"Application of DEA in the environment of Slovak hospitals"

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Application of DEA in the environment of Slovak hospitals

Abstract

The main motivation for the processing of this paper was to present the technical efficiency of health care facilities in the Slovak Republic. The importance of such research derives from the fact that many studies in foreign literature deal with issues of health care efficiency, but at present there is a lack of studies on Slovak health care system and hospitals. Although there are formal indicators evaluating the quality of individual providers, their expressiveness value is very low. Therefore the aim of the paper is to highlight the issue of efficiency measurement in selected general and specialized health care facilities and propose solutions, which aim to improve the efficiency measurement of health care providers. For analysis it is selected to use data envelopment analysis (DEA), both models known as CCR and BBC models. Due to some specific reasons the authors selected only input oriented models. During the analysis it is also identified potential slacks, which could be helpful for selected health care hospitals in case they want to improve their overall efficiency. For the analysis researchers selected period from 2009 until 2013 as the authors had data provided for this period of time. In the period it is analyzed, and recorded a slight increase in the level of efficiency in overall set of monitored health care facilities.

Keywords: efficiency, data envelopment analysis, input-oriented model, healthcare.
JEL Classification: D24, I11, I13.

Introduction

The health sector is considered as one of the fastest growing areas of the economy in most developed countries. Governments (and taxpayers) are investing money in healthcare, either directly or indirectly and therefore expect high quality services (Zgodavova, 2015). In fact, the performance of this sector is different and is characterized by particularly long waiting times, inefficiency, low productivity, stressful healthcare professionals and dissatisfaction of patients. 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 (Turisová, 2014). Measuring the efficiency provides information about existing practices, values and assumptions and can help to develop a systematic approach for identifying deficiencies and to improve future efficiency. Despite the fact that the healthcare systems of countries differ either in the form of funding or organization, common goal is to improve health of the population of the country. Every health system, however, brings with it various problems and the effort of policy makers on improving the efficiency of individual health care providers. Achieving optimal efficiency is crucial for both private and public hospitals in order to preserve the quality of care and the needs of the various stakeholders. Despite the diversity of public and private sectors, whether in terms of issues or stakeholders, decision makers are aware of the fundamental importance of the hospital management as a business unit that must be operated as efficiently as possible. Hospitals with efficient systems can subsequently ensure quality and avoid unnecessary waste of resources.

1. Methods for measuring the efficiency of healthcare facilities

The two most commonly used approaches for measuring the efficiency of hospitals are data envelopment analysis DEA and SFA. A common feature of both methods is that they measure the efficiency as the relation to the best or efficient frontier. Deviations from this limit, measured as the geometric distance, determine the efficiency of the subject (Rajitkanok and Rosenman, 2008). The third most used method is OLS. As to the number of units (DMUs – Decision Making Unit) studies vary. There are a number of studies, which include a sample of hospitals nationwide, as in a Strumanna and Herwartz (2012) study, who investigated 1600 German hospitals. Secondly, we meet with the studies that monitor only a selected sample, as in the case of Tarazona et al. (2010) who examined 22 Spanish hospitals from selected region. Within the literature, however, we have not found paper or research which would determine the exact or the recommended number of units. In principle, this number is tailored to the needs of the country or target region. Monitoring at least two units, however, can ensure the preservation of logic in the process of assessing the efficiency of health care facilities.

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There is an absence of studies either directly from Slovakia or the Czech Republic. Among the authors of such a study in the Czech Republic were Dlouhy et al. (2007), who analyzed a sample of 22 hospitals, but their work did not take into account any environmental effects on the efficiency of the monitored facilities. Szabo and Sidor (2014) studied the performance measurement system-potentials and barriers for its implementation in health care facilities. The study on inefficiency in health care, where Slovakia was also included, was performed by the International Monetary Fund (Grigoli, 2012). They applied DEA method to a sample of 37 countries and in Slovakia they identified significant scope for reducing inefficiency, particularly in resource savings of up to 64%. The OECD confirmed these results by their study (Joumard et al., 2010), which stated that at an unchanged level of expenditure, life expectancy can extend by more than four years. In Slovakia there were also other significant deficiencies recorded, for example in the area of medication and inpatient facilities.

