Performance analysis of healthcare systems in European countries

Corrado lo Storto*

Introduction

Over the last two decades the costs of healthcare have increased significantly in the developed countries, and public spending on healthcare has become one of the largest government spending items, representing about the 10% of GDP according to the World Health Organization (OECD, 2015), while healthcare per capita expenditure has risen by about 70% since the early 1990s (OECD, 2010).

It is widely believed that expenditure growth is caused by a diffused inefficiency in the healthcare sector in a country, both at the level of the facilities and organizations that provide service and the national healthcare system. Consequently, achieving greater efficiency of public spending in the healthcare sector - and particularly improving the quality of service and outputs of the healthcare system while containing expenditure - has become one major concern and important challenge for both national and regional government.

The recent economic and financial downturn has further reinforced the need to improve the level of efficiency in the healthcare sector, and because in European countries the healthcare service is mostly financed from public funds, evaluating to what extent resources are utilized efficiently has become an important issue in the policy maker agenda.

As a consequence of the tremendous pressure to evaluate the efficiency of healthcare facilities and systems, several scholars and policy makers have devoted great attention to the measurement and comparison of efficiency rates in order to identify more effective policies to manage public resources in the healthcare sector.

This paper presents the results of a recent benchmarking study that compare efficiencies of the national healthcare systems in 31 European countries from 2011 to 2014. The study implements Data Envelopment Analysis (DEA) to calculate and compare the efficiency rates of the healthcare systems under evaluation.

The paper is organized as follows. The second section discusses shortly main approaches to measure efficiency in the healthcare sector. The third section introduces major issues that explain how DEA works as a method to calculate efficiency and conduct benchmarking studies. Focus is on the Slack-Based Measure model. The benchmarking study is illustrated in the fourth section. Finally, the last section presents conclusions.

The measurement of efficiency in the healthcare sector

Efficiency in the healthcare sector can be measured at different levels, i.e. macro, meso and micro (Häkkinen and Joumard, 2007; Joumard et al., 2010). At the macro level, focus is on the national or regional healthcare systems and the efficiencies of the healthcare systems across countries or regions over time are measured and compared (Afonso and St. Aubyn, 2006; Anton and Onofrel, 2012; Berger and Messer, 2002; DeRosario, 1999; Retzlaff-Roberts et al., 2004; Spinks and Hollingsworth, 2009). At the meso level, focus is on the facilities, organizations or organizational units that provide healthcare services, such as hospitals, acute care hospitals, district hospitals, rural hospitals, etc. (Amado and Santos 2009; Athanassopoulos and Gounaris, 2001; Butler and Li, 2005; Coyne et al. 2009; Goncalves et al., 2007; Hofmarcher et al., 2002; Hollingsworth, 2008; Jacobs et al., 2006; Kirigia et al., 2004; Osei et al., 2005; Rebba and Rizzi 2007; Wei, 2006). Finally, at the micro level, focus is on the measurement of efficiency of the specific disease or healthcare (quality improvement) program (Chilingerian, 1995; Santos et al., 2012; Siciliani et al., 2013).

Two different methodological approaches are implemented to measure efficiency at the macro or system level. The first one is based on the calculation of individual partial indicators generally developed as ratios that provide measurements for different sub-dimensions of efficiency, i.e. resources expended, responsiveness of each healthcare system, etc. (Davis et al., 2004; Davis et al., 2007; Jamison and Sandbu, 2001; WHO 2012). However, information that is provided by these partial indicators is usually conflicting and they are

* *Prof. Corrado lo Storto, PhD*
Department of Industrial Engineering
University of Naples Federico II

unable to classify comprehensively and unambiguously the healthcare systems under evaluation in terms of their performance. The second approach is based on the adoption of non-parametric or parametric econometric techniques, i.e. regression, stochastic frontier analysis (SFA), and data envelopment analysis (DEA) that compute a comprehensive single index of efficiency (Giuffrida and Gravelle, 2001; Hollingsworth, 2003; Ozcan, 2008; Skinner, 1994).

