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THE IMPACT OF HEALTH EXPENDITURE TO THE HEALTHCARE SYSTEM EFFICIENCY

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ABSTRACT

Health is the most precious human value. It contributes to the economic potential of the country and therefore requires the interest of both the state and the public authorities. How can countries really influence the health of their inhabitants? No doubt, appropriate number of hospital beds and practising physicians are important. But what else does matter? Health expenditure has a significant role in national economies. We examine healthcare systems efficiency in 27 European countries using Data Envelopment Analysis (DEA). Then we compare the impact of health expenditure per capita and the health expenditure share of GDP to the efficiency scores of compared countries. We show that the share may be preferable to use in DEA calculations, because it takes into account the "country's wealth".

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Keywords: Healthcare system efficiency, Health expenditure, European countries, GDP, Data envelopment analysis, Super-efficiency, Super slack based measure (Super-SBM).

Contribution/ Originality

The study contributes in the existing literature on the assessment of healthcare systems' efficiency using DEA. In contrast with previous studies, we consider health expenditure as a share of GDP. This approach allows us to eliminate the influence of different price levels on efficiency scores.

1. INTRODUCTION

The paper focuses on the comparison of the efficiency of healthcare systems of selected European countries with respect to their economic performance. We calculate the super-efficiency scores to compare and rank the countries according to two alternative DEA models. The models differ just in one input variable. Once we consider health expenditure per capita, otherwise we take into account health expenditure as a percentage of GDP. We show how the different ways in which health expenditure can be expressed influence the healthcare system efficiency.

Health expenditure is a significant policy issue since it forms a substantial part of public and household expenses. Naturally, efficient use of public and private financial sources allocated in healthcare systems is expected by all stakeholders. We define the efficiency of the healthcare system as the ratio

$$\text{healthcare system efficiency} = \frac{\text{healthcare outcomes}}{\text{healthcare inputs}},$$

where healthcare outcomes characterise the health state of the inhabitants and healthcare inputs capture the main resources allocated in healthcare system. It is well known that healthcare systems can only partially influence the population health. However, in accordance with standard DEA terminology we will refer to healthcare outcomes as outputs of healthcare systems.

The study of healthcare system efficiency helps to estimate the contribution of various healthcare resources to the population health outcomes. Thus the evaluation of healthcare system efficiency is a complex and challenging socioeconomic problem.

Many researchers have focused on the measurement of efficiency in the healthcare. Different approaches were proposed regarding the inputs and outputs incorporated into the analysis. Retzlaff-Roberts *et al.* (2004) studied the impact of the social environment, population lifestyles, attitudes and behaviours, available medical care services, and health expenditure per capita on healthcare outcomes, Spinks and Hollingsworth (2009) examined the impact of socioeconomic determinants (such as unemployment rate, education attainment, GDP per capita). Schwellnus (2009) and Economou and Giorno (2009) used a combination of socioeconomic determinants and population lifestyles. Only few studies, e.g. Bhat (2005) and Afonso and St Aubyn (2005), included the number of inpatient beds and levels of health employment as inputs rather than health expenditure. Hadad *et al.* (2013) divided the inputs into two categories to distinguish the indicators with high healthcare system's control (physicians' density, inpatient beds) from those with low healthcare system's control (GDP per capita, health expenditure per capita, fruit and vegetables intake).

In most studies the healthcare outcomes were measured by life expectancy at birth. Just Hadad *et al.* (2013) used two outputs: life expectancy at birth and infant survival rate. We shall follow this approach.

2. METHODOLOGY

We apply DEA to analyse the efficiency of healthcare systems in 27 European countries for which the data is available of the year 2011. The countries are considered to be decision making units. This approach allows us to consider several indicators of different nature as the inputs and outputs of the healthcare systems and rank the countries by the relative efficiency of their healthcare systems.

DEA is a nonparametric method of measuring a relative efficiency of decision making units (DMU) based on linear programming. Using DEA we have no need to explicitly specify a mathematical form for the production function. Since we are capable of handling multiple inputs and outputs measured in different units, we can uncover relationships that remain hidden for other methodologies. The DEA results do not only distinguish efficient and inefficient DMUs and rank the DMUs by their efficiency scores, but also identify and quantify the sources of inefficiency for any evaluated DMU.