1.1. DEA method. Researchers use a variety of DEA model variants in the process of measuring efficiency. Among the two most common we include CCR model which is proposed by Charnes, Cooper and Rhodes (1978) and BBC model designed by Banker et al. (1989). DEA can be oriented either on inputs or outputs, depending on the purpose of performing DEA. Due to the fact that the hospital has a social responsibility to provide medical treatment and care to the public, assessment of operational efficiency of hospitals should follow especially the input-oriented DEA model, which focuses on minimizing inputs with fixed outputs. Selection of appropriate inputs and outputs has a significant role in the application of DEA model, because the use of various inputs and outputs may result in completely different score for efficiency.

Understanding of efficiency in the DEA models is based on the assumption that each system has certain inputs and outputs. In this case, the production of output is necessary to make the consumption of a number of inputs. The overall efficiency is therefore defined according to the formula in the following understanding: (Kuah et al., 2010; Cooper et al., 2007).

$$E_i = \frac{EX_i}{IM_i}, \quad (1)$$

where E_i is a measure of the efficiency of the unit (DMU), EX_i represents the volume of the unit outputs and IM_i represents the volume of the unit inputs.

1.2. Selection of a suitable DEA model. In terms of DEA model it is necessary to select suitable model to be used. This choice may to some extent also have an effect on the actual outcome. In theory we meet with both the input and output oriented models, depending on what can be handled from the perspective of the evaluator. On this basis, we can distinguish:

1. input-oriented models – expect maintaining the same output with fewer inputs (CCR, BCC);
2. output-oriented models – expect maintaining the same input at higher outputs (CCR, BCC);
3. additive models – are a combination of previous models (SBD).

A separate chapter when deciding on the use of models is the use of a so-called tracking of returns to scale. In this case, we focus on whether the impact of revenue growth leads to changes in their relation to the volume of inputs or not and therefore whether the ratio of output and input is constant or by changing volume of output this ratio is changing. On this basis, according to Majorová (2007) we may define the following typical procedures:

1. constant returns to scale;
2. variable returns to scale.

CCR DEA model is based on historically oldest design that started to be used. They represent an acronym names of the founders. We assume that there are analyzed *n* units (DMU). For these units *m* inputs and *s* outputs are used. For these inputs and outputs there is a set of weights of individual inputs and outputs that are marked as v_i *a* u_i. Then the efficiency of each unit can be detected through the use of linear programming tools through a set of relational equations that are presented in the next section, namely:

$$\begin{aligned} &e_0 = max \sum\nolimits_r u_r y_{r0}. \\ &s.t. \sum\nolimits_i v_i x_{i0} = 1, \quad (2) \\ &\sum\nolimits_r u_r y_{r0} - \sum\nolimits_i v_i x_{i0} \le 0, \\ &u_r, v_i \ge 0. \end{aligned}$$

The disadvantage of this model usage is in constant returns to scale, which in practice is often not confirmed. Therefore, there is progress in the development and application of DEA models that prompted the expansion of these models to new conditions and removal of the assumption of constant returns to scale.

BCC DEA model is the second analyzed model, which assumes variable returns to scale and therefore production possibilities frontier is not defined by a straight line but a curved curve. In this case, we define a following equation:

$$\min \theta_0$$
$$s.t. \sum_j \lambda_j x_{j0} - \theta_0 x_{j0} \le 0,$$
$$\sum_j \lambda_j y_{rj} - y_{r0} \ge 0, \quad (3)$$
$$\lambda_j \ge 0,$$
$$\sum_j \lambda_j = 1.$$

In this case we can assume that the unit is effective in the case of defined result of variables, which are $\theta = 1$, $\lambda = 1$ a $\lambda \neq 0$.

2. Object of the research

This paper evaluates the efficiency of general and specialized hospitals in the Slovak Republic. The selected health centers were observed in the period 2009 to 2013 and total sample includes 55 facilities, out of which 37 are general and specialized hospitals. We excluded hospitals that did not have complete data or possibly experienced extreme values. The selected general and specialized hospitals were evaluated and compared with 13 university hospitals and 5 private hospitals.

