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EFFICIENCY OF HEALTHCARE SYSTEMS IN EUROPEAN COUNTRIES - THE DEA NETWORK APPROACH

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Abstract: Healthcare systems in Europe are constantly undergoing reforms which adapt them to social, economic and political requirements. The aim of this article is to examine the efficiency of healthcare systems in 30 European countries in 2014. The Network Data Envelopment Analysis (NDEA) model was used. The efficiency of the countries' overall health systems and their two main components were examined: the public health system and the medical care system. The models include variables that are out of control of policy makers and the ones that can be controlled by them. The research results show that countries which reformed their healthcare systems achieved higher efficiency more often.

Keywords: healthcare system, public health, medical care, network Data Envelopment Analysis

JEL classification: C61, H51

INTRODUCTION

Ensuring healthcare to citizens is the goal of every government and the efficiency of the healthcare system is a recurrent and important topic of discussion as regards health policy. According to the Global Health Expenditure of the World Health Organization (WHO), health expenditure calculated as a percentage of GDP in recent years has increased significantly. Due to demographic changes, it can be assumed that this trend will continue in the coming decades.

Therefore, it is important to assess the efficiency of healthcare systems in different countries. The efficiency analysis may indicate a possible reduction of resources or an increase in health outcomes at a given level of expenses. For this reason, the

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comparison of healthcare systems is important for identifying best practices and the most effective healthcare systems.

Global health challenges related to the ageing of the population, the imbalance between cost containment while maintaining access to and quality of healthcare, shifting from treatment of acute cases to management of chronic diseases that burden the resources of medical care more heavily, as well as fragmentation of treatment, prompted many European countries to introduce significant changes into their healthcare systems in the last decade [Yaya & Danhoundo 2015]. Some countries have completed reforms, while others are still implementing them, and yet others are on the planning stage.

The number of healthcare systems in Europe subjected to the long process of structural and organizational reforms is growing. Both tax-financed and contribution-based systems often change their organizational and institutional structures in order to ensure individual and populational public health. They also conduct initiatives aimed at encouraging entities operating in other sectors to implement health-oriented habits. A significant part of the political objectives implemented in the countries surveyed remains unchanged, while the strategies and mechanisms by which decision-makers want to achieve these goals undergo significant changes.

The wide-ranging debate on the reform of health systems has been ongoing since the end of the 1980s in Western Europe and the early 1990s in Central and Eastern Europe [Saltman & Figueras 1998].

There is no universal model according to which healthcare system should be reformed. Healthcare in each of the European countries is organized differently but all of them face similar problems, related to excessive demand for high-quality health services and insufficient resources of public health and medical care. Despite the diversity of healthcare systems, reforms in most countries have many common features. These include: expanding and strengthening primary healthcare, expanding environmental care, improving the availability of healthcare, changing the models of payment and reimbursement for health services, improving the quality of services or increasing the use of information technology in health [Yaya & Danhoundo 2015].

