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Technical efficiency of Slovak general hospitals

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Abstract In this study, technical efficiency of Slovak general hospitals was investigated. The well-known non-parametric Data Envelopment Analysis was used to compare performance of Slovak health care providers. Results are based on four slightly differentiated models. Both CRS and VRS variation with different input approaches were used. Our results suggest low average efficiency in Slovak hospitals in the range 0.45 to 0.62 with great variations in efficiency score between individual Decision Making Units (DMUs). These results are relative without appropriate cross-country comparisons. Furthermore, in type of hospital entity there is no significant difference in efficiency score. However there is not a single efficient DMU in a group of municipality hospitals. Although, these results must be taken with caution due to questionable quality of data, this paper provides some valuable overview on technical efficiency of health care providers.[1]
Keywords: DEA; Hospitals; Efficiency

Introduction

In recent years there, is widespread interest in evaulating efficiency of public services like health care. Meta-type analysis of such studies were done by Hollingsworth (1998, 2003, 2008). In the last paper, 317 publications on the topic of efficiency evaulation in hospital sector were analysed. The meta-type paper claims some prominent results. Firstly, the dominant method is non-parametric DEA, with some malmquist or regression extension. However, parametric SFA methods increased to 20 % share of papers compared to 50 % of basic DEA. Secondly, when compared with American

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hospitals, European hospitals have higher efficient score. This is also true within a particular form. Considering all analysed publications Hollingsworth concluded that public rather than private hospitals seem more efficient. Most studies use output measures of physical performance e.g. days of hospitalization or discharges. However, there is longterm discussion that these variables do not reflect real output of health care industry. The patient's change in health should be somehow considered. Input variables are mainly staff and number of beds as capital proxy. Another approach is to use overal costs as single input (Hollingsworth, 2008). To our knowledge, there is not a single investigated performance of Slovak hospitals. However, there has been some prior research on overall efficiency of health sectors. Institute of Financial Policy analysed sector's effectiveness using OLS model. On estimated life expectancy authors concluded low efficiency of health system with even growing costs for such low performance. The decreased efficiency between years 2003 and 2007 were driven by growing real costs within the sector (Filko, Mach, Zajíček, 2012).

Slovakia has been included in several cross country studies comparing performance of health systems. In the study of health and education performance of OECD countries, Slovak republic performed as inefficient one with score 0.895 for input oriented model and 0.966 for output oriented (Afonso & Aubyn, 2004). However, due to aggregated inputs and outputs used in the study, one can't truly identify drivers of such inefficiency. Secondly, even though that health systems are comparable, the question whether one can consider them as a same with at least similar technology should be asked. There are some other studies that include Slovak healthcare system. However, the efficiency of Slovak health sector scored bellow average (Asandului et. al., 2014). The most recent Country Report on Slovakia from 2017 concluded that the cost-effectiveness of healthcare in Slovakia remains low (European Commission, 2017). In a case of hospitals the debt and low occupancy of care beds had been mentioned.

Several comparable studies have been identified on country level. Linna et. al. examined significant difference in cost efficiency between Norwegian and Finnish hospitals (Linne et.al, 2006). However, such direct comparison of two or more countries on a level of hospital's management is quite rare due to different health systems and hospital financing. Some efficiency measurement have been done in Czechia. The lack of quality and availability of data is the main problem of hospital efficiency studies (Dlouhý, et.al., 2007). Authors further suggest that comparison on level of wards more than hospitals should be done. Several studies in neighbouring Austria have been published. Hofmacher et.al. investigated change in efficiency of disaggregated wards for the time period 1994 - 1996. However, the ward level is much more informative. Secondly health system in Austria is using special credit points for different diagnosis. In such cases, output is more accurate. There is significant differences in using discharges and inpatient days compared to credit points for DRG type of financing (Hofmacher et. al. 2002).

The rest of the paper is organized as follows: Section 2 explains the background of Slovak healthcare system. Section 3 focuses on SBM model and SBM efficiency. Further part some descriptive statistics on inputs and outputs data is shown. Results and conclusion are last parts of the paper.

1 Beckground

Health spendings in Slovakia have been estimated to have accounted for 6.9 % of GDP, which is bellow 9 % average of OECD members in 2016 (OECD, 2017). From comparable countries of so-called Visegrad-four only Poland had lower share of GDP as an expenditure on health care. However, all four Visegrad partners are bellow the OECD's average and same is true for health expenditures per capita. Health system in Slovakia is based on universal coverage with some out-of-pocket payments e.g. co-payments for prescribed pharmaceuticals, dentists care or spa treatment. Identification of cost inefficiency and containment of spendings in hospital care became major policy goal for Ministry of Health and involved institutions. Hospital care, as a significant part of health system, has had growing costs. Main driver has been a rise in salaries after the strikes in 2014.