2.1. Inputs and outputs. Selection of the input and output variables is very complex task. However, the DEA inevitably faced the problem of selecting the appropriate inputs and outputs. Selection of appropriate inputs and outputs has a significant role in the application of DEA model, because the use of various inputs and outputs may result in completely different score for efficiency. In our research selection of inputs and outputs was largely based on previous research, whether in domestic or foreign literature. Overall, we have included in the analysis 6 inputs and 3 outputs, as listed in Tables 1 and 2.

Table 1. Inputs

Input	Label	Explanation
No. of doctors	Plek	Registered number converted to full-time work in professions of doctor and dentist
No. of nurses	PS	Registered number converted to full-time jobs in professions of nurse and midwife
Other stuff	OP	Registered number converted to full-time work - health care workers without professions of doctor, dentist, nurse, midwife
Material costs	MN	Material costs from the income statement - cost of medicines, medical devices costs, costs of additional assortment in the pharmacy, the cost of blood
No. of beds	Plôž	Number of beds in facility to the date 31.12 of reporting period
Costs per bed	NL	The total cost of income statement/beds

Source: own processing.

When identifying inputs, we included the variables of human resources in the form of the number of doctors, nurses and other staff. We have done so primarily because human resources are considered as a key determinant of success in healthcare facilities. Human resources are the carriers of knowledge, skills and know-how, which is an integral part of health services.

Table 2. Outputs

Output	Label	Explanation
No. of treatment days	OD	Total number of days that patients were treated
No. of patients	PP	The number of patients admitted
No. of outpatient visits	AN	Total number of outpatient visits

Source: own processing.

One of the outputs are outpatient visits that are from our perspective, important especially in health promotion and prevention. Visit is understood as the active presence of the patient in the clinic for the purpose of examination, treatment, sampling of biological material, drug prescription or regulatory changes, obtaining findings/results, or for the purpose of administrative effort related to health or healthcare provision.

3. Results

In this part of the paper we will present the results of the efficiency measurement of selected Slovak general and specialized hospitals. In the analysis we applied only input oriented models, assuming that the outputs are represented mainly by the need of services; and individual objectives of healthcare providers should be to minimize inputs. Understanding of efficiency in the DEA models and also in the case of our analysis is based on the assumption that each system has certain inputs and outputs. In this case, the production of output is necessary to make the consumption of a number of inputs. Based on theoretical assumptions, it is clear that the highest degree of efficiency is 1 or 100%. However, it is important to note that the presented analyses have their limitations, which are reflected primarily in the analyzed data set, which does not ensure comparability of health facilities due to the absence of data about specialization of hospitals, geographical location and other influencing factors which may be explanatory in achieving certain efficiency.

The problem of this method is that the efficiency is understood as deterministic and therefore is not expected that there is also the effect of change, which affects effective system. Therefore, any deviation from full effectiveness is due to an error even though it can also be caused by statistical noise (Majorová, 2007). DEA method carries out an assessment of individual DMUs compared with a whole set of units where for each inefficient unit benchmark is identified, which is characterized by a similar combination of inputs and outputs. In our analysis it means that the unit, which achieved efficiency at 100%, it may not actually be effective at 100%. It represents the unit with the best combination of inputs and outputs.

3.1. Input-oriented CCR model. As we already mentioned in previous text, for our analysis we applied input oriented models. First of them is CCR model and the result values are shown in Table 3.