Since healthcare system desires both to maximize health gains and minimize inputs, we have chosen a non-oriented model. Due to significant differences in size, population and the level of economic development between individual countries we assume variable returns to scale (VRTS) for their healthcare systems.

For our purpose we utilize a non-radial and non-oriented Super-SBM DEA model. SBM was developed by Tone (2001) and allows us to determine non-radial (non-proportional) input excesses and output shortfalls (generally called slacks) for all compared DMUs. Based on the slacks, a unique efficiency score for each DMU is calculated to identify efficient and inefficient systems. Efficient systems are assigned the unit efficiency scores, while inefficient systems are assigned efficiency scores less than one. In order to distinguish and rank the efficient healthcare systems among themselves, we apply so-called super-efficiency. The super-efficiency method for radial models was developed by Andersen and Petersen (1993) to rank the efficient DMUs. This approach allows the efficient DMUs to receive an efficiency score greater than one. Tone (2002) introduced non-radial super-efficiency models using the slack based measure (Super-SBM).

In order to study the impact of healthcare expenditure to the healthcare system efficiency we apply two alternative DEA models. In Model I we consider health expenditure per capita while in Model II we take into account health expenditure as a percentage of GDP. Then we compare the efficiencies calculated by the two models. Figure 1 shows the details of applied DEA models.

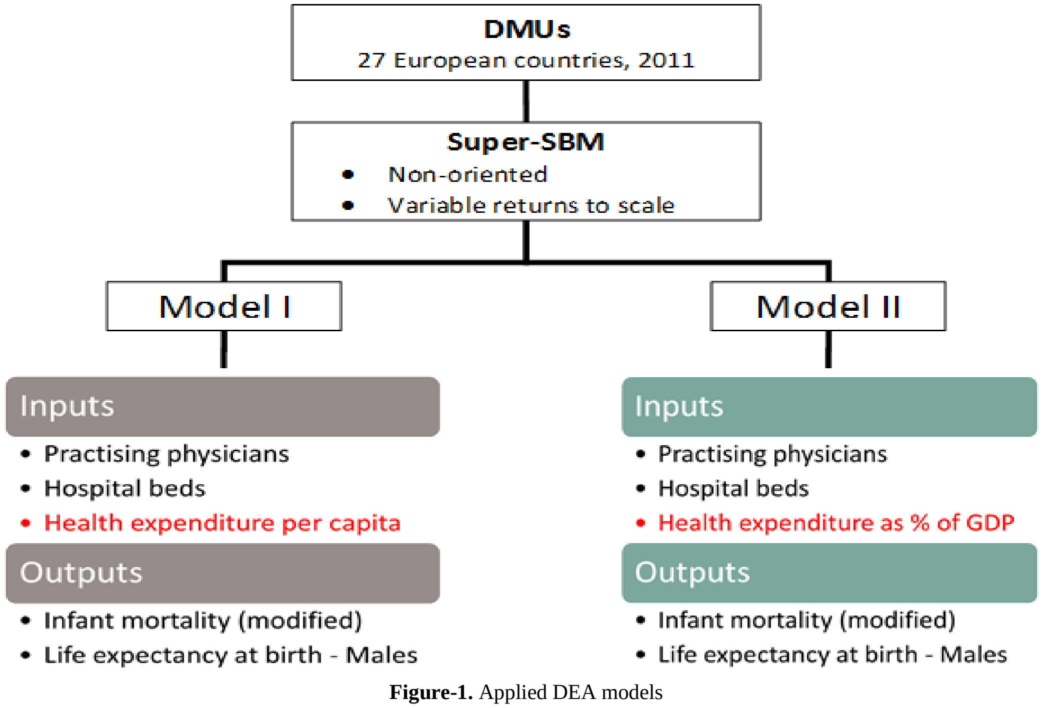

Figure-1. Applied DEA models

Source: The Authors

Note that all inputs and outputs, with the exception of life expectancy, are ratio variables. But using ratios in standard DEA models may lead to incorrect results since they do not comply with the convexity axiom which is one of the main underlying assumptions of the production possibility set in DEA (see Emrouznejad and Amin (2009) for details). To solve this, we may consider both the numerator and denominator of any ratio indicator as separate variables and use them accordingly as inputs and outputs replacing the original ratios in the models. However, in Section 3 we present the values of original ratio variables since they provide a more illustrative comparison of the countries. The data is analysed using DEA-Solver software (www.saitech-inc.com).