Health Systems in Transition study identified several categories for improvement in hospital care. Firstly, there is an urgent need for debt settlement, since most of public hospital accumulated considerable amount of debts. Secondly, modernization of hospitals is necessary and should be considered as priority. According to authors the technical infrastructure of hospitals is outdated with average age of 35 years. The differences in built-up areas also contributed to total costs of hospitals. General hospitals have around 30 buildings within the land with up to 81. The burden of investments and renovation is on providers itself, mainly covered by health insurance funds. Ministry of Health provides coordination of EU funds, yet due to bureaucratic lag and other difficulties the estimated impact on overall health care system is small.

The hospital care can be divided between in- and outpatient service. Inpatient care is defined as a care for patients, that require continuous treatment for at least 24 hours. To second category belong patients that are not hospitalized overnight and mostly cared in polyclinics. Most of such clinics are part of hospitals and clear separation is not easy. Another argument why one should not separate between in- and outpatient care within hospitals and polyclinics is shared time of specialists between their practices and working at inpatient facilities e.g. gynaecologists assist in giving birth and perinthal health care (Smatana et.al., 2016). There is a huge difference in evaulationg the capital and human resources. Inherited infrastructure of hospitals is characterized by overcapacity in number of beds. On the other hand, such case is presented in several neighbouring countries also. On the other side in 2015 less than 5 % of total workforce worked in health industry, from which approximately three quarters are medical staffs. There are just two countries in OECD, where total number of staff in health industry decreased between years 2000 and 2015. These countries were Slovakia and Latvia. Main problems within human resources are ageing and outflow of health personal. Roughly 45 % of doctors and 33 % of nurses are 50 years of age or older.

2 Methodology

The main objective of Data Envelopment Analysis (DEA) is to measure an efficiency of Decision Making Units (DMUs) by scalar ranging from zero to one. Furthemore, no assumptions on functional form are needed. DEA also allows to handle multiple input and multiple output framework. (Luptáčik, 2009) The main concern then is appropriate choice of inputs and outputs. The most common approach in efficiency publications is to use Charnes-Cooper-Rhodes (CCR) model, that deals with a ratio of inputs and outputs of specific DMU to all DMUs. Such a programme can easily be transformed to linear program using Charnes-Cooper transformation. Any excesses in inputs or shortfalls in outputs are so-called slacks. Optimal DMU has objective value equal to 1 and 0 slacks. Therefore, one needs to consider objective value as well as slacks. Another approach is to use additive model that can handle slacks directly (Charnes el.al., 1985). However, in additive model objective value is not clear efficiency score, but there is possible to distinguish between efficient and inefficient DMUs. Because of such disadvantages in basic CCR model and additive model, hereby Tone's slack-based model (SBM) is used (Tone, 1999).

Let's begin with n DMUs. Input matrix $X = (x_{i,j}) \in \mathbb{R}^{s \times n}$ and output matrix $Y = (y_{i,j}) \in \mathbb{R}^{m \times n}$. In basic model we assume, that all variables are positive so $X > 0$ and $Y > 0$. However, this is not our case, because some of hospitals had one of outputs equal to 0 at the particular year. According to Tone, if the target DMU has function with potential of producing outputs but does not utilize it, such zero output may be replaced by small positive number. Technology is then given by production possibility set

$$P = ((\mathbf{x},\mathbf{y})|\mathbf{x} \geq X\lambda, \mathbf{y} \leq Y\lambda, \lambda \geq 0) \tag{1}$$

where λ is n size vector. Because both constant (CRS) and variable returns (VRS) to scale have been adapted, we can impose further constraint on λ that $\sum_{j=1}^{n} \lambda_j = 1$ for VRS variation. Every $o-th$ DMU$(\mathbf{x}_o, \mathbf{y}_o)$ can be expressed as $\mathbf{x}_o = X\lambda + s^-$ $\mathbf{y}_o = Y\lambda + s^+$, where s^- and s^+ are input and output excesses called slacks and $\lambda \geq 0, s^- \geq 0, s^+ \geq 0$. On basis of slacks we can now define index ρ:

$$\rho = \frac{1 - (1/m) \sum_{i=1}^{m} s_i^- / x_{io}}{1 + (1/s) \sum_{i=1}^{s} s_r^- / y_{ro}} \tag{2}$$

index ρ is range $[0, 1]$. Numerator is a mean reduction rate of input, ergo input inefficiency. Similarly for denominator we have the mean expansion rate of outputs so output inefficiency. ρ is product of input and output inefficiencies.
To estimate efficiency of $o-th$ DMU we set following program.

