CAN MONEY BUY HEALTH? DATA ENVELOPMENT ANALYSIS OF HEALTHCARE EXPENDITURE

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Dá sa kúpiť zdravie za peniaze? Analýza obalu dát výdavkov na zdravotníctvo

Abstract: *The aim of this paper is to estimate the efficiency of public healthcare expenditures using Data envelopment analysis. We propose two equivalents of DEA models. The first is based on per capita type of variables (health expenditures per capita, healthy years of life and preventable deaths per million people) and second equivalent accumulates all the health expenditures for last 10 years (PPP US dollars in 2011 prices), aggregates healthy years and preventable deaths of population in given country and year. Slovakia has one of the least efficient healthcare systems among EU countries, while Cyprus and Bulgaria seem to be efficient under all specifications of the models. Results from DEA analysis suggest considerable space for improving in Slovakia. Slovakia would need to reduce health expenditure per capita and number of preventable deaths by more than half while keeping the same level of health life years per capita to become efficient. We also briefly looked at the evolution of efficiency in time, since 2011. However, we suggest, that more sophisticated analysis (e.g. Malmquist index) is needed.*

Keywords*: DEA, healthcare, expenditure efficiency, CCR model, BCC model*

JEL Classification: C61, I11, H51

1. Introduction

OECD countries experienced significant increase in health-care expenditures over the last decades, both in nominal term and as a share of GDP. Since 1970, health-care expenditure to GDP ratio rose from 4.6% to 8.9% in 2017 on average. According to ÚHP [4] healthcare can be considered as luxury good. Therefore, the wealthier country, the higher healthcare related expenditure.

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Efficiency of public spending on healthcare is currently hot research area, both in Slovakia and abroad. There could be found a vast number of scientific papers concerning healthcare efficiency. We aim to build on existing literature and contribute with slightly different specification of models in area of Data Envelopment Analysis.

DEA represents the nonparametric approach for frontier estimation in the sense that it does not require any assumption about the functional form. Any deviation from the frontier is treated as inefficiency. It provides single measure of efficiency even when dealing with multiple inputs and outputs [9]. The advantage of this method is that it allows us to evaluate efficiency of subjects using inputs without market prices (measured in physical units) or subjects using multiple inputs and outputs.

This analysis aims to compare the efficiency of Slovak health care system with those in our region, rather than provide conclusion on determinants or problem-solving policies on this issue. However, we believe that this paper will contribute to an ongoing debate about efficiency of healthcare in Slovakia. Furthermore, we would like to suggest direction for subsequent research.

This paper is structured as follows. The second chapter consists of literature overview on healthcare efficiency, both international and domestic. We describe Data Envelopment Analysis (DEA), explanation of the used model and data description in the third chapter. Brief overview of results provides fourth part, and we summarize our findings in last, fifth chapter.

2. Literature Review

With the increase of expenditures naturally comes debate about outcomes of health-care system and efficiency of expenditures. Literature provides several areas and approaches to efficiency analysis, both in Slovakia and abroad.

2.1 International literature

Michael Schlander [11] discussed different measures of efficiency in healthcare in his paper. Although cost-benefit analysis (CBA) is grounded in economic welfare theory and attempts to identify alternatives with a net social benefit, cost-effectiveness evaluation (CEA) is more widely used in applied health economics. It is due to adopting a modified efficiency criterion, minimization of incremental costs per quality-adjusted life year (QALY) gained (cost utility analysis – CUA).

Data envelopment analysis is a method for evaluation of efficiency and is also often used for estimation healthcare efficiency. Different specifications of this method were used e.g. by Asanduluia, Romanb and Fatulescua [1],

Hadad, Hadad and Simon-Tuval [6] or Meaney, Oyewole and Bedogni [10] to estimate efficiency of healthcare system. On the other hand, Helming and Lapsley [8] used DEA to estimation of the efficiency of the German hospital sector.

The hospitals in the public and the welfare sectors are relatively more efficient than the hospitals in private ownership in Germany. Paper by Helming and Lapsley [8] suggests that ownership affects efficiency: (1) public, welfare and private hospital sectors have different best practice frontiers; and (2) public and welfare hospital sectors appear to use relatively fewer resources. These results suggest differences in quality of care arising from ownership.