3. DATA AND VARIABLES

We compare relative efficiency of healthcare systems in 27 European countries, namely Austria, Belgium, Bulgaria, Croatia, Cyprus, Czech Republic, Estonia, Finland, France, Germany, Hungary, Iceland, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, Norway, Poland, Romania, Slovakia, Slovenia, Spain, Sweden, Switzerland, and United Kingdom. These countries are considered to be DMUs for DEA.

Data has been collected from two sources: the Eurostat Statistics Database and the OECD Health Data. Two outputs were chosen to represent healthcare outcomes – life expectancy at birth of males and infant mortality rate (transformed to correspond with the DEA assumptions as follows). The DEA technique requires outputs to be measured in such a way that “more is better”. Since infant mortality rate (IMR) does not meet this rationale, we calculate the modified infant mortality rate (MIMR) by the formula MIMR = 1000/IMR that corresponds to the number of live births over the number of deaths of infants under 1 year of age. The inputs included in our analysis depend on the chosen model. The number of practising physicians per 100 000 inhabitants and the number of hospital beds per 100 000 inhabitants are included in both models. The total health expenditure per capita is included in Model I and the share of total health expenditure in relation to GDP is included in Model II. Since data on practising physicians and hospital beds in some countries is not available for year 2011, we estimate the missing values based on these in previous years. Definitions of selected variables used in the analysis and data sources are given in Table 1.

Table-1. Variables and data sources

Variable	Definition	Data source
GDP per capita	Gross domestic product per capita (current US$)	(OECD, 2013)
Practising physicians	Total number of practising physicians (medical doctors) per 100 000 inhabitants (Practising physicians provide services directly to patients.)	(Eurostat Statistics Database, 2014)
Hospital beds	Total number of hospital beds per 100 000 inhabitants	(Eurostat Statistics Database, 2014)
Health expenditure	Total health expenditure per capita (current US$)	(OECD, 2013)
Share of GDP	Share of total health expenditure in relation to GDP (%)	(OECD, 2013)
Modified infant mortality	Number of live births over the number of deaths of infants under 1 year of age	(Eurostat Statistics Database, 2014)
Life expectancy	Life expectancy at birth – males (years)	(Eurostat Statistics Database, 2014)

Source: The Authors

We show source data for individual variables in the following charts. All data is of the year 2011. For illustration's sake, we divide the selected countries into four categories based on GDP per capita (Figure 2). Three countries with the highest GDP are assigned red colour, the other countries with GDP greater than 25 000 US$ are assigned green, the countries with GDP between 10 000 and 25 000 US$ are assigned yellow and two countries with the lowest GDP are blue. Note that the former two categories include countries of Western Europe while the latter two categories cover transforming countries of Central and Eastern Europe.

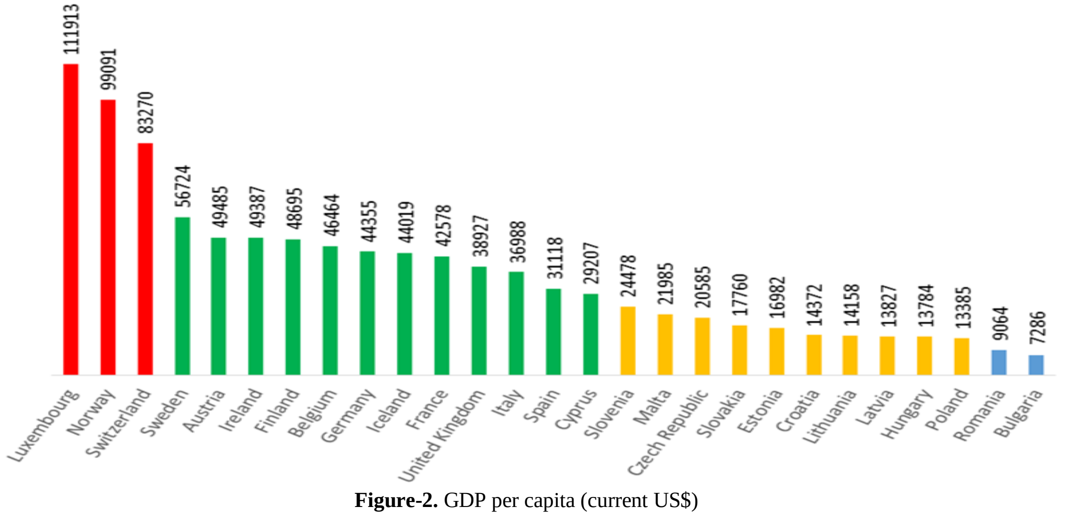

Figure-2. GDP per capita (current US$)

Source: OECD (2013), processed by the Authors

In Figure 3 we see that there is a close connection between GDP per capita and Health expenditure per capita. But there are greater differences between countries. Health expenditure per capita in Norway is nearly 20 times higher than in Romania. This naturally reflects the different pricing levels in the countries.