DEA and SFA are commonly adopted methodological approaches to measure efficiency. Both approaches estimate an efficient frontier and generate a measurement of efficiency as a distance from that frontier, but they use different techniques to generate this latter. Particularly, DEA has the advantage of not requiring strong assumptions about the specification of the functional form to estimate the frontier, and provides acceptable results even with small samples. For these reasons it is extensively used by scholars in benchmarking analyses (Bhat, 2001; Borisov et al., 2012; Giokas, 2002; Jafarov and Gunnarsson, 2008; Mirmirani et al., 2008; Verhoeven et al. 2007).

Data Envelopment Analysis

Healthcare systems can be modeled as a black box in which an unspecified production function combines a multiplicity of resources (i.e. inputs as labor and capital) to promote, restore and maintain health (i.e., outputs generated as increased life expectancy of people, lives saved, better quality of life) (Roemer, 1991). The performance in terms of efficiency of this sort of production function can be easily calculated by implementing DEA. DEA has been widely used in healthcare efficiency research since the 1990s to identify sources of inefficiencies and develop effective improvement strategies (Hollingsworth, 2008; Ozcan, 2008). It is a non-parametric technique that computes the relative efficiency of a number of units denominated decision making units (DMUs) by running the same number of linear programming models, one for each unit that should be evaluated (Charnes et al., 1978).

As emphasized in the previous section, a key advantage of DEA over other methodological approaches is that it does not require any strong assumption about the peculiar relationships between inputs and outputs, while the production possibility set (PPS) frontier is constructed as a set of linear combinations of the input and output measurements of the evaluated DMUs. Efficiency is henceforth quantified by measuring the distance of a DMU from the PPS frontier. Moreover, DEA can handle complex relationships between multiple inputs and outputs.

DMUs lying on the envelopment frontier are considered efficient (or 100% efficient). Vice versa, a DMUo results inefficient if a virtual DMU formed as a linear combination of some of the real DMUs under evaluation outperforms it. If DMUo is unable to increase one of the outputs without increasing at least one input or decreasing at least one of the other outputs, it is efficient.

Radial measures of efficiency based on the model proposed by Charnes et al. (1978) are unable to capture all sources of inefficiencies. To avoid such a drawback, Tone (2001) has introduced a more comprehensive measurement of efficiency in which input and output slack variables s+ and s- are utilized to evaluate deviation of a DMU from the efficient frontier.

Assume that there are n homogeneous DMUs that should be evaluated with input and output matrices $X=(x_{ij})\in\Re^{m\times n}$ and $Y=(y_{ij})\in\Re^{s\times n}$ and X>0 and Y>0, the production possibility set PPS is defined as follows

$$PPS = \left\{ x, y) \middle| x \geq X\lambda,\ y \leq Y\lambda, \lambda \geq 0 \right\} \tag{1}$$

where λ is a nonnegative vector in $\Re^n$.

A certain $DMU_o(x_o,y_o)$ can thus be described as follows,

$$\begin{aligned} x_o &= X\lambda + s^- \\ y_o &= Y\lambda - s^+ \ \lambda \geq 0 \end{aligned} \tag{2}$$

where s^- and s^+ are respectively input and output slack variables. By increasing output by s^+ and/or by decreasing input by s- the performance of DMU_o can be improved to full efficiency.

For an input oriented and constant returns to scale Slack-Based Measure model (SBM-model) the efficiency of a $DMU_o(x_o, y_o)$ can be measured by solving the following fractional program

$$\begin{aligned} \rho^{\iota} &= \min\ \rho = 1-\frac{1}{m}\sum_{i=1}^{m}\frac{s_i^-}{x_{io}} \\ s.t.\ &\sum_{j=1}^{n} x_{ij}\lambda_j + s_i^- = x_{io} \\ &\sum_{j=1}^{n} y_{rj}\lambda_j - s_r^+ = y_{ro} \\ &\lambda_j \geq 0,\ s_i^- \geq 0,\ s_r^+ \geq 0, \\ &i = 1,2,...,m,\ r = 1,2,...,s, \\ &j = 1,2,...,n \end{aligned} \tag{3}$$

Variables s^- and s^+ measure the distance of DMUo inputs and outputs from inputs $\chi\lambda$ and outputs $\Upsilon\lambda$ of a virtual unit. DMUo is efficient if $\rho^*=1$, that means $s_o^+ = s_o^- = 0$. By adding the additional constraint $e^T\lambda=1$ in which e denotes the unit vector variable returns to scale (VRS) are taken into account (Banker et al., 1984).