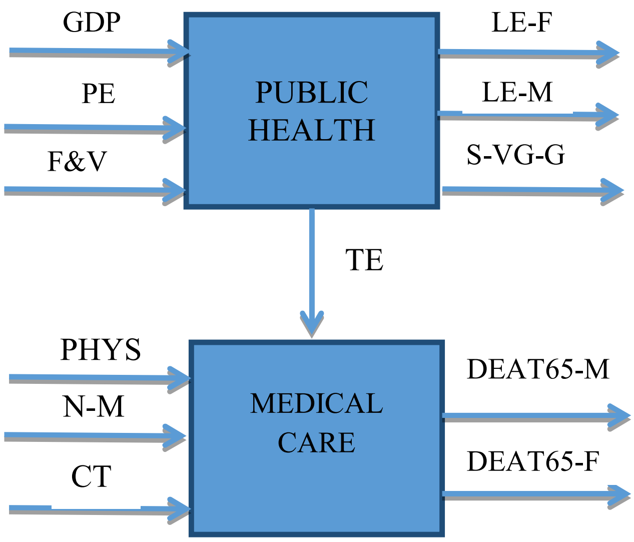
METHODOLOGY AND VARIABLES

The authors of many studies have attempted to investigate the efficiency of healthcare systems. Most of these studies are based on the traditional DEA (Data Envelopment Analysis) method, used to obtain results of the efficiency of healthcare systems in the compared countries [Afonso & St Aubyn 2006, Joumard et. al. 2010, Mirmirani et al. 2008, Retzlaff-Roberts et al. 2004]. In the traditional DEA model, the healthcare system is treated as one division in the calculation of efficiency based on a set of inputs and outputs. One of the drawbacks of these models is the neglect of intermediate products or linking activities. This makes it difficult to distinguish the efficiency of various elements of the healthcare system. According to a panel of experts from high-income countries, healthcare systems are based on the interaction of public health and medical care. It is recommended that both of these elements — public health and medical care — are examined when making comparisons between countries [Woolf & Aron 2013, Ozcan & Khushalani 2017].

The network-DEA approach makes it possible to describe the structure of processes in the healthcare systems in an unambiguous way while maintaining the advantages of the DEA method. The network-DEA model goes beyond the traditional DEA model, enabling the calculation of the efficiency of separate sub-processes, in addition to the efficiency of the entire healthcare system [Tone & Tsutsui 2009]. The DEA method is chosen mainly due to the difficulty of defining the production function, which would combine the inputs and outputs of the healthcare system through appropriate technology. In addition, the healthcare systems have multiple outputs.

The variables and combinations used in the NDEA model applied in this paper are shown in Figure 1.

Figure 1. Variables in network DEA model



Source: own elaboration

The inputs related to public health include non-medical determinants of health that are beyond the control of healthcare systems. These inputs are related to the wealth of the society and lifestyle and contribute significantly to individual health effects but their control and regulation is usually performed by the public health departments in each country. The most common variables include legal regulations and education aimed at promoting healthy lifestyles, the wealth of the society and the reduction of social inequalities. From among many variables, those that meet the isotonicity criterion have been selected, i.e. those for which there is a significant positive correlation between inputs and outputs. Therefore, annual gross domestic product (GDP) in EUR, converted according to the purchasing power standard (PPS) per inhabitant, preventive care expenditure (PE) per inhibitant in EUR and the percentage of the population declaring consumption of fruit and vegetables at least once a day were used as inputs to the public health subsystem. These inputs were used in previous studies evaluating the efficiency of healthcare systems [Ravangard et al. 2014, Hadad et al. 2013].

The inputs to the medical care subsystem represent capital, labour and technology and are widely used in assessing efficiency. They include the number of physicians (PHYS) and the number or nurses and midwives (N-M) per 100,000 inhabitants, and the number of computer tomographs (CT) per 100,000 inhabitants. The introduction of the number of computer tomographs variable is a response to the introduction of new technologies in treatment and the increasing frequency of diagnosing patients on the basis of imaging services.

These inputs were used, inter alia, in [Hadad et al. 2013, Mirmirani et al. 2008, Samut & Cafri 2016] studies. Annual per capita spending on healthcare taking into account the purchasing power standard of the currency in EUR (TE) is an intermediate variable connecting both subsystems and has been treated as an input to the subsystem of medical care and as an output of the public health subsystem.

It is a variable that is partly beyond the control of decision-makers — it is the result of the functioning of the entire healthcare system. Its value should be maximised in terms of public health and expenditure on preventive care and maintained at an appropriate level (minimised within reasonable limits) in the case of medical care.

The variables reflecting the outputs from the public health subsystem include life expectancy at birth for women (LE-F) and men (LE-M) as variables calculated for each of the countries and the percentage of inhabitants self-assessing their health as very good and good (S-VG-G) as a variable indicated in the social study. The outputs in the subsystem of medical care include reversed variables related to the standardised death rate of less than 65 years for women and men (DEAT65-F and DEAT65-M) per 100,000 inhabitants, describing the so-called premature death. It is believed that the vast majority of diseases before the age of 65 can be cured as long as the medical care is working properly.

All of these outputs were commonly used in calculating the efficiency of healthcare systems [de Cos & Moral-Benito 2014].