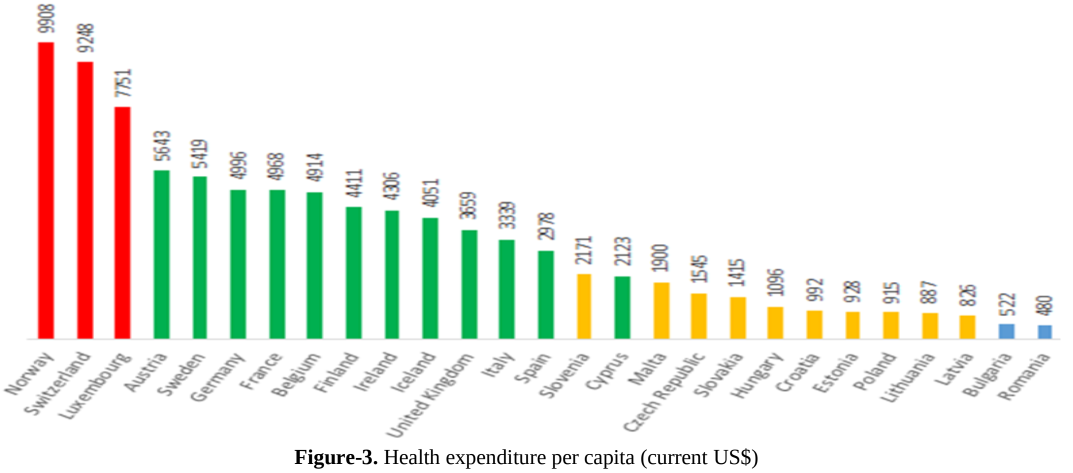

Figure-3. Health expenditure per capita (current US$)

Source: OECD (2013), processed by the Authors

If we take health expenditure as a percentage of GDP (Figure 4) instead of health expenditure per capita, the ranking of countries significantly change. But the distance between the top and the bottom values in this ranking is not so great: France has just a twice higher share of GDP than Romania.

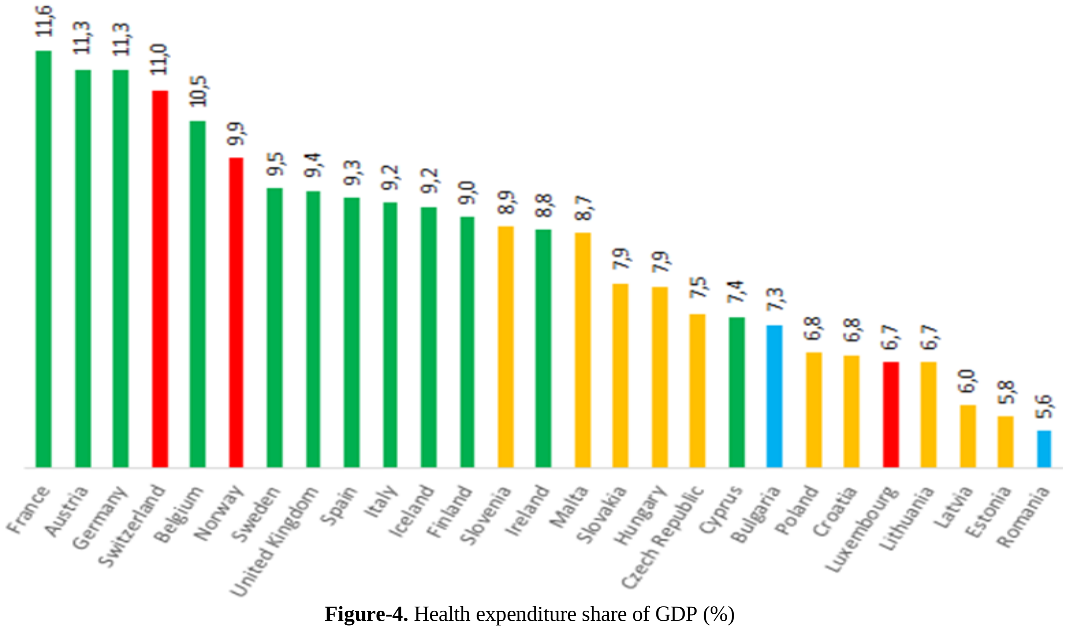

Figure-4. Health expenditure share of GDP (%)

