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Article

Using the DEA method to optimize the number of beds in the Slovak hospital sector

Ekonomický časopis

Using the DEA Method to Optimize the Number of Beds in the Slovak Hospital Sector[1]

*Richard KALIŠ – Erika STRACOVÁ**

Abstract

The Slovak hospital sector is characterized by overcapacity in the total number of beds due to inherited infrastructure. In this paper, we use the Data Envelopment Analysis technique to optimize the number of beds for 62 Slovak hospitals. Models with variable and constant returns to scale are used. Moreover, our models account for the quality of hospital care as well as the long-standing problem of a low number of medical staff. Based on the calculated technical efficiency, the number of beds could be decreased by 20% to 33% while keeping other variables constant at current levels. A reduction of up to 10% in the total number of beds would be satisfactory in roughly 30% of all hospitals.

Keywords: *data envelopment analysis, beds, general hospitals*

JEL Classification: I11, G18, C44

Introduction

There has been a widespread interest in the Slovak healthcare sector. Recently, hospitals in Slovakia have been attracting increased attention in terms of health expenditures.

According to the Health at a Glance study, health expenditures in 2016 accounted for nearly 7% of the Slovak GDP. This proportion is significantly below the OECD average of 9%. Compared to 2013, this figure was 7.9% and the OECD average was higher by only 0.3%. These numbers indicate convergence in healthcare expenditures, but the trend in output indicators, like life expectancy, remains hidden. Between 1970 and 2015, the OECD life expectancy at birth

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increased on average by more than 10 years from 70 to 80.6 years. In contrast, in Slovakia the life expectancy fell short of the OECD average, reaching only 77 years (OECD, 2017). Despite the convergence in healthcare spending, it is necessary to investigate this issue.

The healthcare system in Slovakia is based on the universal coverage with some out-of-pocket payments e.g. co-payments for prescribed pharmaceuticals, dental care and spa treatments. The identification of cost inefficiency and containment of expenditures in hospital care has become a major policy goal for the Slovak Ministry of Health. Hospital care, as a dominant part of the health system, has been recently characterised by its growing costs. The main driver of such growth is the rise in salaries after doctors' strikes in 2014. As much as 75% of all expenditures in the Slovak health care sector is spent on three categories: medicines, inpatient care and outpatient care. In 2017, the largest part of the expenditures of health insurance companies (HIC) was spent on inpatient care (28%). Then, 24% was spent on medicines and 23% on outpatient care (Ministry of Finance of the Slovak Republic and Ministry of Heath of the Slovak Republic, 2018).

Hospital care can be divided into inpatient and outpatient care. Inpatient care is defined as care for patients requiring continuous treatment for at least 24 hours. The outpatient care category is for patients who are not hospitalized overnight and mostly diagnosed in clinics. Most of these clinics are parts of hospitals, so a clear separation is not easy. Another argument why inpatient and outpatient care within hospitals and clinics should not be separated is the shared time of specialists between their practices and inpatient facilities. As an example, gynaecologists both perform deliveries and provide prenatal health care. Within the Slovak hospital care environment, there is a long-standing difference in the development of capital and human resources. Due to inherited infrastructure, hospitals are characterized by overcapacity in the number of beds. However, the situation is similar in several neighbouring countries. In 2015, less than 5% of the total workforce worked in the health care sector, and medical staff accounted for approximately three quarters of them. Between the years 2000 and 2015, the total number of staff within the health care sector decreased only in two countries in the OECD, namely Slovakia and Latvia. Furthermore, other issues in human resources include ageing and outflow of health personnel. Roughly 45% of doctors and 33% of nurses are 50 years of age or older (Smatana et al., 2016).

Smatana et al. (2016) further identified several areas in which the efficiency of hospital care could be improved. First, there is an urgent need for debt settlement since most of public hospitals accumulated a considerable amount of debt. Also, hospitals need to be modernized. The technical infrastructure of hospitals is outdated reaching an average age of 35 years. The differences in built-up areas also contributed to the total costs of the hospitals. General hospitals have an average of 30 buildings on one site, in one case reaching up to 81. The burden of investments and renovations is carried by the providers themselves and it is mainly covered by health insurance funds. The Ministry of Health coordinates European Union funding, but due to bureaucratic lag and other difficulties, the estimated impact on the overall health care system was small. Furthermore, as mentioned before, the high number of unused beds was identified as one of the key issues in the Slovak hospital sector. In the late 1990s, Slovakia had one of the highest numbers of acute beds per person in Europe. Since then, there were several reductions: first between 2000 and 2011 and then between 2011 and 2014. The total number of beds was reduced by 30%. According to the Strategic Framework for Health document, another dramatic reduction in the number of beds is planned. Between 2014 and 2030, the number of beds is expected to fall by up to 50% of the current state, which is 11,000 in absolute terms (Ministry of Heath of the Slovak Republic, 2013).

Therefore, the aim of our paper is to propose a DEA model specific to the Slovak hospital care system. Using our model, we calculate the optimal efficient number of beds, ensuring that the other variables remain unchanged at the current level.