Statistical information from 2014 from the Eurostat and WHO databases was used.

Healthcare benefits belong to most important services performed in every country in the world. In general, ensuring health is effective if the healthcare providers (its producers) make the best use of available resources. Expenditure on health is a heavy burden for public finance and therefore a careful analysis of the efficiency of spending is required. An ineffective healthcare system would mean that outputs (or "performance") could be raised without spending extra money, or that care costs could be reduced without affecting the results, provided that greater efficiency is ensured. The research results indicate that there are cases in which the efficiency of health systems can be significantly improved without increasing financial resources [Grigoli 2012].

Particularly important is the fact that on average over 70% of spending on healthcare in EU countries is financed from public funds.

Table 1 presents the basic characteristics of the variables used.

Table 1. Descriptive statistics for all variables used in the Network DEA model

Statistics	GDP	PE	F&V	LE-F	LE-M	S-VG-G
Mean	28 476.7	65.2	51.8	82.5	76.7	67.2
Standard error	12 213.2	37.6	8.9	2.1	3.6	10.2
Median	24 650	63.2	53.1	83.3	78.3	69.4
Max	78 600	140.1	66.4	85.3	81.1	82.5
Min	12 900	6.3	29.2	77.8	67.9	44.9

Continued

Statistics	PHYS	N-M	CT	DEAT65-M	DEAT65-F	TE
Mean	349.9	899.2	2.2	316.2	145.6	2 465.6
Standard error	61.6	347.4	0.9	150.9	43.3	1 134.3
Median	336.4	825.4	2.1	259.5	131.6	2 208.4
Max	504.9	1786.3	3.8	670.2	234.8	4 709.8
Min	230.7	347.4	0.8	164.8	92.4	809.0

Source: own computation

The study covered healthcare systems of 30 European countries - 28 countries of the European Union, as well as Norway and Switzerland.

NETWORK-DEA MODEL

The healthcare system of each of the compared European countries consists of two sub-units — public health and medical care. Both sub-units were assigned the same weights, as both processes are equivalent components of the healthcare system [Woolf & Aron 2013]. The NDEA modification of inputs-oriented BCC model with variable return to scale (VRS) was applied. The input oriented of the model is a consequence of the fact that decision-makers cannot influence outputs. The size of medical personnel, the amount of equipment or health-promoting behaviours can be influenced but it is not possible to directly influence e.g. the level of mortality rate.

The calculations were made using the MaxDEA for Data Envelopment Analysis software provided by Beijing Realworld Software Company Ltd.
If every country is considered to be one DMU (decision making unit) within which a healthcare system operates, in this study we assume that each DMU_j (j = 1, 2, 3,..., n) has m^1 input column vector $X_{i}{}^{2}{}_{j}=(i^1=1,2,...m^1)$ and s^1 final output column vector $Y_{r}{}^{1}{}_{j}=(r^1=1,2,..,s^1)$ for the public health sub-process. In the medical care sub-process there is m^2 input column vector $X_{i}{}^{2}{}_{j}=(i^2=1,2,..,m^2)$ and s^2 final output column vector $Y_{r}{}^{2}{}_{j}=(r^2=1,2,..,s^2)$ for each country. There are p intermediate products $Z_{pj}=(p=1,2,..q)$ to connect the two sub-processes.
In order to take the scale effect into account, we introduce Models 1.1-1.3, based on the VRS assumption [Chen et al. 2009]. The model has no pre-assigned weights for the sub-processes [Guan & Zuo 2012].