SBM:

$$\begin{aligned}
\text{minimize} \quad & \rho = \frac{1 - (1/m) \sum_{i=1}^{m} s_i^- / x_{io}}{1 + (1/s) \sum_{i=1}^{s} s_r^- / y_{ro}} \\
\text{s.t.} \quad & \mathbf{x}_o = X\lambda + s^- \\
& \mathbf{y}_o = Y\lambda - s^+ \\
& \lambda \geq 0 \\
& \mathbf{s}^- \geq 0 \\
& \mathbf{s}^+ \geq 0
\end{aligned} \tag{3}$$

Such program can be transformed using Charnes-Cooper transformation (Charnes and Cooper, 1962). If we use $t(> 0)$ to both numerator and denominator there will be no change in value of ρ. We can adjust t to get 1 in denominator. Therefore we can move denominator to constraint. New objective is to minimize sole numerator:

$$\begin{aligned}
\text{minimize} \quad & \tau = t - (1/m) \sum_{i=1}^{m} t s_i^- / x_{io} \\
\text{s.t.} \quad & 1 = t + (1/s) \sum_{i=1}^{s} t s_r^- / y_{ro} \\
& \mathbf{x}_o = X\lambda + s^- \\
& \mathbf{y}_o = Y\lambda - s^+ \\
& \lambda \geq 0 \\
& \mathbf{s}^- \geq 0 \\
& \mathbf{s}^+ \geq 0
\end{aligned} \tag{4}$$

There is still non-linearity in objective function. Still, another transformation is possible such that:
$\mathbf{S}^{-} = t\mathbf{s}^{-}$, $\mathbf{S}^{+} = t\mathbf{s}^{+}$ and $\Lambda = t\lambda$ then SBM become linear program with optimal solution $(\tau^*, t^*, \Lambda^*, S^{+*}, S^{-*})$ where $\tau^* = \rho^*, \lambda^* = \Lambda^*/t^*, \mathbf{s}^{*-} = S^{-*}/t^*, \mathbf{s}^{+*} = S^{+*}/t^*$.

SBM-efficient DMU is only when $\rho = 1$, that is equivalent to $\mathbf{s}^{*-} = 0$ and $\mathbf{s}^{*+} = 0$.

Furthermore, it can be proven that SBM-efficiency is not greater than radially measured CCR-efficiency, so DMU is SBM efficient only if it is CCR-efficient (for more see Tone, 1999).

3 Data and variables

Some informations and descriptive statistics should be provided. Firstly, all state-owned hospitals (11) were excluded from dataset. These seems to have different technology. Not only they provide teaching, but also some specialized wards are gathered within.

In all models two outputs and two inputs, or even single input have been used. For robustness of results two different input approaches have been used. In a question what kind of inputs to use, there is a general agreement through literature to use physical variables number of beds and staff. However, in second model single input - operational costs has been used for some robustness check. Operational costs are mainly wages, and other daily maintenance. Any kind of capital costs are excluded. Within outputs on the other hand there exists a discussion whether the number of interventions and patients can be treated as acceptable output. Some measurement in change of patient's health should be considered. Due to a lack of data only hospitalization and number of interventions have been used.

The dataset contains 51 hospitals with three different types of entity. Some statistics on number of these categories can be seen in Table 1.

Table 1: Type of entity

Private (P)	27
Non-profit (NO)	16
Contributory organisation (CO)	8
Total	51

Table 2 provides summary statistics according to these categories. There is no statistically significant difference in mean of inputs or outputs between different types of entities.