The rest of the paper is organized as follows: Section 1 presents earlier literature and background concerning the Slovak health care system as well as DEA literature dealing with the healthcare sector. Section 2 introduces basic and augmented models. Some descriptive statistics on inputs and outputs are provided in the subsequent part of the paper. The last sections contain results and conclusions.

1. State of Literature

The current section can be divided into two sub-categories. First, some information on previous studies and papers dedicated to the Slovak healthcare system is presented. Furthermore, DEA literature in the field of interest is reviewed.

To our knowledge, some investigation of the Slovak health care system and hospital efficiency has already been done. Recently, the paper by Štefko et al. (2018) evaluated the technical efficiency of healthcare on the regional level. Using the window method for intertemporal analysis, the authors investigated whether there was a significant change in efficiency after the gradual addition of specialized medical equipment, e.g. CT or MR. According to the authors, the answer seems to be negative. The DEA models did not reveal any impact of specific technologies on health care in terms of efficiency (Štefko et al., 2018).

Some comments on the results: First, the regional level (NUTS 3) seems to be too highly aggregated for a detailed analysis of using medical equipment. Furthermore, it is not clearly visible where the authors expect to get positive impact by additional medical equipment. The technology is described by used inputs and outputs. The outputs – bed occupancy and average nursing time in days – seem not to be related with the quantity of medical equipment. Some measurement of quality should be included, e.g. re-operating due to problematic post-operation care, etc. Most importantly, as mentioned in Chilingerian and Sherman (2004), absolute data should not be mixed with relative data within the same model. As mentioned before, the authors not only used outputs as bed occupancy rate and ratio of treatment days to the total number of patients, but at the same time, they used the input of total number of beds in a health facility.

Among previous papers, the efficiency evaluation of the Slovak healthcare sector was done by Sendek (2014) and Sendek, Svitálková and Angelovič (2015). Both papers used the basic model with variable returns to scale assumption. These models are input oriented and use hospital-level data. The results show that smaller hospitals seem to be more efficient than large university hospitals. Furthermore, authors ran several scenarios including potential e-health systems and measured the change of efficiency. Another analysis of efficiency was also done by the Institute of Financial Policy. Authors investigated the sector's effectiveness using the simple ordinary least squares econometric model. Regarding estimated life expectancy, the authors concluded that the efficiency of the health system was low with even growing costs for such low performance (Filko et al., 2012).

Furthermore, Slovakia has been included in several cross-country studies. Particularly in the study of OECD countries, Slovakia came out as inefficient with the efficiency score of 0.895 for an input-oriented and 0.966 for an output-oriented model (Afonso and Aubyn, 2005). However, due to aggregated inputs and outputs used in this study, the drivers of inefficiency cannot be truly identified. Second, even though the health systems are comparable, it needs to be discussed whether we can really see them as a similar technology. The result is quite similar in Asanduluia et al. (2014), where the efficiency of the Slovak healthcare sector scored below average. The most recent Country Report on Slovakia from 2017 concluded that the cost-effectiveness of healthcare in Slovakia remains low (EC, 2017). The mentioned causes included the debt and the low occupancy of care beds.

It is also important to look at some information on the evolution of the DEA analysis within the field of healthcare. Firstly, an outstanding meta-type analysis of such studies has been done by Hollingsworth (1999; 2003; 2008). The analysis included 317 publications on the topic of efficiency evaluation in the hospital sector. The study offers some prominent results. Most importantly, the dominant method within the field of efficiency in healthcare is a non-parametric DEA. In addition, some Malmquist index extension or even a second stage regression is used. However, the parametric SFA method is also on the rise. This method already accounts for 20% of publications compared to 50% in the case of the traditional DEA. Moreover, comparing American and European hospitals, the European ones seem to have higher efficiency scores. The same is true regarding the form of entity. Considering all analysed publications, Hollingsworth concluded that public rather than private hospitals are more efficient. Most of the studies use output measures of physical performance e.g. days of hospitalization or discharges. However, there is a long-term discussion that these variables do not reflect the real output of the health care sector. The patient's change of health should be somehow considered. Input variables are mainly labour and the number of beds as capital proxy. Another approach is to use the overall costs as single input (Hollingsworth, 2008). The fact that regularly used outputs do not include the true change in the patient's condition seems to play an important role. In the end, the problem of outputs has not been solved properly yet. However, controlling for some qualitative aspect of production as well as the overall quantity could slightly overcome this problem. More recent meta-type analysis has been published by Kohl et al. (2018). In their analysis, the 262 papers applying DEA in healthcare were investigated. According to these authors, the paper works as a roadmap and provides a comparison of the used models as well as the choices of inputs and outputs. Most of the papers used the basic model and only few of them enhance the methodology in some way. Even though most of the papers are policy oriented, only one has been found to be applied into practice by policy makers. Such an exception is Rouse and Swales (2006), who used DEA to set a price for hospital services in New Zealand.

