectively.

The CPOEs and electronic patient's record do also contribute to the reduction of average length of stay (bed-days) through quicker retrieval of tests and other medical information in the electronic form resulting to a quicker discharge of a patient. The 7% reduction is estimated by BUELL (2007), and in our model too, even though considerably more time might be saved in practice.

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. The reports by WHO and OECD do also aim at the area of prevention of chronic diseases associated with unnecessary hospitalizations. 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 (EHR) of a patient, a total amount of ca. 22% in clinical staff productivity (measured as FTEs by hospitals for statistical purposes) may be saved through reduced time in searching, retrieving and capturing information about the patient's medical history. Hence in our hypothetical hospitals with e-health tools being implemented we estimated the 22% reduction in FTEs.

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.

6 The CPOE are in wide use nowadays. However, the CDS are still rare.

Cost of Medicines Prescribed

There are several studies looking into the potential of electronic prescription and medication. (GARTNER, 2009) Slovak health insurance companies do also regular calculations and estimations on potential unnecessary medicines which did not need to be prescribed since a patient either does already have the drug in his possession or simply there is no need for it at all because another medicine taken regularly by a patient has the positive side effect needed to set in. Even though some studies prove higher numbers, we estimated that at least 10% of medicines prescribed[7] during a hospitalization or within the outpatient care in a hospital (clinic) might be saved if the EHRs were fully implemented in the health system.

RESULTS

We collected data from Slovak acute care hospitals (*n = 102*) of which 13 are state university or teaching hospitals and 89 other hospitals or specialized hospitals. After the selection of institutions for which data were available we chose 48 state hospitals with non-missing data from internal statistical database of the National Health Information Center out of which 13 are university hospitals.

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 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.

In addition, there are also counted two ratios of bed days to hospitalizations and cost of medicines and medicinal products to hospitalizations. Higher ratios are generally to refer to a more inefficient use of inputs than lower ratios even though exceptions may apply, which we discuss later.

Output Measures

In our model, the output measures are represented by 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. Understandably, their demand is not driven by changes in inputs of a hospital. It is the inputs which are expected to be optimized in the process of the provision of health care.

We run 6 DEA models to count efficiency scores in time. In two years, 2009 and 2012, we hypothetically assumed that e-health tools, as described above, are implemented in those of 13 university hospitals which did not reach efficiency scores of 1. The same applies to the year 2012. These two models are referred to as *e-2009* and *e-2012* respectively.

We decided to 'theoretically' implement electronic healthcare only in university hospitals which are the biggest in size and provide the highest amount of medical services in Slovakia. Running a model with e-health tools implemented in all hospitals would be useless since weights counted in the radial BCC model would be the same.

The Tab. I represents the development of efficiency scores in our four input/two output BCC model. University hospitals are marked in grey. Names of hospitals are in English followed by their Slovak equivalent separated by an underscore.

Tab. II represents basic statistics of real efficiency scores of 48 hospitals in 2012. 17 hospitals were selected as efficient. The average inputs of efficient hospitals are higher than 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.

In Tab. III there are presented basic statistical outputs for a semi-hypothetical model of 48 Slovak hospitals. In the total of 8 out of 13 university hospitals, identified as inefficient (refer to the Tab. I), were theoretically introduced e-health tools. e-Health 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 hospitals (marked in bold). Even though none of them reached the efficiency level of 1, all of them came nearer to the highest level of efficiency.

By the results of the Tab. III we see that the average numbers of FTEs, bed days and MMD

7 Based on estimations of three Slovak health insurance companies within the CBA. See note 2.

I: *Efficiency scores development of Slovak hospitals in 2009–2012 without and with some e-health tools hypothetically implemented in all 14 university hospitals (marked in grey) in 2009 and 2012*