Table 2: Summary Statistics

	mean	sd	min	max
CO_Empl	607	256.6387	191	899
NO_Empl	399.5	284.4902	31	1135
P_Empl	471.0741	304.1022	33	1289
CO_Beds	330.125	149.4814	95	517
NO_Beds	230.5625	156.4331	62	615
P_Beds	275.8148	183.7471	30	672
CO_Inter	2185.625	1029.311	349	3412
NO_Inter	1495.375	1707.274	0	5921
P_Inter	1922.37	1616.495	0	6224
CO_Hospit	9675.375	4359.41	2690	14372
NO_Hospit	7198.188	5163.325	1063	21027
P_Hospit	7961.148	5705.752	366	20398
CO_Costs	1.62e+07	7543770	4009241	2.61e+07
NO_Costs	9957826	7707534	1163335	3.09e+07
P_Costs	1.32e+07	9465261	1132795	4.17e+07

As can be seen on Table 3 there is high correlation not only between inputs and outputs, but also between two different input approaches. Correlation up to 0.966 within employees and operation costs suggests that dominant part of such costs are most likely wages.

Table 3: Correlation matrix

	Costs	Empl	Beds	Inter	Hospit
Costs	1				
Empl	0.966***	1			
Beds	0.858***	0.899***	1		
Inter	0.841***	0.870***	0.791***	1	
Hospit	0.782***	0.866***	0.899***	0.806***	1

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Data on inputs and outputs are mainly from INEKO web page. INEKO is a non-governmental non-profit organization established in support of economic and social reforms. For one of their project they collected data on transparency of hospital's management that includes also these informations. There are few things to mention. Firstly, there exists a difference in number of beds according to informations from different health insurance companies (HIC). This is possible because not all HICs have agreement with all wards within hospitals. There should be mentioned, that number of beds is not any official indicator for HIC as well as for Ministry of Health so exact number can be slightly different. If there exists difference in no. of beds maximum value is used in dataset.

Operational costs and number of employees are informations from yearly reports gathered from Finstat web page. We are fully aware that there should be distinguished between medical and other staff, despite this was not available currently.

Table 4: Possible improvements of data

Inputs	separate cathegories of personal
Outputs	to use specific diagnosis more then general hospitalization
DMUs	ward level more than aggregated hospitals
Overall	be able to separate between in- and outpatient care

In table 4 some possible improvements on inputs, outputs and DMUs are provided. On the other hand, even limited analysis with these data is better than no analysis at all.

4 Results

Four models have been used to evaluate efficiency of Slovak hospitals. CRS and VRS variation and two input approaches. Table 5 provides some introduction to these models.

Table 5: Efficiency summaraize

Model	Inputs	Outputs	Returns to scale
SBM_C_22	employees, beds	hospitalization, interventions	CRS
SBM_V_22	employees, beds	hospitalization, interventions	VRS
SBM_C_21	operational costs	hospitalization, interventions	CRS
SBM_V_21	operational costs	hospitalization, interventions	VRS

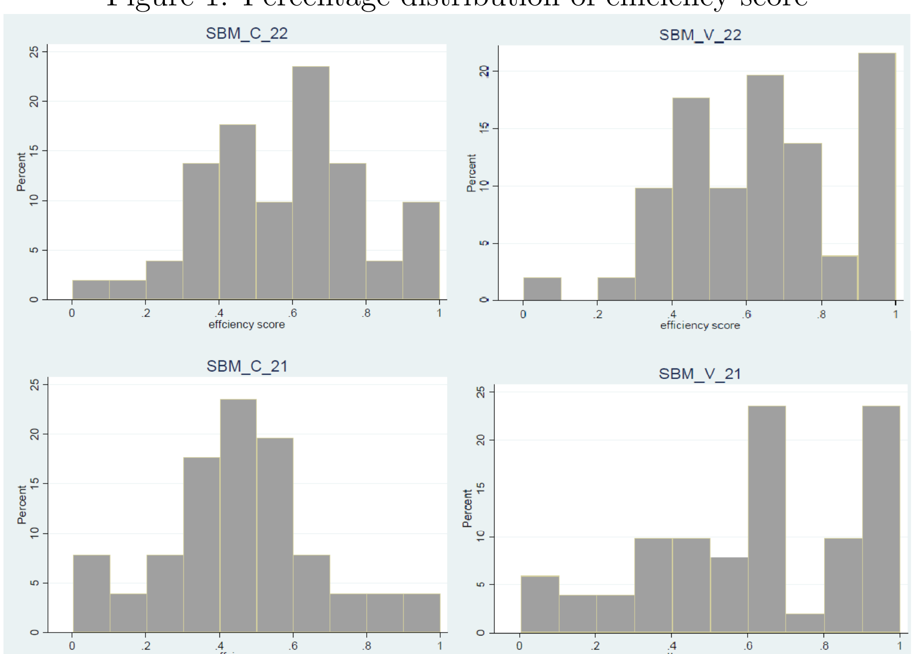
According to results, there seems to be low average efficiency for all model variations. More efficient hospitals are presented in two input, two output model than in the model with single output. Anyhow, there is not significant difference in median score between different return to scale models. On the other side, there is significant difference within CRS variation. There is more variations in efficiency score in operational costs version of inputs. Fewer number of efficient DMUs in VRS models is understandable due to set up of model, where VRS variation better take into consideration the size of a hospital. For deeper understanding of results some exogenous factors are considered.