While the Data Envelopment Analysis has several advantages (see section on methodology), the main disadvantage remains the strong volatility depending on chosen inputs and outputs. For this purpose, an overview of similar papers and applications is presented. We start with the matter of variables. The most common inputs are some capital proxies e.g. beds, the area of a hospital, the number of buildings or the labour force of a hospital. The last of the mentioned inputs should be ideally divided into several categories, e.g. administrative and medical staff or even doctors and nurses. The most detailed information on personnel can be found in Sheikhzadeh et al. (2012). The labour force in this paper was divided into 5 sub-categories. However, most of the studies used just one or maximum of two categories of labour according to the meta-type analysis. The beds input was used for example in Podgórska (2018), Dlouhý et al. (2007), Hofmarcher, Paterson and Riedel (2002) and many other studies. The less popular substitution for beds is the overall area of a hospital. Another approach is to use medical equipment. In general, these two categories could be considered as one, called equipment and infrastructure, as a proxy for the capital of a hospital. Such approach can be found in Štefko et al. (2018), who used medical devices, while Marshall and Flessa (2009) used equipment depreciation and the total area and Gai et al. (2010) used the estimated value of capital. Furthermore, the operational costs were used in Magnussen and Nyland (2008) or Dharmapala (2009). On the side of outputs, the number of hospitalizations and different types of visits are considered to be a mainstream within the DEA literature on healthcare. The number of outpatient visits was used in Sommersguter-Reichmann (2000). Some studies even include detailed data thanks to the specific healthcare system within the studied country. Weighted visits and hospitalizations can be considered as more preferred. The weights are usually set up by concrete diagnoses. This is the case e.g. in Linna, Häkkinen and Magnussen (2006). This paper is rare also due to the cross-country comparison on the hospital level, more specifically for Norway and Finland. Fewer studies use qualitative aspects. According to the aforementioned meta-type analysis, a lot of studies considered this a major weakness of their analyses. Nayar and Ozcan (2008) used several detailed approaches in order to capture the qualitative aspect. However, such detailed approach seems to be highly reliant on private medical data and insider's knowledge. The approach like the one used by Thanassoulis, Boussofiane and Dyson (1995) can be seen in DEA papers more often. The absolute value of satisfied or very satisfied patients from a survey was used as a quality indicator. Furthermore, survival rate, mortality or even adjusted mortality is a common approach. Such examples can be found e.g. in Bilsel and Davutyan, (2014) with the risk-adjusted mortality or basic mortality rate in Tiemann and Schreyögg (2014). In our paper, we use mortality in absolute terms to capture the quality of provided services within the hospital.

2. Methodology and Models

The objective of the Data Envelopment Analysis is to measure the efficiency of Decision-Making Units (DMUs) by scalar ranging from zero to one. The advantage is that no assumptions on functional form are needed. DEA also allows to handle multiple input and multiple output framework (Luptáčik, 2010). The main concern is an appropriate choice of inputs and outputs. According to the meta-analysis mentioned before, the most common approach is Charnes-Cooper-Rhodes (CCR) model introduced in 1978 (Charnes et al., 1978). The main assumption of the CCR model is a constant return to scale (CRS). In contrast, variable returns to scale allow for some savings due to the size of the unit. Such adjustment was proposed by Banker, Charnes and Cooper (1984). Optimal DMU has an objective value equal to one and at the same time zero slacks.

As already mentioned, another advantage of non-parametric DEA is the possibility to handle multiple inputs and multiple outputs. However, some weights for inputs and outputs need to be defined. To set the weights, linear programming is used.

Let us consider $\boldsymbol{x}$ and $\boldsymbol{y}$ to be the vectors of inputs and outputs, respectively, where $\boldsymbol{x}$ is an *m-size* vector and similary, the $\boldsymbol{y}$ is an *s-size* vector. There is n number of DMUs, where j is the *j-th* DMU. For every *j-th* DMU we have some $\boldsymbol{x}_j$ inputs and $\boldsymbol{y}_j$ outputs. Therefore, matrices $\boldsymbol{X}$ and $\boldsymbol{Y}$ can represent the ordered vectors for all n DMUs. For these matrices we assume that $\boldsymbol{X} \epsilon \mathbb{R}_+^{m\,x\,n}$ and $\boldsymbol{Y} \epsilon \mathbb{R}_+^{s\,x\,n}$, respectively. In other words, we assume that all inputs and outputs are positive.

Before the model itself, the so-called orientation needs to be introduced. An efficient projection of any DMU can be obtained in two directions: (*i*) reducing inputs (therefore input-oriented) or (*ii*) increasing outputs (output-oriented). Due to the fact that our goal is to optimize the number of beds, the input oriented model is used.

The model used in our calculations is BCC-I model, where "I" stands for input oriented. This is the version of the classic model publised in 1984:

$$\begin{aligned} \mathit{min} \quad & \theta + \epsilon(\boldsymbol{e}^T \boldsymbol{s}^x + \boldsymbol{e}^T \boldsymbol{s}^y) \\ \mathit{s.t.} \quad & \boldsymbol{Y\lambda} - \boldsymbol{s}^y = \boldsymbol{y_o} \\ & \boldsymbol{X\lambda} + \boldsymbol{s}^x = \theta \boldsymbol{x_o} \\ & \boldsymbol{e^T \lambda} = 1 \\ & \boldsymbol{\lambda},\ \boldsymbol{s}^x,\ \boldsymbol{s}^y \geq 0 \\ & \epsilon > 0(\text{"}\mathit{Non-Archimedean}\text{"}) \end{aligned} \tag{1}$$