Source: OECD (2013), processed by the Authors

In Figure 5 the number of practising physicians per 100 000 inhabitants is shown. Austria reports the highest number of practising physicians while Poland and Romania have the lowest numbers.

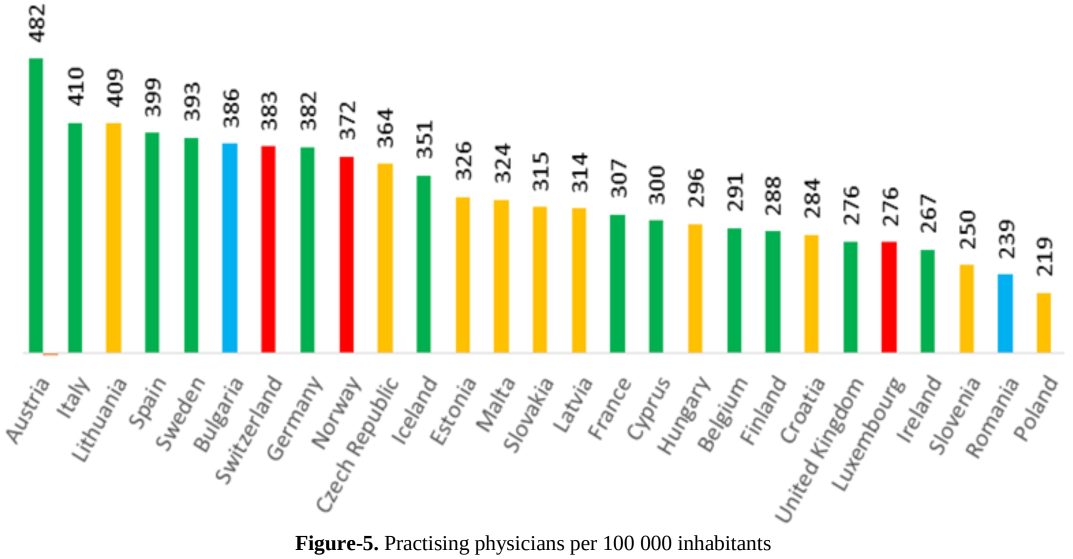

Figure-5. Practising physicians per 100 000 inhabitants

Source: Eurostat Statistics Database (2014), processed by the Authors

Figure 6 depicts the number of hospital beds per 100 000 inhabitants. Germany and Austria report the highest numbers of hospital beds while Ireland, UK and Sweden have the lowest numbers. No significant correlation between the number of practising physicians or hospital beds and the economic performance of the countries can be observed.