Table 3. Result values of input oriented CCR model

CCR-INPUT					
DMU	2009	2010	2011	2012	2013
V1	92.43 %	90.18 %	82.26 %	88.53 %	92.86 %
V2	96.93 %	88.33 %	86.25 %	89.25 %	89.96 %
V3	75.58 %	76.35 %	77.20 %	77.79 %	82.77 %
V4	100.00 %	100.00 %	100.00 %	97.69 %	100.00 %
V5	92.40 %	96.26 %	88.56 %	83.06 %	81.55 %
V6	100.00 %	70.69 %	71.76 %	70.21 %	65.19 %
V7	87.25 %	87.89 %	83.91 %	81.93 %	77.42 %
V8	86.98 %	82.99 %	83.76 %	85.65 %	83.57 %
V9	100.00 %	98.21 %	93.97 %	94.99 %	92.89 %
V10	97.76 %	82.12 %	82.32 %	86.30 %	83.58 %
V11	78.27 %	64.07 %	86.24 %	97.75 %	87.48 %
V12	86.24 %	83.94 %	78.33 %	80.52 %	79.96 %
V13	97.54 %	100.00 %	98.76 %	99.55 %	100.00 %
V14	67.74 %	69.80 %	84.70 %	83.03 %	82.22 %
V15	89.97 %	88.01 %	92.10 %	90.89 %	97.69 %
V16	77.98 %	75.25 %	76.18 %	74.97 %	76.31 %
V17	100.00 %	100.00 %	91.21 %	82.02 %	97.48 %
V18	67.18 %	67.19 %	69.59 %	68.16 %	71.56 %
V19	100.00 %	81.08 %	69.37 %	80.09 %	88.93 %
V20	91.13 %	81.16 %	78.25 %	77.54 %	82.05 %
V21	100.00 %	79.15 %	90.90 %	89.03 %	87.42 %
V22	100.00 %	97.30 %	96.90 %	85.98 %	87.16 %
V23	100.00 %	98.01 %	92.31 %	100.00 %	100.00 %
V24	100.00 %	100.00 %	100.00 %	100.00 %	100.00 %
V25	100.00 %	100.00 %	95.83 %	88.95 %	87.52 %
V26	75.33 %	66.96 %	91.86 %	94.13 %	100.00 %
V27	82.88 %	84.81 %	81.14 %	81.55 %	82.18 %
V28	100.00 %	96.60 %	87.10 %	85.46 %	81.34 %
V29	100.00 %	69.91 %	49.36 %	49.39 %	73.88 %
V30	100.00 %	100.00 %	100.00 %	96.25 %	90.47 %
V31	100.00 %	86.83 %	89.81 %	75.92 %	100.00 %
V32	100.00 %	100.00 %	100.00 %	100.00 %	100.00 %
V33	87.70 %	81.40 %	78.13 %	73.52 %	66.94 %
V34	100.00 %	90.01 %	78.52 %	75.09 %	91.99 %
V35	90.32 %	78.68 %	76.09 %	75.36 %	74.76 %
V36	62.63 %	60.47 %	60.47 %	72.62 %	74.78 %
V37	84.38 %	78.76 %	78.98 %	87.84 %	100.00 %

Source: own processing.

Out of the 37 hospitals that we evaluated, there are only two hospitals which achieved full efficiency in whole period, V24 and V32. The lowest efficiency was monitored in case of hospital V36, where the efficiency level was 62.63% in 2009 and 74.78% in 2013. Therefore we can say, that we monitored improvement in case of this hospital, what cannot be said about hospital V33, where we monitored decrease in level of efficiency from 87.7% to 66.94%.

As part of our analysis we also identified slacks for hospitals which did not achieve 100% efficiency in observed period. In this paper we present only slacks for 2013. In this case, these are the slacks based on input oriented CCR model, which expects constant returns on scale.

Table 4. Slacks based on input oriented CCR model, 2013

CCR-INPUT 2013						
DMU	PLek	PS	OP	MN	Plôž	NL
V1	6.09	0	0	2 068 319	0	41 299.52
V2	68.16	86.83	76.82	15 490 983	0	141 028.8
V3	3.09	0	0	0	0	2 712.18
V5	16.81	2.56	16.21	0	0	0
V6	2.34	22	13.68	0	0	0
V7	4.64	0	0	0	0	0
V8	1.78	0	40.36	0	0	0
V9	0	40.78	40.28	0	0	0
V10	22.95	0	43.98	0	0	0
V11	0	2.41	13.79	0	0	21 811.58
V12	7.58	2.54	0	0.02	0	0
V14	12.56	2.25	44.87	0	0	10 348.73
V15	2.63	0	20.43	0	0	7 641.12
V16	54.08	136.54	0	24 414 594	0	91 434.74
V17	0.83	0	6.63	0	0	31 503.24
V18	7.88	16.54	0	0	0	0
V19	21.84	1.84	7.29	204 905.1	0	55 295.33
V20	0	2.83	0.6	0	0	4 433.86
V21	6.41	31.19	12.72	0	0	0
V22	44.17	0	142.55	0	0	0
V25	19.15	0	22.85	0	0	0
V27	17.95	1.69	2.85	2 811 243	0	55 203.82
V28	0	19.57	0	6 847 895	0	89 492.94
V29	0	7.99	13.69	0	69.19	8 918.63
V30	0	44.03	0	0	0	8 071.95
V33	14.35	49.59	0	0	9.46	0
V34	0	42.74	4.48	0	0	3 581.06
V35	0	0	23.98	0	0	0
V36	4.55	0	0	513 549.8	0	12 103.31

Source: own processing.