However, as mentioned before, we augmented the model to control the quality. Such an aspect is measured via mortality in absolute terms, and this output should be treated as the so-called undesirable (bad) output. There are several ways how to treat undesirable outputs in DEA models. However, as shown in Korhonen and Luptáčik (2004), efficient units are efficient in all ways. On the other hand, efficiency scores slightly differ. The possibilities of how to treat undesirable outputs within the DEA model are:

a) to treat the undesirable outputs of a treated unit (*o-th* DMU) as an upper bound for the linear combination of other undesirable units. In such case, the undesirable outputs are taken fixed,

b) to treat undesirable outputs as inputs. In such case the DMU reduces inputs and undesirable outputs at the same time,

c) to use the difference between weighted desirable and undesirable outputs. In such case, only desirable outputs are reduced to increase efficiency.

Since we consider mortality as a fully uncontrollable and unfortunate process, we will treat the output as undesirable according to version a). Therefore, the model (1) can be augmented as:

$$\begin{aligned} \min \quad & \theta + \epsilon(\boldsymbol{e}^T \boldsymbol{s}^x + \boldsymbol{e}^T \boldsymbol{s}^g + \boldsymbol{e}^T \boldsymbol{s}^b) \\ s.t. \quad & \boldsymbol{Y}_g \boldsymbol{\lambda} - \boldsymbol{s}^g = \boldsymbol{y}_o^g \\ & \boldsymbol{Y}_b \boldsymbol{\lambda} + \boldsymbol{s}^b = \boldsymbol{y}_o^b \\ & \boldsymbol{X\lambda} + \boldsymbol{s}^x = \theta \boldsymbol{x}_o \\ & \boldsymbol{e}^T \boldsymbol{\lambda} = 1 \\ & \boldsymbol{\lambda}, \boldsymbol{s}^x, \boldsymbol{s}^y \geq 0 \\ & \epsilon > 0 (\text{"}Non-Archimedean\text{"}) \end{aligned} \tag{2}$$

In the case of CRS, we can simply remove the condition of the sum of lambdas (4th row within constraints). As can be seen in (2), to consider the qualitative aspect, one extra row was added to the program. From now on, we will distinguish between desirable (good) outputs as matrix $\boldsymbol{Y}_g$ with their vector of slacks $\boldsymbol{s}^g$ and undesirable (bad) outputs $\boldsymbol{Y}_b$ with slacks $\boldsymbol{s}^b$.

One additional adjustment is necessary to capture the specific environment of the Slovak healthcare sector. As mentioned in the introduction of the paper, Slovakia is one of the two countries with a decreasing trend in the number of medical staff. Furthermore, the age of doctors and medical personnel in general is higher than the average of the OECD. Moreover, the outflow of this labour represents another issue. For this reason, there is no logic to expect further reduction in hospital labour force. Unfortunately, we were not able to distinguish between several types of labour force within hospitals. Therefore, we treat all labour as an uncontrollable input to prevent any reduction. The model looks as follows:

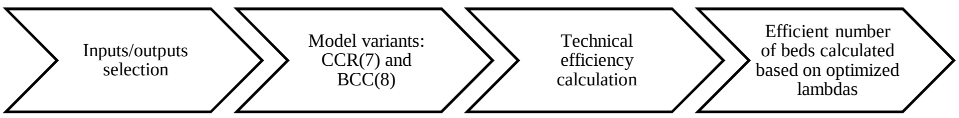
$$\begin{aligned} \min \quad & \theta + \epsilon(\boldsymbol{e}^T \boldsymbol{s}^c + \boldsymbol{e}^T \boldsymbol{s}^u + \boldsymbol{e}^T \boldsymbol{s}^g + \boldsymbol{e}^T \boldsymbol{s}^b) \\ s.t. \quad & \boldsymbol{Y}_g \boldsymbol{\lambda} - \boldsymbol{s}^g = \boldsymbol{y}_o^g \\ & \boldsymbol{Y}_b \boldsymbol{\lambda} + \boldsymbol{s}^b = \boldsymbol{y}_o^b \\ & \boldsymbol{X}_c \boldsymbol{\lambda} + \boldsymbol{s}^c = \theta \boldsymbol{x}_o^c \\ & \boldsymbol{X}_u \boldsymbol{\lambda} + \boldsymbol{s}^u = \boldsymbol{x}_o^u \\ & \boldsymbol{e}^T \boldsymbol{\lambda} = 1 \\ & \boldsymbol{\lambda}, \boldsymbol{s}^x, \boldsymbol{s}^y \geq 0 \\ & \epsilon > 0 (\text{"}Non-Archimedean\text{"}) \end{aligned} \tag{3}$$