In order to increase discrimination capability, Tone (2002) has proposed a SBM super-efficiency model, in which Model (3) is performed preliminarily to identify efficient DMUs, and next the super-efficiency SBM DEA model is run only for the efficient DMUs.

Making the same assumptions as in Model (3), we have a set of n DMU which produce *s* outputs and consume *m* inputs, and an input orientation and constant returns to scale. Additionally, let us suppose that DMUo is 100% efficient as in the basic SBM DEA formulation. The super-efficiency *ρ** of DMUo can be computed using the following input oriented SBM model (Tone, 2002)

$$\rho_o^{\iota} = \min \rho_o = \frac{1}{m}\sum_{i=1}^{m}\frac{\overline{x_i}}{x_{io}} \tag{4}$$

$$\begin{aligned} \text{s.t.} \quad & \sum_{j=1, j\neq o}^{n} x_{ij}\lambda_j \leq \overline{x_i} \quad i=1,\ldots,m \\ & \sum_{j=1, j\neq o}^{n} y_{rj}\lambda_j \geq \overline{y_r} \quad r=1,\ldots,s \\ & 0 \leq \overline{x_i} \leq x_{io} \ \forall i, \\ & \overline{y_r} = y_{ro} \ \forall r, \\ & \lambda_j \geq 0 \ \forall j \ j \neq o \end{aligned}$$

where λj (j=1,…,*n*) is an intensity variable.

Model (4) can be easily transformed into a linear program by means of the Charnes-Cooper transformation (Charnes and Cooper, 1962).

The benchmarking study

Data source and variables

A retrospective, cross-sectional and time dependent perspective was adopted in the benchmarking analysis. Raw data relative to the healthcare systems in 31 European countries have been collected from the Eurostat dataset, covering the period from 2011 to 2014. Variables to be utilized in the DEA efficiency analysis have been categorized into input and output types (Table 1).

Input variables relate to labor and capital resources employed by the national healthcare system to deliver service. The input category includes the following 3 inputs: 1) the number of practicing medical doctors (or practicing physicians), 2) the number of practicing nurses, midwives and healthcare assistants, and 3) the number of beds available in hospitals. Practicing medical doctors provide medical services directly to patients. They apply preventive and curative measures, improve or develop concepts, theories and operational methods and conduct research in the area of medicine and health care. Practicing nurses and midwives provide services directly to patients, assuming responsibility for the planning and management of patient care, including the supervision of other healthcare workers, working autonomously or in teams with medical doctors. In particular, midwives provide care before, during and after pregnancy and childbirth. Practicing healthcare assistants include health care assistants in institutions but not home-based personal care workers. They provide personal care and assistance to patients and residents in hospitals, clinics and residential nursing facilities. The number of beds provides information on health care system capacities, i.e. on the maximum number of patients who can be treated by hospitals. The number of available beds includes all hospital beds that are regularly maintained and staffed and immediately available for the care of admitted patients, either occupied or unoccupied.

Health outputs are measured in terms of outcomes or benefits enjoyed by people. The output category includes 4 outputs: 1) infant mortality between 0 and 1 year of age, 2) healthy life years in absolute value at birth for both males and women, 3) life expectancy at birth in absolute value for both males and women, 4) total country population. Because efficiency analysis implicitly assumes that every output is measured in such a way that a higher amount of the output is associated to a better situation, and, consequently, to a higher efficiency, the first output – infant mortality – should be considered an "undesirable" or "bad output" of the health care system, while the remaining 3 outputs – healthy life years at birth, life expectancy at birth, and population – should be considered "good outputs". As suggested by literature, in performing DEA the bad output was treated as an input (lo Storto, 2016; Scheel, 2001; Yang and Pollit, 2009). Infant mortality is measured by the ratio of the number of deaths of children below one year of age during the year to the number of live births in that year. Healthy life years at birth in absolute value provide a measure of the number of years that a person at birth is still expected to live in a healthy condition, henceforth combining information on mortality and morbidity. Because data are provided separately for males and females, a weighted average measurement was calculated adopting fractional distributions of males and females as weights. Life expectancy at birth measures the mean number of years a newborn child can expect to live if subjected throughout his or her life to the current mortality conditions and the probabilities of dying at each age. A weighted average measurement was also used for this variable as the Eurostat dataset provides two separate measurements for males and females. Finally, total country population is a proxy of total demand for healthcare service.

