TWO VIEWS ON EFFICIENCY OF HEALTH EXPENDITURE IN EUROPEAN COUNTRIES ASSESSED WITH DEA

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Abstract

We focus on the use of health expenditure to build effective and economically efficient health systems. Data Envelopment Analysis is applied to assess the efficiency of national health systems in supporting health outcomes of the population as well as in financing the resources for providing health services. The aim of the paper is to design DEA models to compare the efficiency of health systems from both viewpoints. We include to the comparison all European countries with the population above 400,000 inhabitants. In order to minimize the impact of different socio-economic environment, we divide the countries into three groups by Gross National Income per capita and do the analysis within the groups. This approach allows us to identify countries in each group which can be considered the most successful in using their health expenditure since they are efficient from both perspectives.

Key words: *healthcare system efficiency, effectiveness and economy of health expenditure, data envelopment analysis (DEA), European health systems.*

1. Introduction

The main function of a health system is to support the health conditions of the population which are traditionally measured by health outcomes such as life expectancy and infant mortality. Expenditure on health systems is naturally expected to improve the health outcomes. For this purpose, countries must build and maintain adequate health resources for providing health care. They include human resources (health staff) as well as capital resources (e.g., hospitals and health equipment). Thus, an efficient use of health expenditure should result not only in good health outcomes, but also in sufficient health resources.

This is why we study technical efficiency of national health systems from two viewpoints, effectiveness and economy. The effectiveness means that health expenditure is efficiently used to reach desirable health outcomes of the population. The economy means that health expenditure is efficiently allocated to human and capital resources needed for health care provision. A country is considered efficient in the use of health expenditure if it is efficient from both viewpoints.

Our approach to the study of health system efficiency is based on DEA methodology. A few studies applying DEA to compare national health systems among themselves have been published in latest years. In most of them, labour and capital resources used in health systems (namely, the numbers of health staff and hospital beds) along with health expenditure per capita are considered as inputs while the health outcomes of the population being outputs (Afonso and St Aubyn, 2005; Bhat, 2005). Hadad et al. (2013) compared the health systems by two models, using discretionary inputs in the former and inputs beyond the control of health systems in the latter.

Hsu (2013) used DEA to evaluate health expenditures to demonstrate how productivity had changed over time for selected countries in Europe and Central Asia. Grausová et al. (2014) applied DEA to analyze the development of healthcare systems in the Visegrád group with regard to other European countries. Dlouhý (2015) used a two-stage DEA approach to evaluate the efficiency of health system in two steps: efficiency of health resources to produce health services and efficiency of health services to produce health of the population.

Besides the natural heterogeneity of health systems (e.g. national specificities in the structure of health staff and health care financing), the crucial difficulty of the research lies in the fact that health outcomes are influenced by a large number of exogenous factors that are not under control of health systems and their impact may be rather different in individual countries. For example, the differences in socio-economic environment across Europe still significantly influence the national health systems.

In order to reduce the impact of socio-economic factors on the efficiency we divide the European countries into three groups based on Gross National Income (GNI) which reflects the economic power of the citizens. We calculate DEA efficiency scores for health systems to compare the countries within each group, and to identify the potential for improvement the values of input and output indicators in inefficient countries.

2. Methodology

In order to measure the efficiency of health expenditure from both the effectiveness and the economy perspectives, we apply a couple of DEA models (Table 1).

Health expenditure per capita is a unique input in both models. It is the sum of public and private health expenditures as a ratio of total population. Data is in international dollars converted using 2011 purchasing power parity (PPP) rates.

In Model 1, standard health indicators of the population (life expectancy at births and Infant mortality rate) are used as outputs. 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 use in our calculation the modified infant mortality rate (MIMR) computed by the formula MIMR = 1,000/IMR that corresponds to the number of live births over the number of deaths of infants under 1 year of age. In order to emphasize the differences between countries, we consider the value of life expectancy at birth that exceeds the age of 65.

In Model 2, the outputs cover labour and capital resources financed by health expenditure. Labour resources are represented by the health staff and capital resources are estimated by hospital beds, both expressed per 1,000 inhabitants.

In both Model 1 and Model 2, the non-oriented slack-based measure with variable returns to scale (SBM-V) is applied. SBM which was introduced by Tone (2001) allows us to identify input excesses and output shortfalls and include all of them to the efficiency score calculated for each country.