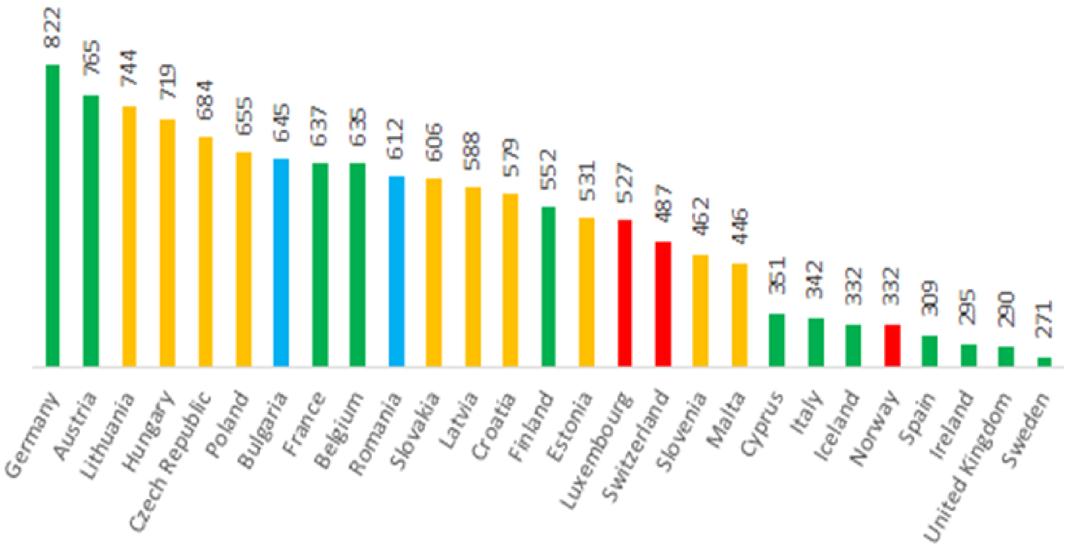

Figure-6. Hospital beds per 100 000 inhabitants
Source: Eurostat Statistics Database (2014), processed by the Authors

While the previous charts showed the resources used by healthcare systems, the following two charts present the indicators of health condition of the population.

Figure 7 displays the life expectancy at birth of males. The best situation is in Iceland and Switzerland, the worst in Lithuania and Latvia.

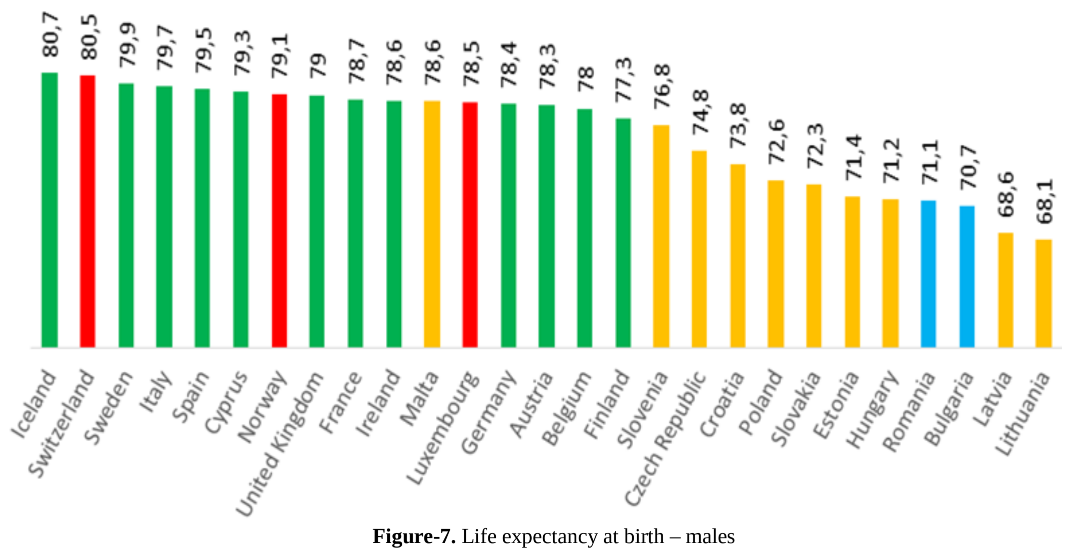

Figure-7. Life expectancy at birth – males
Source: Eurostat Statistics Database (2014), processed by the Authors

Figure 8 shows that the best infant mortality rate is reached by Iceland and northern countries, while far the worst situation is in Bulgaria and Romania.