In (3), the controllable inputs are $\boldsymbol{X_c}$ and uncontrollable inputs are $\boldsymbol{X_u}$ with corresponding slacks. Again, the CRS version of the model does not include the condition of the sum of lambdas equal to one. Specifically:

$$\begin{aligned} min \quad & \theta + \epsilon(\boldsymbol{e}^T\boldsymbol{s}^c + \boldsymbol{e}^T\boldsymbol{s^u} + \boldsymbol{e}^T\boldsymbol{s^g} + \boldsymbol{e}^T\boldsymbol{s^b}) \\ s.t. \quad & \boldsymbol{Y_g\lambda} - \boldsymbol{s^g} = \boldsymbol{y_o^g} \\ & \boldsymbol{Y_b\lambda} + \boldsymbol{s^b} = \boldsymbol{y_o^b} \\ & \boldsymbol{X_c\lambda} + \boldsymbol{s}^c = \theta\boldsymbol{x_o^c} \\ & \boldsymbol{X_u\lambda} + \boldsymbol{s^u} = \boldsymbol{x_o^u} \\ & \boldsymbol{e^T\lambda} = 1 \\ & \boldsymbol{\lambda}, \boldsymbol{s}^x, \boldsymbol{s}^y \geq 0 \\ & \epsilon > 0(\text{"}Non - Archimedean\text{"}) \end{aligned} \tag{4}$$

To fulfil the aim of our paper, we use optimized lambdas. These identify projections for every evaluated DMU. Based on these lambdas, we can calculate the optimally efficient number of beds. The summary of methods, models and processes can be seen in a simple diagram below.

F i g u r e 1
Diagram of Research Stages and the Model Selection Process



Source: Authors' creation.

We add one more comment on economies of scale assumptions. As mentioned before, the most common model in DEA hospital care literature is the one with the CRS assumption following the VRS version. However, the CRS assumption with the linearity of the production function may seem unrealistic, since at least some savings resulting from the size of the hospital exist. In this case, the VRS variation seems more realistic. Furthermore, the CRS version of the model assumes that if there is some efficient size of the hospital, there must also be a much smaller but still proportional version of the same hospital. Again, this can be difficult to observe. Nevertheless, we decided to follow previous literature, which often uses the CRS assumptions. In this case, the CRS version of the model can be interpreted as the hard scenario that does not allow any size effects within the hospital sector. The VRS version is therefore a mild or soft scenario. Potentially, there is a space to further classify the VRS scenario as the non-decreasing returns to scale (NDRS) model that allows some savings within large-scale hospitals but does not allow linear combinations of small units to exist. For simplicity reasons, we distinguish only between the hard and the soft scenario, i.e. the CRS and the VRS assumptions.

2.1. Data and Variables

In this section, some information on variables and data are provided. In Table 1, we present variables in the structure of controllable and uncontrollable inputs as well as desirable and undesirable outputs.

Table 1

Structure of Variables

Inputs	**Description**	**Variable name**
Controllable	*Total number of beds*	*Beds*
Uncontrollable	*Total number of personnel*	*Employees*
Outputs:		
Desirable	*Total number of hospitalizations*	*Hospitalizations*
	Total number of interventions	*Interventions*
Undesirable	*Total number of deaths – absolute mortality*	*Mortality*

Source: Authors' creation.

Data on inputs and outputs mainly come from the INEKO website. INEKO is a non-governmental non-profit organization established as a support for economic and social reforms (INEKO, 2018). For one of their projects, data on transparency of hospital management were collected. These data include the information used within our paper. There are several things to be mentioned. The main source for INEKO are health insurance companies (HIC). First, there are differences in the number of beds according to information from different health insurance companies. This is possible since not all HICs have an agreement with all hospital wards. We also have to mention that the number of beds is not an official indicator for HIC or even for the Ministry of Health. Therefore, the numbers can slightly differ. If a difference in the number of beds exists, the maximum value is used in our dataset.

Table 2

Summary Statistics of Variables

	mean	**Sd**	**min**	**max**
Employees	767.42	922.94	31	6 176
Beds	402.32	400.02	30	2 569
Interventions	3 496.60	4 810.00	0	30 719
Hospitalizations	12 172.42	12 405.12	366	79 245
Mortality	353.98	358.85	0	2 270
Number of observations	62			

Source: Authors' calculations.

The number of employees is an information received from yearly reports gathered thanks to the Finstat website. The aim of Finstat is to provide a web service to evaluate the financial condition of Slovak firms (Finstat, 2018).

As already mentioned, the dataset includes information on 62 general hospitals. Furthermore, there is a lot of variation among the hospitals. The size of hospitals measured by inputs differs significantly. According to the presented data, there is one outlier – Bratislava's university hospital. Moreover, as can be seen, at least one hospital has a zero value as an output. In such case, to ensure correct functionality of our model, we replace zero with a very small number. Furthermore, there are very strong relations between inputs and outputs.

Table 3

Correlation Matrix of Variables

	Employees	Beds	Interventions	Hospitalizations	Mortality
Employees	1				
Beds	0.970***	1			
Interventions	0.977***	0.953***	1		
Hospitalizations	0.967***	0.982***	0.965***	1	
Mortality	0.917***	0.952***	0.910***	0.939***	1

Note: * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.

Source: Authors' calculations.

3. Results

The results are presented as follows: first, the overall efficiency scores for the CCR and BCC model are presented and compared. Then, the projected values of beds are shown and evaluated. The technical efficiency for both models and the whole sample, as well as projections can be found in Appendix. Some summary statistics are presented within this section as well.