In 2013, hospital V33 reached the lowest level of efficiency (66.94%). Hospital V29, which had the lowest efficinecy in previous year recorded increase in efficiency to level 73.88%. This increase was caused mostly due to the reduction of number of doctors by more than a half and decrease of material costs by 25.03%. Two hospitals in the context of optimization measures should reduce number of beds. In the case of hospital V33 there is a negligible decrease of 9.46 % from the original 453 beds.

3.2. Input-oriented BCC model. Another model that we applied to analyze efficiency of general and specialized hospitals is input-oriented BCC model. As in the model BCC, we observed selected hospitals in years 2009-2013.

Table 5. Result values of input oriented BCC model

BCC-INPUT					
DMU	2009	2010	2011	2012	2013
V1	100.00 %	100.00 %	97.66 %	93.06 %	96.62 %
V2	97.23 %	88.74 %	86.70 %	89.64 %	90.44 %
V3	78.48 %	79.48 %	79.75 %	79.66 %	83.33 %
V4	100.00 %	100.00 %	100.00 %	98.16 %	100.00 %
V5	92.78 %	96.36 %	89.58 %	83.48 %	81.70 %
V6	100.00 %	82.36 %	83.09 %	78.27 %	75.99 %
V7	89.97 %	90.14 %	87.85 %	86.39 %	82.36 %
V8	91.40 %	86.83 %	85.32 %	85.72 %	83.87 %
V9	100.00 %	98.75 %	94.86 %	95.00 %	93.14 %
V10	99.70 %	85.82 %	86.23 %	86.57 %	84.33 %
V11	90.85 %	86.78 %	99.44 %	100.00 %	96.36 %
V12	86.81 %	84.87 %	81.33 %	82.06 %	81.33 %
V13	100.00 %	100.00 %	98.76 %	99.99 %	100.00 %
V14	75.05 %	77.88 %	86.43 %	84.78 %	84.55 %
V15	100.00 %	98.45 %	99.99 %	98.02 %	100.00 %
V16	78.05 %	75.45 %	76.25 %	75.09 %	76.35 %
V17	100.00 %	100.00 %	100.00 %	100.00 %	100.00 %
V18	78.14 %	76.48 %	77.88 %	76.39 %	76.88 %
V19	100.00 %	85.66 %	77.34 %	84.59 %	93.27 %
V20	93.34 %	88.51 %	87.11 %	86.59 %	89.16 %
V21	100.00 %	91.77 %	97.02 %	93.44 %	95.77 %
V22	100.00 %	97.85 %	97.38 %	86.28 %	87.74 %
V23	100.00 %	98.98 %	94.23 %	100.00 %	100.00 %
V24	100.00 %	100.00 %	100.00 %	100.00 %	100.00 %
V25	100.00 %	100.00 %	97.04 %	91.89 %	89.93 %
V26	80.75 %	68.59 %	93.11 %	94.26 %	100.00 %
V27	84.65 %	86.56 %	82.89 %	83.22 %	83.82 %
V28	100.00 %	100.00 %	88.59 %	86.99 %	82.57 %
V29	100.00 %	100.00 %	100.00 %	99.25 %	100.00 %
V30	100.00 %	100.00 %	100.00 %	97.37 %	91.20 %
V31	100.00 %	96.26 %	99.07 %	98.75 %	100.00 %
V32	100.00 %	100.00 %	100.00 %	100.00 %	100.00 %
V33	96.41 %	90.33 %	90.93 %	87.36 %	82.21 %
V34	100.00 %	93.66 %	87.85 %	85.17 %	94.63 %
V35	96.54 %	85.91 %	84.77 %	83.11 %	81.15 %
V36	82.15 %	82.04 %	77.10 %	82.36 %	82.46 %
V37	96.29 %	92.88 %	91.08 %	99.44 %	100.00 %

Source: own processing.