Asanduluia, Romanb and Fatulescua [1] evaluated the efficiency of public healthcare systems in Europe using DEA approach. Authors used statistical data for 30 European states for 2010. They have selected three output variables for their model: life expectancy at birth, health adjusted life expectancy and infant mortality rate and three input variables: number of doctors, number of hospital beds and public health expenditures as percentage of GDP. Their findings revealed that there is number of both, developed and developing countries on the efficiency frontier, while the great majority of the countries in the sample are inefficient.

A similar approach but with different specification of the model was used by Hadad, Hadad and Simon-Tuval [6] for the estimation of determinants of healthcare system's efficiency in OECD countries. They developed two different models. The first model incorporated inputs that are considered to be within the discretionary control of the healthcare system (i.e., physicians' density, inpatient bed density, and health expenditure). The second model included mostly inputs beyond healthcare systems' control (i.e., GDP, fruit and vegetables consumption, and health expenditure). Life expectancy and infant survival rate were considered as outputs in both models. Authors also analyzed whether institutional arrangements, population behavior, and socioeconomic or environmental determinants are associated with healthcare efficiency. Authors concluded that countries striving to improve their healthcare efficiency should aim to impact population behavior and welfare rather than only ensure adequate medical care. In addition, they may consider avoiding specific institutional arrangements, namely gatekeeping and the presence of multiple insurers.

Efficiency of Irish Public Spending was analyzed by Meaney, Oyewole and Bedogni [10], where healthcare was one of areas of research. The paper was part of spending review, which is currently widely used in Ireland. Ireland has a relatively high level of health expenditure compared to EU peers. Ireland is not achieving the greatest level of efficiency from inputs. The DEA analysis

estimates that there could be considerable savings to be made on inputs as well as possible gains on possible outputs/outcomes.

2.2 Efficiency of healthcare in Slovakia

Increasing expenditures but stagnation of outcomes are drawing attention to healthcare system efficiency in Slovakia. The first complex analysis of efficiency of healthcare system in Slovakia was provided by Filko et al. [5]. Analysis suggests that Slovakia belongs between the worst performing developed countries. Healthcare efficiency declined below OECD average, due to increase in expenditures without increase in performance.

In 2015, the Institute for Financial Policy, analytical unit at the Ministry of Finance of the Slovak Republic, identified healthcare (together with labor market) as the greatest challenge for the Slovak economy [7]. Both sectors remain between the three greatest challenges also two years later, in updated manual in 2017.

For the reasons mentioned above, healthcare was one of the most important sectors to focus on during the start of Value for Money project in Slovakia. The first spending review conducted in 2016, identified saving in amount of 363 mil. Euro. However, these savings were meant to stay in the sector to bring higher value for money for the taxpayers. The importance of the healthcare sector together with space for another improvement of its efficiency is highlighted by second round of spending review, which is currently in progress [4].

Even after the fact, that there were several papers pointing at inefficiency of healthcare expenditures during recent years, preliminary report from second spending review published in the end of 2018 found persistent imperfections.

3. Data and methodology

3.1 Data envelopment analysis

For the efficiency measure in our analysis we use two simple equivalents of data envelopment analysis (DEA) models. Model by Charnes, Cooper and Rhodes, which is called CCR model, is used in the case we expect constant returns to scale and for variable returns to scale is used model by Banker, Charnes and Cooper with abbreviation BCC model. DEA approach has some advantages compering to other measures of efficiency. We do not need to know the form of production function in DEA model. It is sufficient just to operate with inputs and outputs of some process. Secondly, we do not need to have all inputs and outputs in the same measuring units. Then, in comparison to usual index measures of efficiency, DEA approach does not assign weights a priori, but we derive weights from the solution of linear optimization

program. Optimal weights vary from one country to another. There is also output orientation equivalent, when we try increase efficiency by increasing outputs while inputs do not change. In input orientation we try to increase efficiency by decreasing inputs while outputs don't change.