We apply this approach to assess health systems in European countries. Since DEA methods are extremely sensitive to outliers, it may happen that countries with a low level of health expenditure are identified efficient even though they also have low health outcomes. Hence, the countries with relatively low health outcomes may decrease the efficiency scores of the others. Therefore, it is necessary to compare countries with similar economic level.

Table 1. The input and outputs in applied DEA models

Model 1: Effectiveness of health expenditure	Model 2: Economy of health expenditure
Input	
HE per cap. – Health expenditure per capita, PPP	
Outputs	
IMR – Infant mortality rate per 1,000 live births (undesirable output, modified to MIMR)	Hospital beds – Number of hospital beds per 1,000 inhabitants
LE – Life expectancy at birth (over the age of 65)	Health staff – Number of physicians, nurses and midwives per 1,000 inhabitants

Source: the authors.

3. Assessed Countries

We include to the comparison all European countries with the population above 400,000. Countries are divided into three groups and we do the analysis separately for each group. The segmentation is based on GNI per capita in 2011, converted to U.S. dollars using the World Bank Atlas method (Table 2).

Table 2. Assessed countries grouped by GNI per capita in U.S. dollars

Group 1 (High GNI)	GNI per capita	Group 2 (High GNI)	GNI per capita	Group 3 (Middle GNI)	GNI per capita
Norway	90,270	Cyprus	31,490	Romania	8,610
Switzerland	79,290	Spain	31,140	Montenegro	7,240
Luxembourg	75,650	Greece	24,980	Bulgaria	7,080
Denmark	61,490	Slovenia	24,590	Belarus	6,130
Sweden	56,090	Portugal	22,660	Serbia	5,910
Netherlands	54,120	Malta	20,100	Macedonia	4,820
Austria	50,310	Czech Republic	19,400	Bosnia and Herzegovina	4,700
Finland	49,910	Slovak Republic	17,210	Albania	4,390
Belgium	47,010	Estonia	15,880	Ukraine	3,110
Germany	46,480	Croatia	14,050	Moldova	1,990
France	44,220	Latvia	13,140		
Ireland	43,100	Hungary	13,050		
United Kingdom	40,190	Lithuania	13,020		
Italy	37,690	Poland	12,940		

Source: the authors based on World Bank Data Indicators (2016).

Note that the segmentation reflects not only the different economic power of the countries but also their geographic location. Group 1 includes countries of Western and Northern Europe, Group 2 covers Central European, Mediterranean and Baltic countries, and Group 3 other Balkan and Eastern countries.

Input and output data for the analysis of national health systems is related to year 2011 and collected from the World Bank Data Indicators (2016).

Table 3 displays basic statistics on input and output data and the values of correlation coefficient between health expenditure and the outputs of the models. Taking into account all assessed countries, we see high correlations between health expenditure and all the outputs, with the only exception of hospital beds.

Table 3. Descriptive statistics of data and correlations between health expenditure per capita and outputs in 2011

	Input	Health outcomes		Health resources	
	HE per cap.	Life expectancy	IMR	Hospital beds	Health staff
All countries					
Max	6,661 Lux.	82.7 Switz.	14.5 Moldova	11.3 Belarus	21.3 Switz.
Min	475 Moldova	68.6 Moldova	1.8 Lux.	2.4 Albania	5.1 Albania
Average	2,669	77.9	5.2	5.3	11.6
St. Dev.	1,649	3.7	3.1	1.9	4.3
Correlation	1	0.81	-0.66	-0.21	0.78
Group 1					
Max	6,661 Lux.	82.7 Switz.	4.2 UK	8.2 Germany	21.3 Switz.
Min	3,203 Italy	79.8 Denmark	1.8 Luxembourg	2.7 Sweden	11.0 Italy
Average	4,521	81.2	3.2	4.9	15.9
St. Dev.	990	0.7	0.6	1.8	3.6
Correlation	1	0.10	-0.38	0.22	0.47
Group 2					
Max	3,002 Spain	82.5 Spain	7.8 Latvia	7.2 Hungary	12.1 CZ
Min	1,210 Latvia	73.6 Lithuania	2.6 Slovenia	3.1 Spain	6.7 Cyprus
Average	2,067	77.8	4.5	5.3	9.5
St. Dev.	580	2.8	1.5	1.3	1.4
Correlation	1	0.92	-0.42	-0.76	0.22
Group 3					
Max	1,222 Serbia	77.2 Albania	14.5 Moldova	11.3 Belarus	14.3 Belarus
Min	475 Moldova	68.6 Moldova	4.3 Belarus	2.4 Albania	5.1 Albania
Average	841	73.6	9.1	5.9	8.5
St. Dev.	238	2.6	3.4	2.5	2.5
Correlation	1	0.37	-0.55	-0.03	-0.16

Source: the authors based on World Bank Data Indicators (2016).