$$\begin{aligned}
\theta_k = \max \ & \sum_{r^1=1}^{s^1} u_{r^1} Y_{r^1 k} + \sum_{r^2=1}^{s^2} u_{r^2} Y_{r^2 k} + \sum_{p=1}^{q} w_p Z_{pk} - \mu_k^1 - \mu_k^2 \\
s.t. & \sum_{i^1=1}^{m1} \upsilon_{i^1} X_{i^1 k} + \sum_{i^2=1}^{m^2} \upsilon_{i^2} X_{i^2 k} + \sum_{p=1}^{q} w_p Z_{pk} = 1 \\
& \left(\sum_{r^1=1}^{s^1} u_{r^1} Y_{r^1 j} + \sum_{p=1}^{q} w_p Z_{pj}\right) - \sum_{i^1=1}^{m^1} \upsilon_{i^1} X_{i^1 j} - \mu_k^1 \le 0 \\
& \sum_{r^2=1}^{s^2} u_{r^2} Y_{r^2 j} - \left(\sum_{p=1}^{q} w_p Z_{pj} + \sum_{i^2=1}^{m^2} \upsilon_{i^2} X_{i^2 j}\right) - \mu_k^2 \le 0 \\
& u_{r^1}, u_{r^2}, \upsilon_{i^1}, \upsilon_{i^2}, w_p \ge \varepsilon,\ j = 1,2,...,\ n
\end{aligned} \tag{1.1}$$

$$\begin{aligned}
& \theta_k^1 = \max \sum_{r^1=1}^{s^1} u_{r^1} Y_{r^1 k} + \sum_{p=1}^{q} w_p Z_{pj} - \mu_k^2 \\
& s.t. \sum_{i^1=1}^{m1} \upsilon_{i^1} X_{i^1 k} = 1 \\
& \left(\sum_{r^1=1}^{s^1} u_{r^1} Y_{r^1 k} + \sum_{r^2=1}^{s^2} u_{r^2} Y_{r^2 k} + \sum_{p=1}^{q} w_p Z_{pk}\right) \\
& - \theta_k \left(\sum_{i^1=1}^{m1} \upsilon_{i^1} X_{i^1 k} + \sum_{i^2=1}^{m^2} \upsilon_{i^2} X_{i^2 k} + \sum_{p=1}^{q} w_p Z_{pk}\right) - \mu_k^1 - \mu_k^2 = 0 \\
& \left(\sum_{r^1=1}^{s^1} u_{r^1} Y_{r^1 j} + \sum_{p=1}^{q} w_p Z_{pj}\right) - \sum_{i^1=1}^{m^1} \upsilon_{i^1} X_{i^1 j} - \mu_k^1 \le 0 \\
& \sum_{r^2=1}^{s^2} u_{r^2} Y_{r^2 j} - \left(\sum_{p=1}^{q} w_p Z_{pj} + \sum_{i^2=1}^{m^2} \upsilon_{i^2} X_{i^2 j}\right) - \mu_k^2 \le 0 \\
& u_{r^1}, u_{r^2}, \upsilon_{i^1}, \upsilon_{i^2}, w_p \ge \varepsilon,\ j = 1,2,...,\ n
\end{aligned} \tag{1.2}$$

$$\begin{aligned}
&\theta_k^2 = \max \sum_{r^2=1}^{s^2} u_{r^2} Y_{r^2k} - \mu_k^2 \\
&s.t. \sum_{p=1}^{q} w_p Z_{pj} + \sum_{i^2=1}^{m^2} \upsilon_{i^2} X_{i^2k}) = 1 \\
&(\sum_{r^1=1}^{s^1} u_{r^1} Y_{r^1k} + \sum_{r^2=1}^{s^2} u_{r^2} Y_{r^2k} + \sum_{p=1}^{q} w_p Z_{pk}) \\
&- \theta_k (\sum_{i^1=1}^{m1} \upsilon_{i^1} X_{i^1k} + \sum_{i^2=1}^{m^2} \upsilon_{i^2} X_{i^2k} + \sum_{p=1}^{q} w_p Z_{pk}) - \mu_k^1 - \mu_k^2 = 0 \\
&(\sum_{r^1=1}^{s^1} u_{r^1} Y_{r^1j} + \sum_{p=1}^{q} w_p Z_{pj}) - \sum_{i^1=1}^{m^1} \upsilon_{i^1} X_{i^1j} - \mu_k^1 \le 0 \\
&\sum_{r^2=1}^{s^2} u_{r^2} Y_{r^2j} - (\sum_{p=1}^{q} w_p Z_{pj} + \sum_{i^2=1}^{m^2} \upsilon_{i^2} X_{i^2j}) - \mu_k^2 \le 0 \\
&u_{r^1}, u_{r^2}, \upsilon_{i^1}, \upsilon_{i^2}, w_p \ge \varepsilon,\ j = 1,2,...,\ n
\end{aligned} \tag{1.3}$$

where μ^1_k and μ^2_k are unconstrained in sign.