Table 4

Efficiency Score Summary

	mean	Sd	min	max
Efficiency_score_CCR	.723	.187	.312	1
Efficiency_score_BCC	.799	.180	.322	1
Number of observations	62			

Source: Authors' calculations.

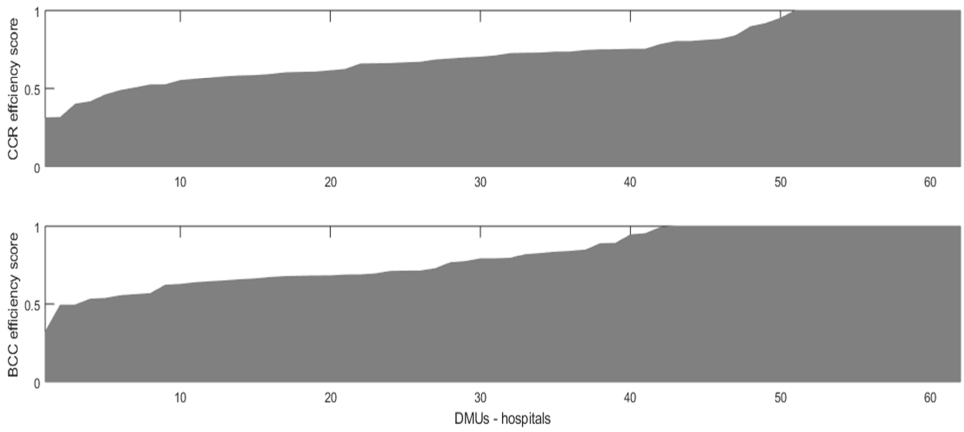
In the case of the CCR variation of the model, we have 6 efficient DMUs. In the case of BCC, 18 hospitals can be considered as efficient according to the specification of our model. Such difference between the number of efficient

DMUs as well as a lower average score in the case of CRS is fully understandable due to the assumptions of DEA analysis. For example, in the case of the BCC version, many large university hospitals are efficient. However, these are not efficient using the CRS assumptions. The same is true for some small units.

The aim of the paper is to project the efficient number of beds in total as well as on the level of individual hospitals. Therefore, we look at Figure 2, which presents the sorted DMUs by efficiency from minimal to maximal (grey area). What is even more interesting in our case are the potential efficiency gains. These can be achieved by reducing the controllable variable, i.e. the number of beds. Such gains are presented as the white area in Figure 2. Again, due to difference in the VRS and the CRS assumption, the white area differs between the two figures. More statistics for the case of reducing the number of beds are presented in Table 4, for both the individual level as well as the whole Slovak hospital sector.

F i g u r e 2

Sorted Efficiency Score (grey area) and Potential Gains by Reducing the Number of Beds (white area)



Source: Authors' calculations.

T a b l e 5

Summary Statistics of the Projected Number of Beds by Hospital and Sector Level

	Hospital level				**Sector level**
	Mean	S.d.	Min	Max	Sums
Beds	402.32	400.02	30	2 569	24 944
Projected beds CCR	289.17	300.62	12.44	1 933.77	17 828
Projected beds BCC	334.33	398.23	30	2 569	20 729
Absolute difference CCR	113	127.77	0	635.23	7 116
Absolute difference BCC	68	78.28	0	455.89	4 215
Number of observations	62				

Source: Authors' calculations.

On average, the number of beds should be reduced by 68 to 113 beds per hospital. In absolute terms, the total number of hospital beds should be reduced from 24,944 to 20,729 in the case of the BCC model or even to 17,828 in the case of the CCR version. In both cases, the other variables – the number of personnel as well as desirable and undesirable outputs – would remain at the current level. The individual reduction of specific hospitals is shown in Appendix. The absolute numbers can be bit misleading due to the differences in the size of the hospitals. Therefore, the distribution of individual reductions in relative terms is presented in Table 6.

Table 6

Distribution of Individual Reductions of Beds in Relative Terms

Efficient reduction (%)	Frequency_CCR	Cumulative %_CCR	Frequency_BCC	Cumulative %_BCC
0	1	1.61	1	1.61
10	13	22.58	22	37.10
20	4	29.03	7	48.39
29	14	51.61	7	59.68
39	12	70.97	17	87.10
49	11	88.71	5	95.16
59	4	95.16	2	98.39
More	3	100.00	1	100.00

Source: Authors' calculations.

According to this table, individual reduction should be up to 30% in 51% of all hospitals in the case of the CCR variation and in less than 60% of hospitals in BCC. Even a much smaller – 10% reduction would be enough for 23% of hospitals in the case of CCR assumptions and almost 40% in BCC to be technically efficient based on the model.