The values of standard deviation indicate that the variability of data within the groups is lower than within the set of all countries. However, there are interesting differences between the three groups of countries. The best health outcomes, the highest number of health staff, but the smallest number of hospital beds are observed in Group 1. The health outcomes are getting worse, the number of health staff decreases, and the number of beds increases as we move from Group 1 through Group 2 to Group 3.

Surprisingly, the correlation between health expenditure and life expectancy is high only in Group 2, but weak in other groups. It means that life expectancy in some countries may be mostly influenced by other factors. On the other hand, a significant negative correlation between health expenditure and infant mortality rate in all groups is naturally expected – higher health expenditure result in smaller values of infant mortality rate.

There is a weak or even a negative correlation between health expenditure and the number of hospital beds in all groups. A strong negative correlation in Group 2 means that countries with higher health expenditure have smaller number of beds. The amount of health staff is significantly correlated with health expenditure only in Group 1 (but the correlation is much higher when we take into account countries of all groups together).

4. Results

For each of the three groups, we present the efficiency scores, input and output data, and their recommended projections for individual countries (Tables 4-6). Efficiency scores are calculated by Models 1 and 2 to compare the effectiveness and the economy of health expenditure, and distinguish countries which are efficient from each perspective. Efficient countries reach the unit scores. Due to applied SBM model, a country with the lowest health expenditure per capita or the highest value in any output indicator is efficient by default (these unit scores are denoted by asterisks).

The differences in efficiency scores across countries with the highest GNI (Table 4) are greater in health resources than in health outcomes. Finland, Italy, and Switzerland are efficient from both perspectives. Italy is efficient because it has the lowest health expenditure per capita within the group. It also has the second highest value of life expectancy and average IMR, but its health resources are below average. Switzerland is also efficient by default, having the highest life expectancy as well as the largest health staff. Sweden and Luxemburg are efficient with respect to health outcomes, but they have relatively small health resources compared to their health spending which results in low efficiency scores by Model 2. On the other hand, Belgium, Denmark, Germany, Ireland, and UK are considered efficient in financing health resources, but lag behind the best countries in health outcomes. Austria and France are inefficient by both models since they have a higher level of health expenditure with respect to relatively high IMR and relatively low amount of health staff. The Netherlands and Norway reach the least efficiency scores in health outcomes as well as in health resources, due to relatively large health expenditure per capita.

Table 4. Group 1 input and output data for 2011, efficiency scores, and DEA projections

Group 1	Model 1							Model 2						
	Score	HE per cap.		LE		IMR		Score	HE per cap.		Hospital beds		Health staff	
		Data	Proj.	Data	Proj.	Data	Proj.		Data	Proj.	Data	Proj.	Data	Proj.
Austria	0.63	4,680	3,386	81.0	81.0	3.4	2.6	0.82	4,680	4,481	7.6	7.6	12.7	17.2
Belgium	0.67	4,246	3,446	80.6	80.6	3.5	2.4	1	4,246	4,246	6.5	6.5	20.6	20.6
Denmark	0.64	4,554	3,463	79.8	80.5	3.2	2.4	1	4,554	4,554	3.5	3.5	21.0	21.0
Finland	1	3,463	3,463	80.5	80.5	2.4	2.4	1	3,463	3,463	5.5	5.5	13.8	13.8
France	0.74	4,202	3,214	82.1	82.1	3.5	3.2	0.77	4,202	4,202	6.4	6.5	12.7	20.2
Germany	0.63	4,612	3,422	80.7	80.7	3.4	2.5	1*	4,612	4,612	8.2	8.2	15.3	15.3
Ireland	0.78	3,748	3,422	80.7	80.7	3.4	2.5	1	3,748	3,748	2.9	2.9	18.6	18.6
Italy	1*	3,203	3,203	82.2	82.2	3.3	3.3	1*	3,203	3,203	3.4	3.4	11.0	11.0
Lux.	1*	6,661	6,661	81.0	81.0	1.8	1.8	0.57	6,661	4,246	5.4	6.5	19.9	20.6
Nether.	0.55	5,231	3,352	81.2	81.2	3.6	2.7	0.50	5,231	4,246	4.7	6.5	11.2	20.6
Norway	0.63	5,785	3,646	81.3	81.3	2.5	2.5	0.46	5,785	4,246	3.3	6.5	17.1	20.6
Sweden	1	3,978	3,978	81.8	81.8	2.4	2.4	0.58	3,978	3,978	2.7	6.2	15.8	18.3
Switz.	1*	5,701	5,701	82.7	82.7	3.8	3.8	1*	5,701	5,701	5.0	5.0	21.3	21.3
UK	0.84	3,224	3,224	81.0	82.0	4.2	3.2	1	3,224	3,224	2.9	2.9	12.2	12.2

Note: *) This is the case of a country efficient by default.