Following Cooper, Seiford and Tone [2], in DEA approach organization under the study is called decision making unit (DMU) – in our case DMUs represent treated countries. Suppose we have j = 1, …, n DMUs (DMU_1, DMU_2, ..., and DMU_n), i = 1, …, m inputs (x_1, x_2, ..., x_m) and r = 1, …, s outputs (y_1, y_2, ..., y_s). All data are assumed to be nonnegative and at least one component of input and output vector must be positive. We arrange data into matrices (by bold letters) in equations.

Output oriented CCR model is formulated as:

$$\begin{aligned} \max_{\eta,\boldsymbol{\mu}} \quad & \eta \\ subject\ to \quad & \boldsymbol{x}_{to} - X\boldsymbol{\mu} \geq \mathbf{0} \\ & \eta \boldsymbol{y}_o - Y\boldsymbol{\mu} \leq \mathbf{0} \\ & \boldsymbol{\mu} \geq \mathbf{0} \end{aligned} \tag{1}$$

An optimal solution of dual linear program can be derived directly from an optimal solution of input oriented CCR model. We define:

$$\boldsymbol{\lambda} = \boldsymbol{\mu}/\eta\,, \quad \theta = 1/\eta \tag{2}$$

Input oriented CCR model is formulated as:

$$\begin{aligned} \min_{\theta,\boldsymbol{\lambda}} \quad & \theta \\ subject\ to \quad & \theta \boldsymbol{x}_o - X\boldsymbol{\lambda} \geq \mathbf{0} \\ & \boldsymbol{y}_o - Y\boldsymbol{\lambda} \leq \mathbf{0} \\ & \boldsymbol{\lambda} \geq \mathbf{0} \end{aligned} \tag{3}$$

thus, an optimal solution of the output-oriented model relates to that of the input-oriented model [2]:

$$\eta^* = 1/\theta^*, \quad \boldsymbol{\mu}^* = \boldsymbol{\lambda}^*/\theta^* \tag{4}$$

The BCC model differs from the CCR model in one additional condition $\sum_{j=1}^{n} \lambda_j = 1$ which we also write as $\boldsymbol{e}^T\boldsymbol{\lambda} = 1$ where $\boldsymbol{e}$ is a vector of ones. After the additional condition the BCC output-oriented model is formulated as:

$$\begin{aligned} & \max_{\eta_B, \boldsymbol{\lambda}} \ \eta_B \\ \textit{subject to} \quad & X\boldsymbol{\mu} \leq \boldsymbol{x}_o \\ & \eta_B \boldsymbol{y}_o - Y\boldsymbol{\mu} \leq \boldsymbol{0} \\ & \boldsymbol{e}^T \boldsymbol{\lambda} = 1 \\ & \boldsymbol{\mu} \geq \boldsymbol{0} \end{aligned} \tag{7}$$

The dual (multiplier) form associated with the above linear program $(\mathrm{BCC} - O_o)$ is expressed as:

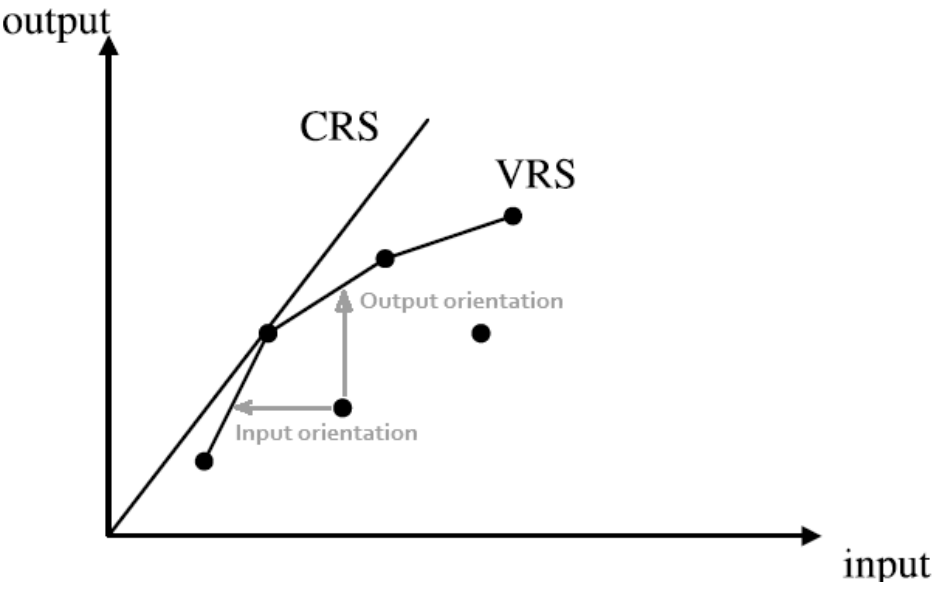
$$\begin{aligned} & \min_{\boldsymbol{v}, \boldsymbol{u}, v_o} \ z = \boldsymbol{v}^T \boldsymbol{x}_o - v_o \\ \textit{subject to} \quad & \boldsymbol{u}^T \boldsymbol{y}_o = 1 \\ & \boldsymbol{v}^T X - \boldsymbol{u}^T Y - v_o \boldsymbol{e}^T \ \geq \boldsymbol{0}^T \\ & \boldsymbol{v} \geq \boldsymbol{0}, \boldsymbol{u} \geq \boldsymbol{0}, \ v_o \ \textit{free in sign}, \end{aligned} \tag{8}$$