Conclusion and Discussion

According to recent research published by the Ministry of Health of the Slovak Republic, the Slovak hospital system suffers from the overcapacity of unused beds. In our paper, we proposed a DEA model in two variants to calculate the efficient number of beds. Such reduction would keep the current outcomes as well as the quality of provided healthcare service fixed. The outcomes are the number of interventions and hospitalizations. Quality is measured as the absolute value of mortality. We proposed input-oriented models in two variants. Particularly, a CCR version with constant returns to scale and a BCC variation with variable returns to scale. The results differ considerably. Therefore, we divided the results into the soft reduction scenario (BCC) and the hard reduction scenario

(CCR). In such case, between 4,216 and 7,015 beds in hospitals could be removed to allow the current (unchanged) level of outputs. In relative terms, such reduction is estimated to range from 20% to 33% of the total number of current hospital beds. It is not easy to compare the proposed reduction with other studies from different countries due to the specifics of the examined health systems. Therefore, we rather use a time-series comparison to interpret our findings. At the first glance, this could seem drastic and unrealistic. However, between the years 2000 and 2014, the total number of beds in acute care was reduced by 9,000. Moreover, the Strategic Framework of Health expects a further reduction in acute care by another 11,000 until the year 2030 (Smatana et al., 2016), (Ministry of Heath of the Slovak Republic, 2013). Even though the total number of hospital beds in our dataset slightly differs from the total number of acute beds (24,944 vs. 22,959 in 2014) based on the National Centre for Health Information source, the proposed reduction is within the range.

Some shortfalls need to be mentioned. First, the dataset itself. We are fully aware that the data used are from a secondary source and therefore can differ from the official one.

Moreover, even hospital level seems to be quite aggregated. While we assume the same technology across the general hospitals, the opposite could be true. As an example, consider the university hospital. The university hospital has other outcomes to consider e.g. the learning and teaching process or can have some specialized wards different from the average general hospital. Furthermore, we could not evaluate the ward level. Even though we did not include specialized hospitals and institutions e.g. kids, oncology or psychiatric hospitals, a difference in the types of wards within the hospitals is worth considering. Therefore, in further research one should focus on obtaining ward-level data. Another disadvantage of our approach is staff-level data. We were not able to distinguish between medical and administrative personnel. Such differentiation would be more than appropriate in further research. We would expect some inefficiency hidden within such input.

Moreover, the pressure on bed reduction could be currently higher than in the case of more controllable inputs. The question how to measure quality remains open. One possible way to enhance the research is to use the survey made by insurance companies. Some robustness check in terms of the quality measure is necessary. The question is highly connected to differences between wards and therefore many researchers adjust the mortality indicator by risk. And last but not least, an intertemporal comparison within the health sector could be made. The static picture provided here can be easily skewed and only long-term relations could show true results.

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A p p e n d i x A

Number of the Hospital and its Name

Number	Name
1	Nemocnica Bánovce – 3. súkromná nemocnica, s.r.o.
2	NsP Sv. Jakuba, n.o. Bardejov
3	Nemocnica s poliklinikou Prievidza so sídlom v Bojniciach
4	Nemocnica svätého Michala, a.s., Bratislava
5	SI Medical, s.r.o., Nemocnica s poliklinikou Medissimo
6	Univerzitná nemocnica s poliklinikou Milosrdní bratia, Bratislava
7	Železničná nemocnica Bratislava, Novapharm, s.r.o.
8	Nemocnica s poliklinikou Brezno, n.o.
9	Kysucká nemocnica s poliklinikou Čadca
10	Dolnooravská nemocnica s poliklinikou MUDr. L. Nádaši Jégého Dolný Kubín
11	Nemocnica s poliklinikou Dunajská Streda, a.s.
12	Nemocnica s poliklinikou Sv. Lukáša Galanta, a.s.
13	Pro Vitae, n. o., všeobecná nemocnica Gelnica
14	Nemocnica Handlová – 2. súkromná nemocnica, s.r.o.
15	Nemocnica s poliklinikou Hlohovec, s.r.o.
16	Gemerclinic, n.o., Hnúšťa
17	Nemocnica A. Leňa Humenné, a.s.
18	Nemocnica s poliklinikou Ilava, n.o.
19	Nemocnica Dr. Vojtecha Alexandra v Kežmarku n.o.
20	Forlife n.o., Všeobecná nemocnica Komárno
21	Nemocnica Košice-Šaca a.s. – 1. súkromná nemocnica
22	Železničná nemocnica s poliklinikou Košice (Železničné zdravotníctvo Košice, s.r.o.)
23	Nemocnica s poliklinikou n.o. Kráľovský Chlmec
24	Nemocnica Krompachy spol. s r.o.
25	Nemocnice s poliklinikami, n.o., Levice a Topoľčany
26	Všeobecná nemocnica s poliklinikou Levoča, a.s.
27	Liptovská nemocnica s poliklinikou MUDr. Ivana Stodolu Liptovský Mikuláš
28	Všeobecná nemocnica s poliklinikou Lučenec n.o.
29	Nemocničná a.s., Nemocnica Malacky
30	Nemocnica s poliklinikou Štefana Kukuru Michalovce, a.s.
31	Nemocnica s poliklinikou Myjava
32	Nemocnica s poliklinikou Nové Mesto nad Váhom, n.o.
33	Nemocnica na okraji mesta, n.o., nemocnica Partizánske
34	Nemocnica Alexandra Wintera n.o. Piešťany
35	Nemocnica Poprad, a.s.
36	Nemocnica s poliklinikou Považská Bystrica
37	Nemocnica s poliklinikou, n.o. Revúca
38	Nemocnica s poliklinikou sv. Barbory Rožňava, a.s.
39	Hospitale, s.r.o., Šahy
40	Fakultná nemocnica s poliklinikou Skalica, a.s.
41	Nemocnica Snina s.r.o.
42	Nemocnica s poliklinikou Spišská Nová Ves, a.s.
43	Ľubovnianska nemocnica, n.o.
44	Nemocnica arm. generála L. Svobodu Svidník, a.s.
45	Nemocnica s poliklinikou Trebišov, a.s.
46	Hornooravská nemocnica s poliklinikou Trstená
47	Všeobecná nemocnica s poliklinikou, n.o., Veľký Krtíš
48	Vranovská nemocnica, a.s. (vrátane prevádzky v Stropkove)
49	Nemocnice Žiar nad Hronom (s prevádzkou Banská Štiavnica) a Rimavská Sobota (Svet zdravia, a.s.)
50	Mestská nemocnica Prof. Rudolfa Korca, Zlaté Moravce
51	Nemocnica Zvolen a.s. (vrátane prevádzky v Krupine)
52	Fakultná nemocnica s poliklinikou F.D. Roosevelta Banská Bystrica
53	Univerzitná nemocnica Bratislava
54	Univerzitná nemocnica L. Pasteura Košice
55	Univerzitná nemocnica Martin
56	Fakultná nemocnica Nitra
57	Fakultná nemocnica s poliklinikou Nové Zámky
58	Fakultná nemocnica s poliklinikou J. A. Reimana Prešov
59	Ústredná vojenská nemocnica SNP Ružomberok – fakultná nemocnica
60	Fakultná nemocnica Trenčín
61	Fakultná nemocnica Trnava
62	Fakultná nemocnica s poliklinikou Žilina