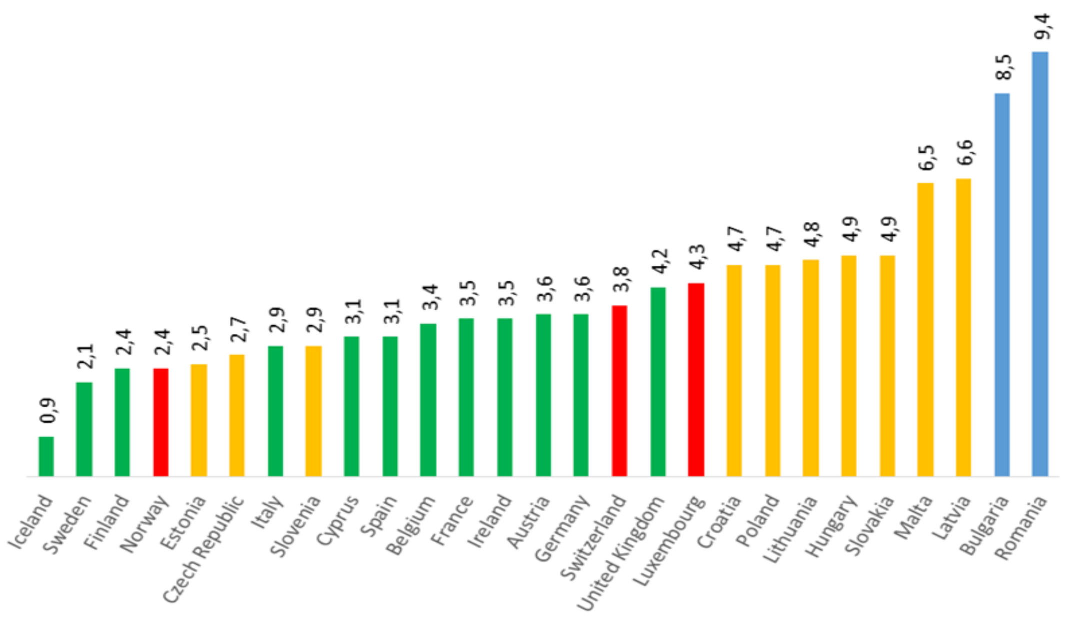

Figure-8. Infant mortality rate

Source: Eurostat Statistics Database (2014), processed by the Authors

Basic statistical characteristics of the variables are given in Table 2.

Table-2. Descriptive statistics of the variables (year 2011)

Variable	Mean	Minimum		Maximum	
		Value	Country	Value	Country
GDP per capita	37 032.93	7 286.39	Bulgaria	111 913.18	Luxembourg
Practising physicians	329.68	218.60	Poland	482.40	Austria
Hospital beds	526.51	270.60	Sweden	822.20	Germany
Health expenditure per capita	3 384.82	479.65	Romania	9 908.21	Norway
Share of GDP	8.53	5.61	Romania	11.63	France
Infant mortality rate	4.07	0.90	Iceland	9.40	Romania
Life expectancy (males)	76.13	68.10	Lithuania	80.70	Iceland

Source: The Authors

As already mentioned in Section 2, we should avoid using ratio indicators in DEA models. To do so, their numerators and denominators will be used as separate inputs and outputs. Thus, the total numbers of practising physicians, hospital beds, and the number of death of infants under one year of age, as well as the total amount of health expenditure will be used as inputs in both Model I and Model II. On the other hand, the total population of the country and the total number of live births along with life expectancy at birth for males will be used as outputs in both models. Besides that, the total GDP of the country will be considered as an additional output in Model II. It means that both models use the same four inputs and the same three outputs, and the only difference between them consists in the fact that Model II takes into account GDP while Model I does not. These sets of inputs and outputs correspond to the ratio inputs and outputs indicated in Figure 1.

4. RESULTS AND DISCUSSION

The results of the analysis are summarized in Figure 9. The left and right tables show the efficiency scores of countries resulted from Model I and Model II, respectively. The countries in the tables are ranked by their efficiency scores.

Efficient countries are assigned scores of at least one, the countries with lower scores are considered inefficient. The high numbers of efficient countries in both models are caused by the fact that we use a relatively high total number of inputs and outputs in relation to the total number of evaluated countries. Nevertheless, super-efficiency scores allow us to distinguish and rank the efficient countries among themselves.

Iceland appears to have the most efficient healthcare system in both models, due to the best output values. On the other hand, healthcare system in Austria seems to be the least efficient. It reaches the outputs above average, but using large resources.

Efficient countries

Model I	Score
Iceland	2,72
Estonia	1,30
Poland	1,30
United Kingdom	1,26
Romania	1,18
Malta	1,17
Sweden	1,13
Czech Republic	1,12
Ireland	1,09
Germany	1,08
Italy	1,08
Cyprus	1,07
Spain	1,07
Finland	1,06
Slovenia	1,05
France	1,05
Luxembourg	1,02
Bulgaria	1,01
Croatia	1,01
Slovakia	0,88
Hungary	0,86
Latvia	0,86
Belgium	0,85
Norway	0,83
Lithuania	0,81
Switzerland	0,70
Austria	0,64