No.	HOSPITALS (n = 48)/YEAR	2009	e-2009	2010	2011	2012	e-2012
1	Children's UH and Clinics_DFNsP Košice	**0.717926**	0.90812	0.755799	0.680587	**0.735138**	**0.983981**
2	Children's UH and Clinics_FNsP Banská Bystrica	1	1	1	1	1	1
3	Children's UH and Clinics_FNsP Bratislava-Nové mesto	**0.82752**	**1**	0.935208	0.793362	**0.729505**	**0.985646**
4	UH_FN Nitra	1	1	1	1	1	1
5	UH and Clinics_FNsP F.D.Roosevelta Banská Bystrica	**0.898848**	**1**	0.964621	1	1	1
6	UH and Clinics_FNsP J. A. Reimana Prešov	**0.89917**	**1**	0.738557	0.871013	**0.628199**	**0.845523**
7	H and Clinics_NsP Skalica	1	1	1	0.763071	0.742981	0.742981
8	UH and Clinics_FNsP Žilina	**0.848229**	**0.933813**	0.711335	0.626719	**0.556895**	**0.685907**
9	UH and Clinics_FNsP Nové Zámky	**0.836717**	**0.979738**	0.752126	0.669736	**0.612258**	**0.823706**
10	UH and Clinics_FNsP Trenčín	**0.741326**	**0.973466**	0.733709	0.660537	**0.612134**	**0.824537**
11	UH and Clinics_FNsP Trnava, so sídlom Andreja Žarnova 11	**0.915703**	**1**	0.82599	0.672414	**0.602835**	**0.816219**
12	H_Ľubovnianska nemocnica	1	1	1	0.926341	0.996718	0.996718
13	National Endocrinology and Diabetology Institute_NEaDÚ	0.598335	0.598335	1	1	0.625193	0.625193
14	National Institute of Cardiovascular Diseases_NÚSCH	1	1	1	0.968765	1	1
15	H_Nemocnica A. Leňa Humenné	1	1	0.936751	1	0.677885	0.677885
16	H_Nemocnica Alexandra Wintera	1	1	0.935237	1	1	1
17	H_Nemocnica arm. generála L. Svobodu Svidník	1	1	0.906999	1	0.949477	0.949477
18	H_Nemocnica Bánovce – 3. súkromná nemocnica	0.896768	0.896768	0.815353	0.794682	0.803603	0.803603
19	H_Nemocnica Dr. Vojtecha Alexandra v Kežmarku	1	1	1	0.94194	0.848909	0.848909
20	H_Nemocnica Poprad	1	1	1	1	0.987176	0.987176
21	H and Clinics_NsP Brezno	0.853414	0.853414	0.870779	0.80809	0.820017	0.820017
22	H and Clinics_NsP Dunajská Streda	0.90834	0.899612	0.847033	0.929206	0.788688	0.788688
23	H and Clinics_NsP Ilava	0.999238	0.999238	1	1	0.802365	0.802365
24	H and Clinics_NsP Kráľovský Chlmec	0.971802	0.971802	1	1	1	1
25	H and Clinics_NsP Nové Mesto nad Váhom	1	1	1	1	1	1
26	H and Clinics_NsP Partizánske	1	1	1	1	1	1
27	H and Clinics_NsP Spišská Nová Ves	1	1	1	1	1	1
28	H and Clinics_NsP sv. Barbory Rožňava	1	1	0.996218	1	0.719237	0.719237
29	H and Clinics_NsP Sv. Lukáša Galanta	0.853554	0.853554	0.853726	0.813707	0.627851	0.627851
30	H and Clinics_NsP Trebišov, a.s.	1	1	0.826965	0.764306	0.664609	0.664609
31	H and Clinics_Nemocnica Snina	0.917709	0.917709	0.851758	0.821529	0.705351	0.705351
32	H and Clinics_Nemocnice a polikliniky Bratislava-Ružinov	1	1	1	1	1	1
33	H and Clinics_NsP Sv. Jakuba Bardejov	0.74596	0.74596	1	1	1	1
34	Psychiatric H_Psychiatrická n. Michalovce	0.623674	0.623674	0.567733	0.578097	0.339246	0.339246
35	Psychiatric H_Psychiatrická n. Philippa Pinela Pezinok	0.447659	0.447659	0.416853	0.419434	0.346417	0.346417
36	H_Regionálna nemocnica Sobrance	1	1	1	1	1	1
37	Specialized H for Ortopedic Protetics_ŠNOP Bratislava	1	1	1	1	1	1
38	Specialized H_ŠN sv.Svorada Zobor	0.498363	0.498363	0.492595	0.622834	0.502074	0.502074