Source: the authors based on World Bank Data Indicators (2016).

In Group 2, more significant differences in efficiency scores among countries and between the two viewpoints can be seen (Table 5). Estonia and Latvia are the only two countries which are considered efficient by both models, but their efficiency is caused by low health expenditure rather than by good values of outputs. Mediterranean countries reach much lower scores in health resources than in health outcomes. On the contrary, most Baltic and Central Europe countries have relatively high scores in health resources, but their health outcomes still are inadequate to their health spending.

Table 5. Group 2 input and output data for 2011, efficiency scores, and DEA projections

Group 2	Model 1							Model 2						
	Score	HE per cap.		LE		IMR		Score	HE per cap.		Hospital beds		Health staff	
		Data	Proj.	Data	Proj.	Data	Proj.		Data	Proj.	Data	Proj.	Data	Proj.
Croatia	1	1,469	1,469	76.8	76.8	4.3	4.3	0.86	1,469	1,469	6.0	6.8	8.6	10.4
Cyprus	0.98	2,400	2,400	79.6	79.6	2.9	2.8	0.35	2,400	1,531	3.5	7.0	6.7	11.0
Czech R.	0.88	2,031	1,885	77.9	77.9	3.2	2.9	1*	2,031	2,031	6.8	6.8	12.1	12.1
Estonia	1	1,356	1,356	76.2	76.2	3.2	3.2	1	1,356	1,356	5.3	5.3	9.7	9.7
Greece	0.87	2,648	2,648	80.7	80.7	4.0	3.1	0.45	2,648	1,531	4.8	7.0	9.8	11.0
Hungary	0.53	1,798	1,356	74.9	76.2	5.5	3.2	1*	1,798	1,798	7.2	7.2	9.3	9.3
Latvia	1*	1,210	1,210	73.6	73.6	7.8	7.8	1*	1,210	1,210	5.9	5.9	7.6	7.6
Lith.	0.62	1,531	1,356	73.6	76.2	5.0	3.2	1	1,531	1,531	7.0	7.0	11.0	11.0
Malta	0.66	2,762	2,696	80.7	80.7	5.6	2.9	0.42	2,762	1,531	4.4	7.0	10.3	11.0
Poland	0.82	1,495	1,495	76.7	76.7	4.7	3.2	0.84	1,495	1,495	6.5	6.9	8.0	10.7
Portugal	0.94	2,673	2,648	80.5	80.5	3.1	2.8	0.36	2,673	1,531	3.4	7.0	9.7	11.0
Slovakia	0.43	2,002	1,356	76.0	76.2	6.8	3.2	0.65	2,002	1,531	6.0	7.0	9.2	11.0
Slovenia	1*	2,559	2,559	80.0	80.0	2.6	2.6	0.47	2,559	1,531	4.6	7.0	11.0	11.0
Spain	1*	3,002	3,002	82.5	82.5	3.8	3.8	0.30	3,002	1,531	3.1	7.0	9.2	11.0

Note: *) This is the case of a country efficient by default.

Source: the authors based on World Bank Data Indicators (2016).

Group 3 is the most heterogeneous, with the highest differences across countries in all indicators (Table 6). It follows that majority of unit efficiencies are reached by default in both models. For example, Albania is efficient by Model 1 since it has the highest life expectancy, although having the second worst value of IMR.

Belarus is the only efficient country by both models in Group 3 in spite of the fact it has a very low life expectancy. The countries which have increased their health expenditure still do not reach adequate health outcomes which may be due to a natural time lag.

Belarus, Moldova and Ukraine are considered efficient by Model 2 since they retain relatively high numbers of health staff and hospital beds with small amounts of health expenditure per capita.

Note that an inefficient country may not be projected by SBM model to the nearest point on the efficiency frontier since SBM model is aimed at maximizing the slacks in inputs and outputs. That is why the inputs and outputs of inefficient countries are frequently projected to the values of their peers (in our case, peers are usually not efficient by default). Thus, an identification of weak points in inputs and outputs is much more relevant information given by the projections than the absolute values of recommendations.