(Cooper, Seiford and Tone [2]).

For better imagination, you can see the difference between CCR and BCC frontier formation on the Figure 1. It is obvious, that in the CCR case we don't count for economy scale effect on efficiency measure.

Figure 1

Constant versus variable returns to scale



Source: Dyson et. al. [3] and own adjustments.

3.2 Data

Our dataset is composed of thirty countries. We feed the model with one input in the form of accumulated health system expenditures for last eleven years in 2011 USD PPP. Later, there is one good output – healthy years of life for female population and one bad output – treated as input in the form of preventable deaths. The source of these time series is Eurostat, but we used also Penn World Tables for adjustment of expenditure data to be more comparable in time and among countries. We propose two equivalents of DEA models. The first one is based on per capita type of variables (health expenditures per capita, healthy years of life and preventable deaths per million people) and second equivalent accumulates all the expenditures, healthy years and preventable deaths per whole population of country. It is not possible to catch scale of economy in the first case so we use per capita measure in CCR model and for BCC model with variable returns to scale are variables aggregated on the population level to capture also the scale effect of economies.

Table 1

Data overview

IndiCode	Variable	Period	Min	Max	Average	Median
Health.exp_pc	Health expenditure in 2011 USD PPP per capita	2001-2011	5306	52223	19909	18815
		2006-2016	7548	60526	23052	20354
Health.Life year. pc fem	Healthy years of life in years for one female	2011	52.3	70.7	62.1	62.4
		2016	54.9	73.3	62.6	61.7
Prev.Death per.mil totpop	Number of preventable deaths per million people	2011	951.7	3497.7	1779.6	1500.7
		2016	931.2	3176.2	1690.2	1428.0
Health.exp_abs_ mil	Health expenditure in millions of 2011 USD PPP for total country	2001-2011	5248	2243247	379729	163505
		2006-2016	5984	2572234	443455	181292
Health.Life year. abs.mil fem	Healthy years of life in millions of years for all female	2011	29.6	4750.8	1080.4	510.8
		2016	31.1	5512.9	1121.6	491.1
Prev.Death abs totpop	Total number of preventable deaths in country	2011	630	127627	26203	12479
		2016	610	120266	25328	12102

Source: authors' compilation

The next dilemma is if we want to use input or output orientation of the model. Expenditures could be reduced, while outputs would stay the same (input orientation) or preventable deaths could decrease and healthy years increase with no change in expenditures (output orientation). Second dilemma challenges our simple methodology, where bad output is treated as input. It means that the interpretation of bad output together with input reduction in

input-oriented model will be as strange as interpretation of healthy years of life increase while keeping preventable deaths constant.