Efficient countries

Model II	Score
Iceland	2,71
United Kingdom	1,30
Estonia	1,27
Poland	1,24
Luxembourg	1,20
Romania	1,18
Malta	1,17
Germany	1,15
Czech Republic	1,13
Italy	1,12
Sweden	1,11
Norway	1,11
Ireland	1,09
Cyprus	1,07
Finland	1,07
France	1,05
Spain	1,05
Slovenia	1,04
Switzerland	1,02
Bulgaria	1,01
Croatia	1,00
Belgium	0,94
Slovakia	0,87
Latvia	0,86
Hungary	0,86
Lithuania	0,81
Austria	0,65

Figure-9. Comparison of efficiency scores for Model I and Model II (with ratio data)

Source: The Authors

We observe a strong correlation between the results of Model I and Model II, both in the efficiency scores (Pearson coefficient = 0.97) and in the ranking (Spearman coefficient = 0.86). However, a more detailed view reveals that the countries with the highest GDP and health expenditure per capita (red category) significantly improve their positions in score and ranking if we take into account the health expenditure as a share of GDP. As for Norway and Switzerland, the change is even qualitative. Regardless of their healthcare outputs which are significantly better than the average, they are considered inefficient in Model I. On the contrary, they become efficient in Model II.

The impact of the healthcare expenditure can be nicely illustrated by the example of Luxembourg and Croatia. The share of GDP is about the same in both countries, but health expenditure per capita in Luxembourg is nearly 8 times higher than in Croatia (see Figure 4 and 3, respectively). By Model I the two countries reach nearly the same efficiency scores, bud the Model II score for Luxembourg is by 20% better.

The case of Romania illustrates the weak point of DEA efficiency evaluation in the context of healthcare systems. Countries with low level of inputs and low level of outputs may be considered efficient too. However, they can hardly be referential for inefficient countries.

5. CONCLUSION

We analysed the efficiency of healthcare systems in selected European countries (using two alternative Super-SBM DEA models). We considered the number of practising physicians per 100 000 inhabitants, the number of hospital beds per 100 000 inhabitants, and the total health expenditure per capita (or alternatively total health expenditure as a share of GDP) as DEA inputs, and modified infant mortality with life expectancy of males as DEA outputs. This approach allowed us to study the impact of healthcare expenditure on the efficiency scores with respect to the performance of national economies. As a result, we identified efficient and inefficient countries and ranked them by their efficiency scores. Although the scores and rankings obtained from the two alternative models are strongly correlated, the positions of countries with the highest GDP per capita are significantly different. In spite of good values in desirable healthcare outcomes, they appear inefficient if we include the healthcare expenditure per capita into the analysis. Thus we conclude that using the healthcare expenditure share of the country's GDP may be better to assess the efficiency of national healthcare systems.

6. ACKNOWLEDGEMENT

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APPENDIX: THE DEA METHODOLOGY

Consider *n* DMUs, (countries in our case) where each DMU *j* (*j* = 1, …, *n*) uses *m* inputs $x = (x_1, \ldots, x_m)$ to produce *q* outputs $y = (y_1, \ldots, y_q)$. According to Cooper *et al.* (2007) the non-radial super-efficiency score under variable returns-to-scale is calculated by the following fractional program:

$$\delta^* = \min \delta = \min_{\lambda, s^-, s^+} \frac{\frac{1}{m}\sum_{i=1}^{m} \bar{x}_i / x_{io}}{\frac{1}{q}\sum_{r=1}^{q} \bar{y}_r / y_{ro}}$$

subject to

$$\bar{x} \geq \sum_{j=1,\neq o}^{n} \lambda_j x_j ,$$

$$\bar{y} \leq \sum_{j=1,\neq o}^{n} \lambda_j y_j ,$$

$$\bar{x} \geq x_o , \bar{y} \leq y_o$$

$$\sum_{j=1,\neq o}^{n} \lambda_j = 1,$$

$$\bar{y} \geq 0, \lambda \geq 0.$$

Where $x = (x_1, \ldots, x_m)$ and $y = (y_1, \ldots, y_q)$ are respectively input and output matrices of observed data, $\bar{x}_i = x_{io} - s_i^-$ and $\bar{y}_r = y_{ro} + s_r^+$ are the recommended projections and the vectors $s^+ \in R^q$ and $s^- \in R^m$ denote output and input slacks.

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