Table 1 Description of variables

type	name	description	measuring unit
	doctors	medical doctors (practicing)	no. of units
Input	nurses	nurses, midwives, healthcare assistants (practicing)	no. of units
	Ľšŕ ℓ	available beds in hospitals	no. of units
bad Output	mortality_chi	infant mortality (less than 1 year)	no. of units
	healthy_yrs	healthy life years in absolute value at birth (both males and females)	no. of years
good Output	life_exp	life expectancy in absolute value at birth (both males and females)	no. of years
	population	population	no. of units

Results

Table 2 reports main statistics relative to input and output variables used in the efficiency study from 2011 to 2014. Data show a great variance across the national healthcare systems of the countries in the dataset. Countries differ to a large extent with respect to size measured in terms of total population. The standard deviation measure relative to both inputs and outputs is generally higher than mean except for healthy_yrs and life_exp. Data also show that there has been a general increase of the amount of some resources (=inputs) utilized by the healthcare systems. For instance, both the number of medical doctors and nurses, midwives and healthcare assistants steadily increased during the period 2011-2014. On the contrary, the mean of the number of beds available in the hospitals has decreased from 88,807 in 2011 to 87,125 in 2014. Data measuring the outcome of the healthcare systems generally indicate an improvement of all variables used as outputs in the DEA model specification. Infant mortality decreased from 2011 to 2014, with the mean passing from 677 to 620 units and the maximum from 3,386 to 2,990 units. Similarly, the mean and maximum of life expectancy years respectively increased from 79.5 years and 82.8 years in 2011 to 80.1 years and 83.3 years in 2014. The healthy life years variable presents a more steady trend.

Table 2 Statistics of the dataset inputs and outputs (years 2011, 2012, 2013 and 2014)

		Inputs			bad Output	good Outputs		
		doctors	nurses	beds	mortality_chi	healthy_yrs	life_exp	population
2011	mean	55,650	218,460	88,807	677	62.1	79.5	16,647,540
	st.dev	77,639	324,716	140,838	907	4.8	2.8	22,277,765
	max	311,223	1,109,917	672,573	3,386	72.6	82.8	80,222,065
	min	1,118	2,951	1,050	4	52.2	74.1	318,452
2012	mean	56,344	222,306	88,235	659	62.5	79.4	16,687,757
	st.dev	78,538	332,923	140,428	891	4.6	2.9	22,347,633
	max	317,390	1,143,463	670,443	3,347	71.9	82.9	80,327,900
	min	1,142	2,972	1,041	5	53.2	73.5	319,575
2013	mean	57,205	226,318	87,535	628	61.9	79.9	16,728,356
	st.dev	79,814	343,949	139,803	850	4.5	2.7	22,430,106
	max	325,407	1,190,700	667,560	3,030	72.2	83.2	80,523,746
	min	1,168	4,421	1,038	8	53.0	74.5	321,857
2014	mean	58,237	230,046	87,125	620	62.2	80.1	16,790,882
	st.dev	80,846	354,075	139,437	836	5.1	3.0	22,562,639
	max	332,695	1,236,908	666,337	2,990	73.6	83.3	80,767,463
	min	1,193	4,509	1,041	9	53.4	73.9	325,671

Table 3 shows the results of the efficiency analysis. Particularly, measurements relative to the implementation of the input-oriented Slack-Based Measure DEA model with constant returns to scale (CRS) and variable returns to scale (VRS) are included in the table.