The efficiency scores calculated using models (1.1) – (1.3) are more discriminative than those independently calculated from the traditional DEA models because models contain more constraints.

THE RESULTS AND THEIR INTERPRETATION

The results of the calculation of the efficiency of healthcare systems for 30 European countries are presented in Table 2. The "efficiency" column contains the result of efficiency and the countries are arranged according to the decreasing efficiency value.

The full efficiency of the network DEA method calculated for all public health and medical care variables was achieved by 3 countries: Cyprus, Greece and Luxembourg. All these countries have high life expectancy and low mortality rates among people up to the age of 65. Cyprus has a very high share of private spending in current spending on health, exceeding 50%, but the share of out of pocket spending amounts to only about 8%. However, this is not a decisive factor, as Cyprus is the country with the lowest mortality rate of women aged under 65. In the case of Greece, apart from good health results, the position in the ranking was also influenced by low inputs. Luxembourg has high level of expenditure but also high health outcomes.

Table 2. Efficiency Scores for the overall health system for the 30 European countries

Item	Country	Efficiency	Item	Country	Efficiency
1.	Cyprus	1.0000	16.	Italy	0.7735
2.	Greece	1.0000	17.	Bulgaria	0.7671
3.	Luxembourg	1.0000	18.	Czech Republic	0.7511
4.	Spain	0.9587	19.	Germany	0.7356
5.	Ireland	0.9457	20.	Denmark	0.7277
6.	Netherlands	0.9378	21.	Switzerland	0.7114
7.	United Kingdom	0.9305	22.	Norway	0.6975
8.	Portugal	0.9141	23.	Poland	0.6759
9.	Slovenia	0.9137	24.	Romania	0.6674
10.	Malta	0.8922	25.	Austria	0.6635
11.	Croatia	0.8434	26.	Slovakia	0.6214
12.	Finland	0.8237	27.	Latvia	0.6189
13.	France	0.7874	28.	Hungary	0.5954
14.	Sweden	0.7796	29.	Estonia	0.5921
15.	Belgium	0.7788	30.	Lithuania	0.4900

Source: own computation

Table 3 presents the results of the study of the efficiency and ranks of 30 countries separately for public health and medical care processes.

The TE P_H column shows the results of the efficiency of the public health subsystem and the TE M_C column the results for the medical care subsystem. In 2014, the full efficiency of the public health subsystem, equal to 1, was reached by 5 countries and the full efficiency of the medical subsystem was reached by 7 countries. In addition to the 3 countries mentioned above, Bulgaria and Romania have also achieved full efficiency as far as public health is concerned. The high position of these countries is due not to the implementation of profound reforms related to prevention and health promotion, but to a very low level of resources.

Four countries were selected for further analysis: two ranked 4th and 6th, i.e. directly behind the fully efficient ones, Romania, which has achieved full public health efficiency, and Lithuania, which has achieved the lowest public health efficiency among the countries surveyed.

Table 3. Efficiency scores and ranks of public health and medical care areas

Country	TE P_H	R	TE M_C	R	Country	TE P_H	R	TE M_C	R
Austria	0.6718	26	0.6552	21	Latvia	0.8730	11	0.3648	28
Belgium	0.5765	30	0.9811	8	Lithuania	0.7345	20	0.2455	30
Bulgaria	1.0000	1	0.5342	24	Luxembourg	1.0000	4	1.0000	4
Croatia	0.9595	7	0.7273	19	Malta	0.8511	13	0.9332	9
Cyprus	1.0000	2	1.0000	1	Netherlands	0.9733	6	0.9022	12
Czech Republic	0.8358	15	0.6664	20	Norway	0.6309	28	0.7641	18
Denmark	0.6890	24	0.7664	17	Poland	0.7500	18	0.6019	23
Estonia	0.6781	25	0.5061	26	Portugal	0.8979	9	0.9303	10
Finland	0.7401	19	0.9073	11	Romania	1.0000	5	0.3348	29
France	0.6966	23	0.8781	14	Slovakia	0.7283	22	0.5146	25
Germany	0.8372	14	0.6339	22	Slovenia	0.8274	16	1.0000	5
Greece	1.0000	3	1.0000	2	Spain	0.9174	8	1.0000	6
Hungary	0.7336	21	0.4572	27	Switzerland	0.7669	17	0.7923	16
Ireland	0.8914	10	1.0000	3	Sweden	0.6249	29	0.7979	15
Italy	0.6522	27	0.8948	13	United Kingdom	0.8610	12	1.0000	7