Table 6: Efficiency summaraize

	Efficient DMUs	mean	sd	min	max
SBM_C_22	5	.5855424	.2284379	.00209	1
SBM_V_22	10	.6497206	.2375638	.00261	1
SBM_C_21	2	.4561335	.2210015	.00365	1
SBM_V_21	8	.6273839	.2834255	.00476	1
Observations	51				

Percentage distributions of individual DMUs can be seen in Figure 1.

Figure 1: Percentage distribution of efficiency score



Results suggests some difference in efficiency score between different types of entity. Firstly, there is no single efficient DMU between municipality hospitals. The average efficiency score in case of contributory organizations is the lowest in all variations of models. There is much higher variations in case of non-profit and private hospitals than in contributory one. However, this can be partly explained by low number of observations (8) in this type of DMUs compared to private (27) and non-profit (16). Fewer efficiency score of contributory organizations in case of CRS means, that there is some difference in size of these hospitals (same can be seen in Table 4). To test overall efficiency of municipality hospitals compared to other types of hospitals wilcoxon rank-sum test was used. Within significance level of 0.05 we can not reject null hypothesis of significant difference in median between the entity groups. In Table 7 p-value can be find in parentheses (for more on non-parametric statistics and DEA see Cooper et.al, 2006)

Table 7: Summary Statistics according to entity type

	mean	sd	min	max
CO_SBM_C_22	.53435	.1086421	.32067	.64767
NO_SBM_C_22	.5743731(.4260)	.2435579	.00209	1
P_SBM_C_22	.6073293(.3454)	.2481461	.11959	1
CO_SBM_V_22	.5943287	.123767	.34852	.70246
NO_SBM_V_22	.6098944(.6241)	.2643507	.00261	1
P_SBM_V_22	.6897337(.3846)	.2459853	.28084	1
CO_SBM_C_21	.429555	.0660928	.32726	.53662
NO_SBM_C_21	.4687212(.4260)	.2464669	.00365	1
P_SBM_C_21	.4565493(.7237)	.2395608	.0284	1
CO_SBM_V_21	.57928	.1242627	.32977	.69723
NO_SBM_V_21	.6459362(.6676)	.2803406	.00476	1
P_SBM_V_21	.630643(.4087)	.3225645	.02874	1

5 Conclusion

This study revealed low average technical efficiency of Slovak hospitals for both types of models with different inputs used. Cross country comparison is not possible due the lack of data and relative approach of DEA, but from Hollingsworth's meta-analysis the average score seems to be higher across countries. There is a considerable variations between hospital's efficiency score. While there is no statistically significant difference in a size of hospitals, VRS variation of model has higher efficiency than CRS. Furthermore, the hypothesis about a same efficiency score based on entity type could not be rejected. Even though there is not a single efficient DMU between municipality hospitals.

DEA methodology is useful tool for comparison of similar subjects, yet one needs to be aware how sensitive the approach is on the data used. In this particular study data are gathered from publicly available sources. There exists difference within inputs and outputs used across different sources as well as no clear explanation how the data were collected. More precise informations should be used with accent on ward more than hospital level.

There are several possibilities how to continue with research. Apart from the better dataset one can adjust qualitative informations about hospitals that are available. With such data some research about the trade-off between efficiency and quality can be done, similar to Almeida & Fique paper (Almeida & Fique, 2011). Furthermore, panel more then cross-section data should be used to intertemporal comparison. Mostly a question of different efficiency between entity types could be answered thanks to some panel data. There is also discussion about overcapacity in number of beds and low number of physicians and nurses in some regions. Some ex-ante evaulation of possible mergers could be done using methodology similar to Kristensen & Bogetoft approach (Kristensen & Bogetoft, 2010). At least but not last, there is some possibilities to compare efficiency score even on hospital level. Due to previously common state with Czech Republic health care systems and financing systems seems to be comparable. Czech hospitals could wider sample size and some cross country comparison is possible at least between these countries.

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