No.	HOSPITALS (n = 48)/YEAR	2009	e-2009	2010	2011	2012	e-2012
39	Specialized Institute for Tuberculosis and Respiratory Diseases_VŠOÚ ŠÚDTaRCH	0.936736	0.936736	0.876123	1	1	1
40	Central Slovak Institute of Cardiovascular Diseases_SÚSCH	0.925021	0.925021	0.899307	0.962748	0.835298	0.835298
41	UH_UN Bratislava	1	1	1	1	1	1
42	UH_UN L.Pasteura Košice	**0.968356**	**1**	1	1	1	1
43	UH_UN Martin	**0.818508**	**0.973961**	0.741051	0.632269	**0.598165**	**0.804348**
44	H and Clinics_VNsP Levoča	0.921184	0.921184	1	1	0.772563	0.772563
45	H and Clinics_VNsP Lučenec	0.909511	0.909511	1	1	0.944433	0.944433
46	East Slovak Cancer Institute_VOÚ	0.756539	0.756539	0.721104	0.746554	0.679659	0.679659
47	East Slovak Institute of Cardiovascular Diseases_VÚSCH	1	1	1	1	1	1
48	Specialized Geriatric Institute_VŠÚG sv. Lukáša v Košiciach	0.632295	0.632295	0.729926	0.598753	0.509679	0.509679

II: *Input and output data of efficient vs. inefficient facilities for model "2012" with no e-health tools implemented in inefficient university hospitals*

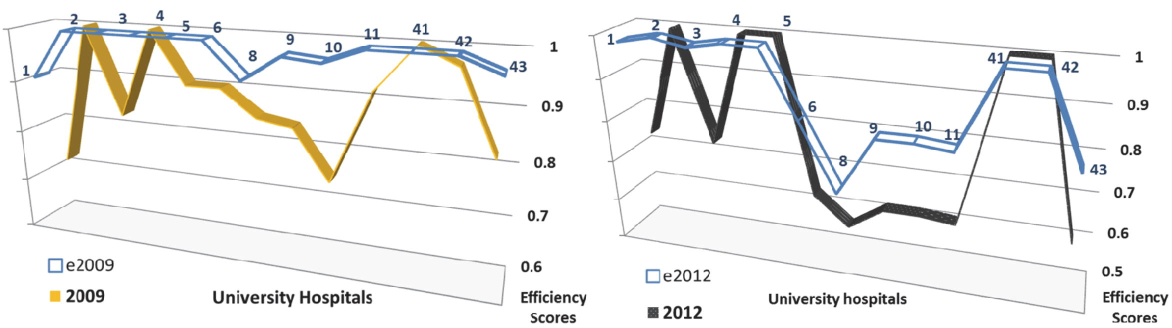
	Beds (n)	FTEs (h)	B-Day (n)	B-Day/Hosp (ratio)	MMD (€)	MMD/Hosp (ratio)	Hosp (n)	OutVis (n)
All facilities (n = 48)								
Real Mean	411	809 678	106 244	7.30	4 325 483	148	15 075	583 244
Real SD	404	1 160 051	112 631	7.36	6 532 345	368	15 856	551 349
Mean with virtual inputs	319	648 501	84 507	5.51	3 663 091	112	15 077	726 077
Efficient (n = 17)								
Real Mean	488	1 112 000	127 742	6.11	6 784 294	142	20 726	896 315
Real SD	587	1 765 138	163 392	3.07	9 441 168	431	23 279	673 079
Inefficient (n = 31)								
Real Mean	369	643 889	94 455	8.05	2 977 103	152	11 975	411 559
Real SD	243	545 408	67 895	8.69	3 472 415	327	8 061	372 859

III: *Input and output data of efficient vs. inefficient facilities for model 'e-2012' with e-health tools implemented in inefficient university hospitals*

	Beds (n)	FTEs (h)	B-Day (n)	B-Day/Hosp (ratio)	MMD (€)	MMD/Hosp (ratio)	Hosp (n)	OutVis (n)
All facilities (n = 48)								
Real Mean	411	757 136	97 909	6.93	4 212 361	146	15 010	583 244
Real SD	404	1 132 233	106 829	7.43	6 467 032	367	15 819	551 349
Mean with virtual inputs	319	652 678	83 906	5.50	3 805 737	116	15 012	737 146
Efficient (n = 17)								
Real Mean	488	1 112 000	127 742	6.11	6 784 294	142	20 726	896 315
Real SD	587	1 765 138	163 392	3.07	9 441 168	431	23 279	673 079
Inefficient (n=31)								
Real Mean	369	562 533	81 549	7.43	2 801 947	148	11 875	411 559
Real SD	243	411 599	47 697	8.84	3 203 097	325	7 909	372 859

input measures, all of the inputs affected by the implementation of e-health tools, decreased when compared to the Tab. II, which proves that electronic health care contributes significantly 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 based on our radial BCC model computed by software which denote the desired amount of inputs in order that each hospital may be identified as technically efficient. Virtual inputs are projected values referred to as efficient targets. Comparing virtual inputs of all facilities in Tab. II with real mean of all facilities