In case of monitored hospitals we can see significant similarity of the results of both models. Therefore, the model identified more efficient DMUs as primarly applied CCR model. In total model identified 3 hospitals, which reach 100% effciency in all monitored years, while CCR model identified only two. Interesting results can be seen in case of hospital V29, which based on CCR model reached low level of efficiency, in years 2011 and 2012 of only 49.36%. BBC model, however, under the assumption of variable returns to scale classified this hospital as effective in up to four reporting periods. Slacks of each input for 2012 are given below.

Table 6. Slacks based on input oriented BCC model, 2013.

BCC-INPUT 2013						
DMU	PLek	PS	OP	MN	PLôž	NL
V1	3.18	0	0	2 293 996	0	0
V2	66.99	87.5	77.95	15 621 404	0	125 437.3
V3	5.76	10.27	0	0	0	0
V5	19.76	24.28	39.69	0	0	0
V6	4.71	0	2.49	0.01	0	0
V7	13.02	0	0	625 212.5	0	0
V8	9.08	0	32.8	0	0	0
V9	0	47.13	41.7	0.38	0	0
V10	25.61	0	49.19	0	0	0
V11	0	0	3.8	26 320.65	0	0
V12	17.82	16.91	0	353 818.6	0	0
V14	12.98	7.69	52.4	166 528.4	0	0
V16	54.02	132.53	2.38	23 942 719	0	81 360.33
V18	12.45	0	2.18	388 746.8	0	0
V19	17.09	0	7.08	322 516.4	0	6 201.8
V20	0	13.87	0	163 385.1	0	0
V21	6.5	0	0.23	0	0	0
V22	48.69	0	113.79	0.03	0	1 015.27
V25	23.89	0	23.62	0	0	0
V27	15.51	0	1.76	2 569 331	0	9 697.33
V28	0	5.63	2.13	5 311 873	0	22 119.5
V30	0	48.75	0	14 214.5	0	0
V33	0	4.53	0	346 711.3	0	0
V34	0	40.14	0.23	12 684.9	0	0
V35	9.44	15.63	30.81	103 214.5	0	0
V36	9.46	25.33	0	803 630	0	0

Source: own processing.

In 2013, overall 11 hospitals reached 100% efficiency. One of the hospitals that reached this level for the first time in whole monitored period was hospital V37, which in 2012 had an efficiency of 99.44%. This increase was caused by improvement of all inputs beside number of nurses, as this number did not change in comparison with previous year. If we compare the difference between 2009 and 2013, the most significant positive shift was monitored in case of hospital V26, which improved its efficiency by 19.25% and in 2013 reached 100% efficiency. The opposite situation was in case of V6, which recorded the largest drop in efficiency by up to 24.01% when comparing 2009 and 2012.

Conclusion

Business efficiency, operational efficiency, efficiency of health care facility is a complex issue, which is solved by a range of experts in the field, not only in theoretical but also in practical level. Theoretical knowledge alone is not sufficient, but it is almost necessary to seek ways and new possibilities to measure efficiency and economic performance in such an environment as health care. The health sector faces significant problems throughout the world. New regulations, technologies and emerging organizations are the result of continuous progress and public policy. Managers in health care facilities must constantly meet new challenges and adapt their decision-making processes to changing conditions. A persistent problem costs which rise and quality of healthcare itself, which consistently fails to meet expectations. Quality management is one of the major strategic problems in health care organizations.

Our examination was based on a series of units (DMU), where the efficiency is compared among these units. We consider unit as effective DMU, which reached the efficiency 1 in the monitored year. As we mentioned above, to measure the technical efficiency of medical facilities we used only input-oriented models. To conclude results of general and specialized hospitals in Slovakia, we can mention that they recorded increase in efficiecy, which was mostly casued by the decrease of material costs and costs per bed. Important fact of our analysis is that we did not consider all the variables that could in some way effect final efficiency. The geographical position of hospital and its specialization can also be one of the factors which could effect efficiency of health care provider. Monitoring of additional details could improve results of our anayslis and therefore we will include those in the next reasearch.

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