4. Empirical Results

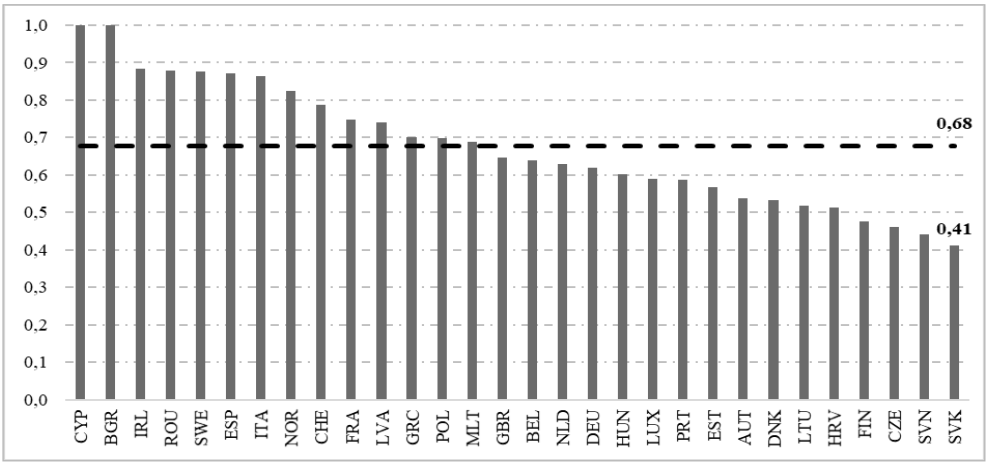
4.1 Efficiency of healthcare in EU countries

Slovakia has one of the least efficient healthcare systems among EU countries. Slovakia ranked last out of thirty countries when using CCR model (see figure 2). The result was slightly better when using BCC model, which assumes variable returns to scale. Slovakia ranked at the 24th place, when six other countries had even worse results.

Only two countries, Cyprus and Bulgaria, seem to be efficient under constant returns to scale assumption (CCR model). Average efficiency score was under 70%. On the other hand, average efficiency in BCC model was over 80%, for both input and output-oriented model, while eleven countries lie on the efficiency frontier. Cyprus and Bulgaria were efficient in both scenarios. However, higher efficiency under BCC model is not surprising, since it is less restrictive regarding efficiency frontier (see figure 1).

Figure 2

Efficiency scores from CCR model



Source: authors calculations.

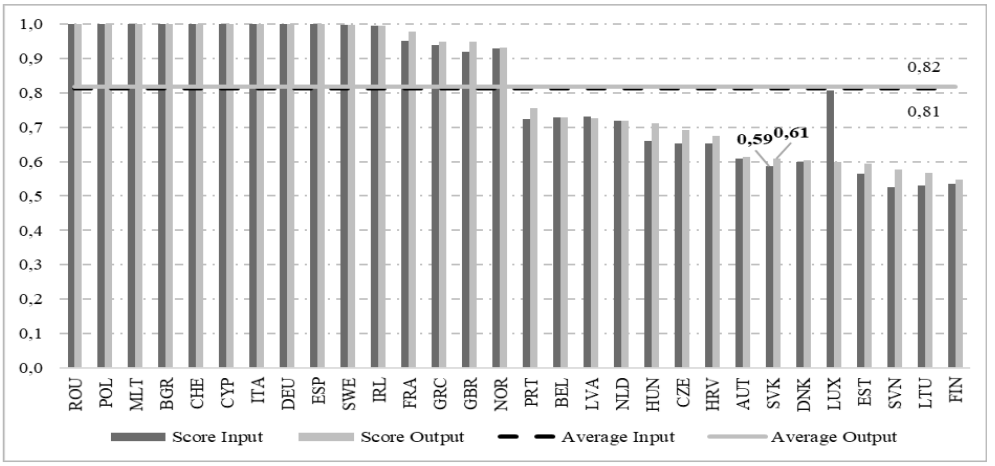
Efficiency scores from both input and output-oriented BCC models are shown in figure 3. Results are fairly similar for both orientations. Significant difference can be observed in Luxembourg, where efficiency increased by 20 percentage points with using input-oriented model. On the other hand, results are completely same for both orientations of model in CCR case. The reason for difference in the efficiency score in basic input and output models is

radial distance measurement of efficiency. There is measured vertical distance from the DMU point to the efficient frontier in the case of output orientation and horizontal distance for input-oriented model (Figure 1 by orange).