Table 6. Group 3 input and output data for 2011, efficiency scores, and DEA projections

Group 3	Model 1							Model 2						
	Score	HE per cap.		LE		IMR		Score	HE per cap.		Hospital beds		Health staff	
		Data	Proj.	Data	Proj.	Data	Proj.		Data	Proj.	Data	Proj.	Data	Proj.
Albania	1*	519	519	77.2	77.2	14.3	14.3	0.41	519	519	2.4	7.1	5.1	10.0
Belarus	1*	819	819	70.6	70.6	4.3	4.3	1*	819	819	11.3	11.3	14.3	14.3
Bos. Herz.	1	915	915	76.0	76.0	6.2	6.2	0.32	915	607	3.5	8.9	7.2	11.6
Bulgaria	0.44	1,138	559	74.2	76.3	10.9	10.9	0.39	1,138	607	6.4	8.9	8.5	11.6
Macedonia	0.85	783	662	74.9	74.9	7.5	7.5	0.43	783	607	4.5	8.9	7.0	11.6
Moldova	1*	475	475	68.6	68.6	14.5	14.5	1*	475	475	6.2	6.2	9.3	9.3
Mont.	0.88	978	864	74.5	74.5	5.7	5.7	0.33	978	607	4.0	8.9	7.2	11.6
Romania	0.52	958	550	74.6	76.5	11.5	11.5	0.43	958	607	6.1	8.9	7.9	11.6
Serbia	0.62	1,222	758	74.5	74.5	6.4	6.4	0.29	1,222	607	5.4	8.8	6.7	11.6
Ukraine	0.67	607	582	70.8	75.8	9.6	9.6	1	607	607	8.9	8.9	11.6	11.6

Note: *) This is the case of a country efficient by default.

Source: the authors based on World Bank Data Indicators (2016).

5. Discussion

Previous studies focused on the efficiency of using health expenditure for reaching desired health outcomes either as a unique input (e.g. Hsu, 2013) or in combination with health resources (e.g. Hadad et al., 2013). In our study we use health expenditure as a unique input, since it covers all expenses on providing health care. Moreover, health expenditure is expected to be efficiently used for two purposes: supporting health outcomes as well as building and maintaining health resources. This approach allows us to separately assess the effectiveness and economy of health systems and identify countries which are efficient from each viewpoint. The countries efficient by Model 1 reach the best results in health outcomes relatively to their health spending. The countries efficient by Model 2 are able to maintain the highest level of health resources with respect to health expenditure. Thus, countries efficient by both models can be considered the most successful in using the health expenditure.

In Model 1 we use traditional indicators to describe the health outcomes, but we modify them in order to emphasize the differences among countries. Hence, we take into account life expectancy at birth which exceeds the age of 65. The necessary modification of the infant mortality to be a good DEA output is realized as the ratio of live births to the number of infant deaths which corresponds with Hsu (2013), but has a more natural interpretation.

While Model 1 responds to the traditional view onto the efficiency of health systems, Model 2 brings a new insight on the efficiency from economic perspective.

Previous studies compared European countries with other OECD countries (Hadad et al., 2013) or with former Soviet Union Republics (Hsu, 2013). However, socio-economic environment of countries within these groups are relatively heterogeneous. In order to avoid this heterogeneity, we restrict to European countries with more than 400,000 inhabitants, and divide them onto three groups based on the economic power of their citizens.

In contrast with mentioned papers where output-oriented BCC model was applied for DEA, we use a non-oriented slack-based measure which is more convenient for benchmarking of health systems since it includes possible improvements of all considered inputs and outputs.

6. Conclusions

The two different views on efficiency of health expenditure related to health production as well as creating resources for health care provision studied in this paper allow us to compare national health systems from both effectiveness and economy perspectives, and identify the potential for performance improvements in individual countries.

The segmentation of countries by GNI into more homogeneous groups occurs to be a perspective approach to produce more valuable results from efficiency analysis based on DEA. In spite of smaller numbers of countries in the groups, significant differences in efficiency between national health systems within the groups have been revealed. Nevertheless, the results need to be verified by statistical analysis with regard to relevant explanatory variables.

Also, some limitations of applied DEA method have been mentioned. Hence, an improvement of methodology for the assessment of healthcare system efficiency to provide valuable results for experts, policy makers and the public is still a challenge for further research.

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