3: *Efficiency scores in university hospitals in 2009 and 2012 with and without e-health tools implemented*

in the e-health model 'e-2012' in III we see that e-health tools lead to the optimization of resources in hospitals, and higher levels of efficiencies are reached.

Fig. 3 illustrates a graphic representation of e-health impact upon university hospitals in 2009 and 2012 in Slovakia. Scores of efficiencies are clearly higher when clinical decision-making is supported by electronic transmission and computer-backed information. Both Tab. I and Fig. 3 do also present still another aspect of the Slovak health system. The average real efficiency score of university hospitals in the model '2009' is equal to 0.89 for all hospitals and 0.88 for university hospitals only, whereas in the real model '2012' the value is equal to 0.81 for all hospitals and 0.76 for university hospitals only. 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).

DISCUSSION AND CONCLUSIONS

There are two most significant theoretical findings of the DEA analysis in the environment of the 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 e-health tools, when fully implemented, do contribute to higher efficiencies and allocation of resources in hospitals.

e-Health, as a promising medium of computerization (paperless form of) processes in the healthcare sector, and having been naturally developed in the wake of an ever-more extensive use of ICT in everyday human activities, is a relatively new means shaping the communication processes of healthcare sectors in developed countries today.

The achievement of a better quality and efficiency performance in the context of e-health implementation has been proved by several studies. 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 lacks assessments of a more thorough analysis aiming at the DEA-super-efficiency of hospitals branded as efficient. 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) There is also a need to further analyse the There is also a need to analyse other hospitals in the region which would make it possible to compare clusters of countries to see how Slovak hospitals perform on international level. Even though a certain level of assessment would be possible, as the approach and results of the study of VARABAYOVA, Y. and SCHREYÖGG, J. (2013), demonstrate, still the kind of data presented in this paper is generally restricted. Still a windows 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 will be examined in further studies.

Efficiency of separate applications is discussed in several studies, with significant positive effects (KORST, 2003; TERRY, 2002) or 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. 4).

SUMMARY

Forty-eight Slovak hospitals, out of which thirteen are university hospitals, were analysed to measure the real yearly hospital efficiency in 2009–2012 and hypothetical hospital 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, 25 hospitals would be efficient compared to 20 hospitals in the same year with real historical efficiency. Out of 13 university hospitals, wherein most healthcare expenses are allocated, 5 of them would obtain the efficiency frontier and the remaining ones would come near to it. In 2012, the real hospital efficiency in providing health care was worse than in 2009 which is primarily attributable to increased indebtedness of Slovak hospitals. With well-functioning electronic healthcare 17 hospitals would be efficient equally as without e-health tools, but their 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.

Acknowledgement

This is to express our gratitude to the National Health Information Center of the Slovak Republic for giving the corresponding author the authorization and access to the non-public internal statistical databases on health statistics for research purposes given in written as of 02/19/2013 and the permission to which is still valid to date. Our gratitude shall be extended also to the Ministry of Health of the Slovak Republic, Section of Informatics, for co-approval of the permission. It is hereby declared that the views, findings or results presented in this report are those of the authors only and do not necessarily reflect those of either of the two institutions mentioned above. Neither the Ministry of Health of the Slovak Republic, nor the National Health Information Center of the Slovak Republic, or any person acting on behalf of either of the institutions is responsible for the information provided in this research paper.

REFERENCES

AMERICAN THORACIC SOCIETY DOCUMENTS. 2005. Guidelines for the Management of Adults with Hospital-acquired, Ventilator-associated, and Healthcare-associated Pneumonia. *Am. J. Respir. Crit. Care Med.,* 171(4): 388–416. Available at: <http://www.thoracic.org/statements/resources/mtpi/guide1-29.pdf>.