Although results are similar in BCC and the same in CCR models, we still use both input and output orientation, since DEA also allows to calculate projections to efficiency frontier. In other words, what levels of inputs (outputs) should a country have to become efficient (on efficiency frontier).

Figure 3

Efficiency scores from BCC models – both input and output oriented

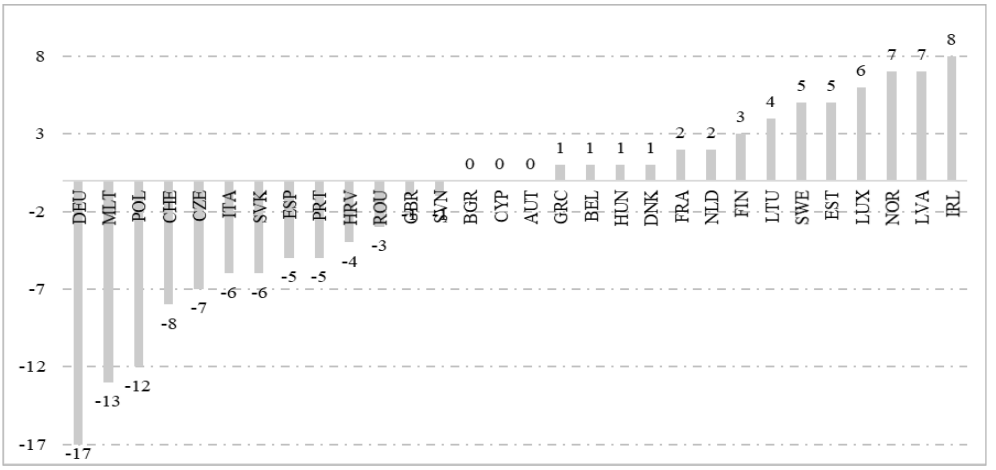


Source: authors' calculations

The difference between CCR and BCC efficiency score in general comes from the way the efficiency frontier is calculated in each model type. But in our application we talk about two different models with two different variablre measures in CCR and BCC model. In BCC approach we use aggegated measures for whole economy (total numbers for economy), so the scale effect (how big the economy and its variables is) is in place to influence shape of the efficiency frontier. In this model type big countries are projected on the efficiency frontier composed by efficient countries which also posess big in inputs and outputs (the same for small). That is why it is more accureate if we suppose, that the size of the health system influences its efficiency. On the other hand, per capita variable measures in CCR approach model is tailored for those, who believe, that the size of health system is irrelevant. In this analysis BCC and CCR models are used in two different approaches – we use them so to take advantage of their speciffications. In other words, we used two basic models, to see a more complex picture in their comparison.

Figure 4

Change in rank caused by using our CCR-O and BCC-O approach



Source: authors' calculation.

4.2 Projections to efficiency frotnier

The results from DEA analysis suggest considerable space for improvements in Slovak health system. Projections to efficiency frontiers allow us to identify possible efficient levels of inputs and outputs. For example, Slovakia would need to reduce health expenditure per capita and the number of preventable deaths by more than a half while keeping the same level of health life years per capita to become efficient.

Output oriented model with constant returns to scale (CCR model) support assumption that Slovakia spend too much with respect to results that are achieved. Projection from this model suggest, that Slovakia should (if possible) increase Healthy Life Years by 82 years (from 57 to 139 years). However, this unrealistic projection suggests that BCC model is more realistic. Further DEA model adjustments in the form of input and output restrictions would be neded for more realistic projection recommendation.

Table 2

Projections to efficiency frontier for inputs and outputs for Slovakia

		Projections			
		Input		Output	
	Current state	CCR	BCC	CCR	BCC
Health.exp_abs_mil	**91 986**		-37 905		
Prev.Death abs totpop	**11 703**		-4 822		
Health.exp_pc	**16 982**	-10 013			
Prev.Death per.mil totpop	**2 150**	-1 267			
Health.Life year.abs.mil fem	**310**				200
Health.Life year.pc fem	**57**			82	

Source: author's calculations.