The minimum efficiency score is between 0.523 (in 2014) and 0.558 (in 2012). Therefore, the largest rate of inefficiency is close to 50%. Comparison between CRS and VRS efficiency measurements allows taking into account the effect of scale economies on efficiency. The mean CRS and VRS efficiency scores remain almost steady in the period under observation. Indeed, mean CRS efficiency is between 0.757 and 0.766 while VRS efficiency is between 0.845 and 0.871. Further, the ratio between mean CRS and VRS efficiencies is on average 0.885 indicating that scale diseconomies and management inefficiencies may affect the efficiency score.

A more in-depth analysis of results from a micro-analytic perspective supports what emerged from the aggregate analysis. In 2011, the healthcare systems of 9 countries were on the CRS efficient frontier - Cyprus, Iceland, Ireland, Luxembourg, Malta, Poland, Portugal, Slovenia and Sweden – and most of them remained full efficient in the following years. However, all countries having inefficient healthcare systems are rather far from the efficient frontier as the best healthcare system among the inefficient ones is about 20% inefficient (or no more than 80% efficient). In 2011, the healthcare systems of 19 countries achieved full efficiency under the assumption of variable returns to scale, while the number of efficient healthcare systems was 17 from 2012 to 2014. Countries whose healthcare system efficiency is largely affected by scale economies are France, Germany, and Switzerland.

During the period 2011-2014 efficiency scores achieved by the healthcare systems of individual countries remained almost steady as the dataset efficiency mean, with the exception of the UK that became full efficient in 2014.

Table 3 Results obtained from the implementation of the input-oriented SBM DEA model

		2011		2012		2013		2014	
DMU	Country	CRS	VRS	CRS	VRS	CRS	VRS	CRS	VRS
CO1	Austria	0.557	0.573	0.580	0.610	0.547	0.547	0.547	0.588
CO2	Belgium	0.642	0.779	0.639	0.706	0.668	0.674	0.724	0.798
CO3	Bulgaria	0.562	0.609	0.558	0.558	0.553	0.557	0.553	0.622
CO4	Croatia	0.708	0.708	0.737	0.737	0.706	0.707	0.715	0.715
CO5	Cyprus	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
CO6	Czech Republic	0.641	0.744	0.668	0.742	0.638	0.654	0.632	0.773
CO7	Denmark	0.719	0.719	0.743	0.743	0.727	0.735	0.772	0.773
CO8	Estonia	0.766	0.770	0.706	0.712	0.765	0.765	0.725	0.727
CO9	Finland	0.689	1.000	0.664	1.000	1.000	1.000	0.699	1.000
CO10	France	0.583	1.000	0.582	1.000	0.571	1.000	0.619	1.000
CO11	Germany	0.582	1.000	0.610	1.000	0.550	1.000	0.538	1.000
CO12	Greece	0.745	1.000	0.877	1.000	0.735	1.000	0.724	1.000
CO13	Hungary	0.608	0.608	0.598	0.599	0.567	0.567	0.597	0.619
CO14	Iceland	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
CO15	Ireland	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
CO16	Italy	0.757	1.000	0.791	1.000	0.729	1.000	0.772	1.000
CO17	Latvia	0.656	0.661	0.658	0.665	0.658	0.661	0.731	0.733
CO18	Lithuania	0.534	0.537	0.559	0.562	0.530	0.530	0.523	0.523
CO19	Luxembourg	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
CO20	Malta	1.000	1.000	1.000	1.000	0.738	1.000	0.747	1.000
CO21	Netherlands	0.654	1.000	0.651	0.848	0.645	0.811	0.696	0.883
CO22	Norway	0.628	1.000	0.647	1.000	0.596	0.726	0.585	0.720
CO23	Poland	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
CO24	Portugal	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
CO25	Romania	0.687	0.706	0.673	0.701	0.659	0.689	0.668	0.692
CO26	Slovakia	0.590	0.591	0.588	0.589	0.584	0.585	0.582	0.582
CO27	Slovenia	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
CO28	Spain	0.802	1.000	0.862	1.000	1.000	1.000	0.852	1.000
CO29	Sweden	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
CO30	Switzerland	0.576	1.000	0.587	0.740	0.536	1.000	0.531	1.000
CO31	United Kingdom	0.789	1.000	0.783	1.000	0.807	1.000	1.000	1.000
	mean	0.757	0.871	0.766	0.855	0.758	0.845	0.759	0.863
	st.dev.	0.172	0.172	0.171	0.172	0.183	0.183	0.175	0.167
	min	0.534	0.537	0.558	0.558	0.530	0.530	0.523	0.523