Source: Authors' calculations.

A p p e n d i x B

Individual Results by Hospitals

		CCR model			BCC model		
Number	*Original number of Beds*	*Efficiency score*	*Projected Beds*	*Percent. Reduction (%)*	*Efficiency score*	*Projected Beds*	*Percent. Reduction (%)*
1	136	1.00	136	0	1.00	136	0
2	379	0.61	229	39	0.67	253	33
3	517	0.58	298	42	0.64	328	36
4	240	0.67	161	33	1.00	240	0
5	40	1.00	40	0	1.00	40	0
6	122	0.59	72	41	0.66	80	34
7	36	1.00	36	0	1.00	36	0
8	214	0.74	159	26	0.79	169	21
9	460	0.61	279	39	0.68	315	32
10	300	0.71	213	29	0.77	231	23
11	434	0.52	227	48	0.57	246	43
12	459	0.57	261	43	0.64	295	36
13	70	0.31	22	69	0.53	37	47
14	62	0.46	28	54	0.72	45	28
15	30	0.41	12	59	1.00	30	0
16	62	1.00	62	0	1.00	62	0
17	361	0.52	189	48	0.56	202	44
18	147	0.40	59	60	0.49	72	51
19	172	0.84	144	16	0.84	144	16
20	408	0.78	319	22	0.79	321	21
21	379	1.00	379	0	1.00	379	0
22	96	1.00	96	0	1.00	96	0
23	147	0.60	89	40	0.62	91	38
24	115	1.00	115	0	1.00	115	0
25	615	0.75	463	25	0.89	546	11
26	340	1.00	340	0	1.00	340	0
27	297	0.66	196	34	0.69	203	31
28	452	0.62	282	38	0.62	282	38
29	111	0.90	99	10	0.99	110	1
30	545	1.00	545	0	1.00	545	0
31	195	0.50	98	50	0.53	104	47
32	80	0.73	58	27	0.79	63	21
33	200	0.55	110	45	0.55	110	45
34	247	0.66	163	34	0.67	167	33
35	566	0.81	458	19	1.00	566	0
36	494	0.62	304	38	0.68	335	32
37	135	0.66	89	34	0.68	91	32
38	389	0.69	269	31	0.69	269	31
39	63	0.92	58	8	1.00	63	0
40	318	0.70	222	30	0.71	226	29
41	169	0.70	119	30	0.71	120	29
42	276	1.00	276	0	1.00	276	0
43	239	1.00	239	0	1.00	239	0
44	252	0.49	122	51	0.49	124	51
45	479	0.58	280	42	0.65	310	35
46	283	0.67	189	33	0.68	192	32
47	122	0.95	116	5	0.95	116	5
48	390	0.68	267	32	0.71	276	29
49	672	0.31	211	69	0.32	216	68
50	95	0.58	55	42	0.65	62	35
51	367	0.73	270	27	0.82	303	18
52	908	0.80	728	20	1.00	908	0
53	2 569	0.75	1 934	25	1.00	2569	0
54	1 347	0.73	990	27	0.94	1 272	6
55	838	0.82	684	18	1.00	838	0
56	717	1.00	717	0	1.00	717	0
57	749	0.80	601	20	0.85	634	15
58	1 281	0.56	715	44	1.00	1 281	0
59	523	0.75	392	25	0.76	399	24
60	839	0.73	610	27	0.82	685	18
61	628	0.73	458	27	0.83	523	17
62	768	0.75	576	25	0.89	683	11

Source: Authors' calculations.