4.3 Evolution of efficiency ranking between 2011 and 2016

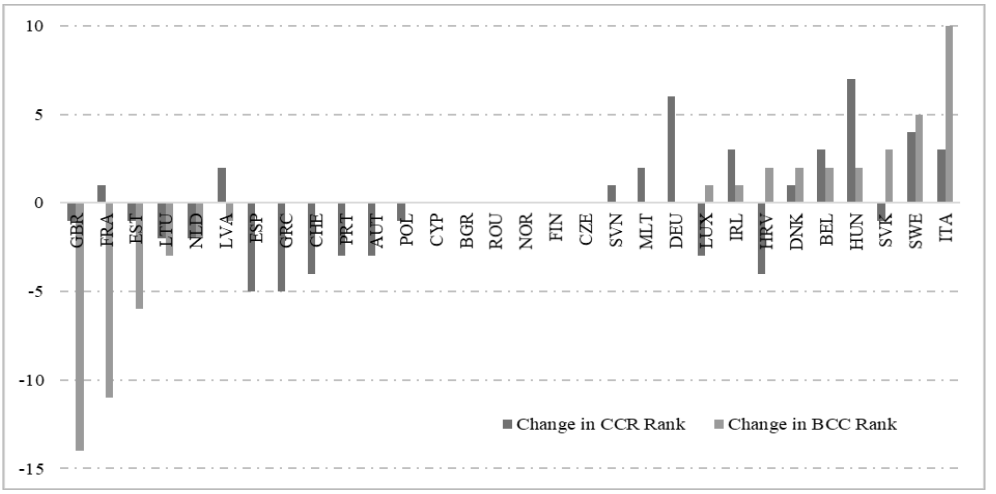
At the beginning of this paper we mentioned increase in healthcare expenditure in OECD countries over last couple of decades. Therefore, we would like to explore also the evolution of efficiency of these expenditures. Although it is not possible to compare efficiency scores (because of change in efficient frontier over time), it is possible to look at least at change in ranking.

Great Britain, France and Estonia experienced significant a decline in rank in BCC model, Spain, Greece, Switzerland and Croatia in CCR. On the other side are countries like Germany and Hungary (CCR) and Sweden and Italy (BCC). However, results for Slovakia are ambiguous since their increase was recorded in BCC rank and their decline in CCR.

While this comparison allows us to identify some trends in the change of efficiency, more sophisticated analysis would be appropriate. We suggest using Malmquist index to analyze both changes in frontier and efficiency of DMU.

Figure 5

Change in ranks of output-oriented models compared to 2011



Source: author's calculations

5. Conclusions

In this paper, we propose two equivalents of basic DEA models for more complex comparison using the advantage of two types of variable measurement. The first is based on per capita type of variables (health expenditures per capita, healthy years of life and preventable deaths per million people) and second equivalent accumulates all expenditures, healthy years and preventable deaths per whole population in country.

Slovakia has one of the least efficient healthcare systems among EU countries. Out of thirty examined countries, it ranked 24th under variable returns to scale assumption, and 30th under constant returns to scale. Only two countries, Cyprus and Bulgaria, seem to be efficient under all specifications of models.

We also compared ranking in CCR and BCC models. Large economies, like Germany, Poland, Switzerland, Italy, Spain declined in rank. On the other hand, smaller economies like Ireland, Latvia or Estonia advanced in the ranking.

The results from DEA analysis suggest a considerable space for improvements in Slovakia. Slovakia would need to reduce health expenditure per capita and number of preventable deaths by more than half while keeping the same level of health life years per capita to become efficient (in input-oriented model). Unrealistic projection for CCR output oriented model suggest that variable returns to scale are more realistic assumption.

We also briefly looked at the evolution of efficiency ranking in time (between 2011 and 2016). BCC and CCR models provide different results. Great Britain, France and Estonia experienced significant decline in rank in BCC model, Spain, Greece, Switzerland and Croatia in CCR. Results for Slovakia are ambiguous: while they advanced in BCC rank, they declined in CCR. This result asks for more complex DEA analysis and deeper investigation of returns to scale in the case of national health system efficiency.

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