Source: own computation

On the basis of the model built, recommendations for inefficient countries will be formulated (actual and forecast values are presented in Table 4).

Table 4. Projection of changes in the inefficient countries

Country		Public health			Medical care		
		GDP	PE	F&V	PHYS	N-M	CT
Spain	data	24 900	43.62	55.65	380.08	514.9	1.75
	proj.	22 844	40.02	51.05	-	-	-
Netherland	data	35 800	140.07	36.15	335	1021	1.33
	proj.	30 518	102.62	35.19	302.23	921.14	0.95
Romania	data	15 200	6.28	29.2	269.82	633.36	1.07
	proj.	-	-	-	86.64	212.07	0.36
Lithuania	data	20 800	24.63	51.2	430.74	790.90	2.22
	proj.	15 277	6.31	29.35	100.48	194.17	0.54

Source: own computation

To be fully efficient as regards public health, Spain needs to reduce its expenditure, e.g. by reducing expenditure on preventive care to 40 EUR per capita, as the model shows that currently the part of GDP over 22,844 EUR per capita is not used efficiently to improve health outcomes. Moreover, fruit and vegetables could be consumed once a day by 51% of the population.

In the case of the Netherlands, expenditure should be reduced — the current health outcomes could also be achieved with: GDP reduced by 5 282 EUR per capita, PE reduced by 37.5 EUR per capita, social consumption of fruit and vegetables reduced by 1%, the number of doctors reduced by 33, the number of nurses and midwives reduced by 100 per 100,000 inhabitants, and the involvement of computer tomography reduced by 0.38 units per 100,000 inhabitants.

Romania, due to the lowest inputs, is achieving full public health efficiency, while the same mortality rates could be achieved with a lower expenditure: 183 fewer doctors and 421 fewer nurses and midwives per 100,000 inhabitants and 0.71 fewer computer tomographs per 100,000 inhabitants.

Lithuania, on the other hand, has the lowest life expectancy among men and the highest mortality rate among men up to the age of 65. Moreover, only 44% of the inhabitants assess their health as very good and good. These health outcomes could be achieved with much lower inputs — on the other hand, if the current resources were maintained, the mortality rates should be significantly reduced, particularly among men. Thus, for the outcomes achieved, GDP could be 27% lower, spending on preventive care 74% lower, the percentage of the population consuming fruit and vegetables 22 percentage points lower, the number of doctors 77% lower, the number of nurses 75% lower, and the number of computer tomographs 76% lower.

SUMMARY AND CONCLUSIONS

All analysed countries make changes in the functioning of their healthcare systems. The implemented reforms are often related to the financing system, which was not evaluated in this study.

The efficiency of the public health system plays an important role in the efficiency of the entire healthcare system and improving its effectiveness should be a priority for all countries.

The efficiency of healthcare systems is also affected by the relation of public and private out-of-pocket expenses. In countries where the private health insurance system is underdeveloped, excessive out-of-pocket expenses may result in resignation from the necessary medical services. This results in lower health results of the society.

However, it should be remembered that the inputs and outputs of public health and medical care systems are highly complex constructs. The variables selected to represent these structures serve only as a proxy to measure them. Although this study is based on variables commonly used in the literature, there are many other variables that could be selected as elements of the DEA model. The results from the DEA model may vary depending on the variables chosen to represent each of the constructs.

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