ANAP. 2010. Création de valeur par les technologies de l'information et de la communication pour les structures de santé – Synthèse des connaissances. *Agence Nationale d'Appui à la Performance des établissements de santé et médico-sociaux*. [online]. Available at: <http://www.anap.fr/uploads/tx_sabasedocu/creation_de_valeur_par_les_TIC.pdf>. [cit. 2014-09-05].

BANKER, R. D., CHARNES, A., and COOPER, W. W. 1984. Some models for estimating technical and scale inefficiencies in Data Envelopment Analysis. *Management Science,* 30: 1078–1092.

BANNICK, R. R. and OZCAN, Y. A. 1995. Efficiency analysis of federally funded hospitals: Comparison of DoD and VA hospitals using Data Envelopment Analysis. *Health Services Management Research,* 8(5): 73–85.

BATES, D. W. et al. 1997. The Costs of Adverse Drug Events in Hospitalized Patients. *Jama*, 277(4): 307–311.

BATES, D. W., CULLEN, D. J., LAIRD, N., PETERSEN, L. A., SMALL, S. D., SERVI, D. et al. 1995. Incidence of adverse drug events and potential adverse drug events: Implications for prevention. *Jama,* 274(1): 29–34.

BARNUM, D. T. et al. 2011. Measuring hospital efficiency with Data Envelopment Analysis: Nonsubstitutable vs. substitutable inputs and outputs. *Journal of Medical Systems,* 35(6): 1393–1401.

BITRAN, G. R., VALOR-SEBATIER, J. 1987. Some mathematical programming based measures of efficiency in health care institutions. *Advances in Mathematical Programming and Financial Planning,* 1: 61–84.

BLACK, A. D. et al. 2011. The Impact of eHealth on the Quality and Safety of Health Care: A Systematic Overview. *PLoS Medicine,* 8(1): e1000387. DOI: 10.1371/journal.pmed.1000387. [online]. Available at: <http://www.plosmedicine.org/article/info%3Adoi%2F10.1371%2Fjournal.pmed.1000387>. [cit. 2013-12-29].

BUELL, J. M. (n. d.). 2007. Flexing their IT muscles. *Healthcare executive*, 22(5): 16–20. [online]. Available at: <http://www.biomedsearch.com/nih/Flexing-their-IT-muscles/17892113.html>. [cit. 2013-12-29].

CHARNES, A., COOPER, W. W. and RHODES, E. L. 1978. Measuring the efficiency of decision-making units. *European Journal of Operational Research,* 2(6): 429–444.

CHILINGERIAN, J. A., SHERMAN, H. D. 1990. Managing physician efficiency and effectiveness in providing hospital services. *Health Service Management Research,* 3(1): 3–15.

COMMISSION OF THE EUROPEAN COMMUNITIES. 2004. *e-Health – making healthcare better for European citizens: An action plan for a European e-Health Area*. [online]. Available at: <http://ec.europa.eu/information_society/doc/qualif/health/COM_2004_0356_F_EN_ACTE.pdf>. [cit. 2014-06-20].

CROLL, P. R., CROLL, J. 2007. Investigating risk exposure in E-Health systems. Elsevier. *International journal of medical informatics,* 76(5–6): 460–465.

DANSKY, K. H., THOMPSON, D., SANNER, T. 2009. A framework for evaluating eHealth research. *Evaluation and Program Planning*, 29(4): 397–404.

DARKINS, A. et al. 2008. Care Coordination/Home Telehealth: the systematic implementation of health informatics, home telehealth, and disease management to support the care of veteran patients with chronic conditions. *Telemed. J. E-Health,* 14(10): 1118–1126. DOI: 10.1089/tmj.2008.0021. PMID:19119835 [PubMed - indexed for MEDLINE].

DEVARAJ, S., KOHLI, R. 2003. Performance Impacts of Information Technology: Is Actual Usage the Missing Link? *Management Science,* 49(3): 273–289.

EMPIRICA et al. 2005. *Study on Economic Impact of eHealth: Developing an evidence-based context-adaptive method of evaluation for eHealth*. [online]. Available at: <http://www.ehealth-impact.org/download/documents/D6_2_Final_Report_ext.pdf>. [cit. 2012-11-25].

EUROPEAN COMMISSION. 2004. *eHealth is Worth it*. [online]. Available at: <http://www.ehealth-impact.org/download/documents/ehealthimpactsept2006.pdf>. [cit. 2013-12-29].

GARTNER, MHSA SWEDEN. 2009. *eHealth for a Healthier Europe*. [online]. Available at: <http://www.sweden.gov.se/content/1/c6/12/98/15/5b63bacb.pdf>. [cit. 2013-12-17].

HARRISON, J. P. et al. 2004. Efficiency of Federal Hospitals in the United States. *Journal of Medical Systems*, 28(5): 411–422.

HEALTH POLICY INSTITUTE. 2013. *Dlhy do konca roka 2013 presiahnu úroveň 300 mil. €*. [online]. Available at: <http://www.hpi.sk/hpi/sk/view/9606/dlhy-do-konca-roka-2013-presiahnu-uroven-300-mil.html>. [cit. 2014-02-17].

HEALTHCARE INFORMATICS. 2007. *Real-time infection protection*. [online]. Available at: <http://www.healthcare-informatics.com/article/real-time-infection-protection>. [cit. 2014-02-17].

JABLONSKÝ, J., DLOUHÝ, M. 2004. *Modely hodnocení efektivnosti produkčních jednotek*. Praha: Professional Publishing.

KAZLEY, A. S., OZCAN, Y. A. 2008. Electronic medical record use and efficiency: A DEA and windows analysis of hospitals. *Socio-Economic Planning Sciences,* 43(3): 209–216.

KORST, L. M. et al. 2003. Nursing documentation time during implementation of an electronic medical record. *Journal of Nursing Administration,* 33(1): 24–30.

KUOSMANEN, T., POST, T. 1999. *Robust efficiency measurement: Dealing with outliers in Data Envelopment Analysis*. [online]. Available at: <http://www.nomepre.net/timokuosmanen/papers/rem.pdf>. [cit. 2014-09-05].

NÚSCH, a. s. 2003. *Zlyhávajúcich sŕdc pribúda pre lepšiu liečbu*. [online]. Available at: <http://www.nusch.sk/sk/633/pravda-zlyhavajucich-srdc-pribuda-pre-lepsiu-liecbu>. [cit. 2014-02-17].

NCZI. 2014: *Statistical internal database of statistical surveys*. [online]. Available at: <http://www.nczisk.sk/en/Statistical_Surveys/Pages/default.aspx>.

OZCAN, Y. A., LUKE, R. D., and HAKSEVER, C., 1992. Ownership and organizational performance: A comparison of technical efficiency across hospital types. *Medical Care*, 30(9): 781–794.

SHEKELLE, P., WACHTER, R., WINTERS, B. et al. 2013. Making healthcare safer II: an updated critical analysis of the evidence for patient safety practices. *Evid. Rep. Technol. Assess. (Full Rep.),* (211): 1–945.

SHOJANIA, K. G. et al. 2001. Making health care safer: a critical analysis of patient safety practices, *Evid. Rep. Technol. Assess. (Summ)*, (43): i–x, 1–668. PMID: 11510252 [PubMed - indexed for MEDLINE].

SMITH, J. 2004. *Building a Safer NHS for Patients: Improving Medication Safety*. [online]. Available at: <http://www.bvsde.paho.org/bvsacd/cd65/medicationsafety.pdf>. [cit. 2014-02-20].

TERRY, K. 2002. EMRs boost efficiency, too. *Medical Economics,* 79(7): 38–40.

VARABYOVA, Y., SCHREYÖGG, J. 2013. International comparisons of the technical efficiency of the hospital sector: Panel data analysis of OECD contries using parametric and non-parametric approaches. *Health Policy,* 112(1–2): 70–9. DOI: 10.1016/j.healthpol.2013.03.003.

WALTON, R., DOVEY, S., HARVEY, E., FREEMANTLE, N. 1999. Computer support for determining drug dose: systematic review and meta-analysis. *BMJ,* 318(7189): 984–990.

WORLD HEALTH ORGANISATION. 2005. *Preventing chronic diseases a vital investment*. [online]. Available at: <http://www.who.int/chp/chronic_disease_report/full_report.pdf>. [cit. 2014-02-20].

WORLD HEALTH ORGANISATION. 2000. *World Health Report*. [online]. Available at: <http://www.who.int/whr/2000/en/>. [cit. 2014-01-10].

Contact information

Stanislav Sendek: x.sendek@pef.mendelu.cz