Figures 1-4 illustrates the dynamics of CRS efficiency and a number of ratios obtained from some of the input and output variables utilized in the benchmarking study during the period 2011-2014. Specifically, the following ratios have been considered: doctors/nurses, beds/population, doctors/beds, doctors/population. Countries COi (i=1,…,31) are sorted over the horizontal axis using the efficiency score. The healthcare system efficiency of countries that are closer to the origin of the axes scores lower, while that of countries which are far from the origin achieves the maximum value (=100%). All figures clearly show that the ratio "number of medical doctors to number of beds available in hospitals" (doctors/beds) increases with efficiency, and generally countries in which the healthcare system is more efficient have a larger number of doctors for every hospital bed. Vice versa, a lower efficiency usually appears associated to a greater measurement of the ratio "number of available hospital beds to population". Figures also indicate that there is a relevant variance in the way ratios and, consequently, inputs and outputs contribute to achieve higher efficiency of the healthcare systems. The radar-shaped graphic in Figure 5 clearly shows this issue considering a reduced number of countries extracted from the dataset in 2014, e.g. Lithuania, Switzerland, Italy, Sweden and United Kingdom. Countries were selected in order to include high, low and medium efficiency rates and every ratio was normalized by dividing its measurement by its maximum value. Lithuania had the lowest efficiency score and, as expected, the higher values of the ratios. On the contrary, even though both Sweden and UK achieved high efficiency scores in 2014 (=100%), they had very different ratio measurements.

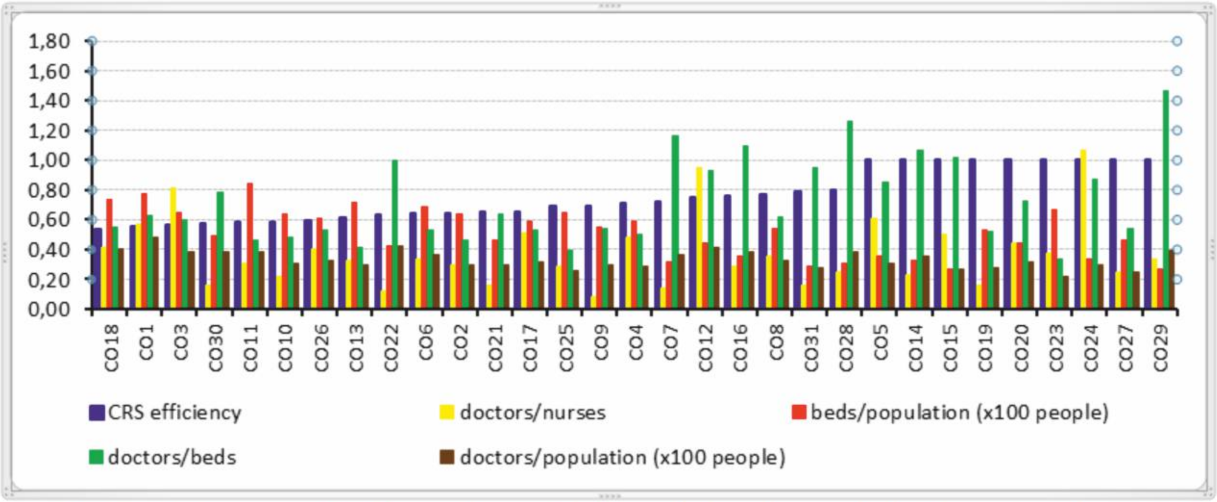

Figure 1 CRS efficiency vs ratios (doctors/nurses, beds/population, doctors/beds, doctors/population) in 2011

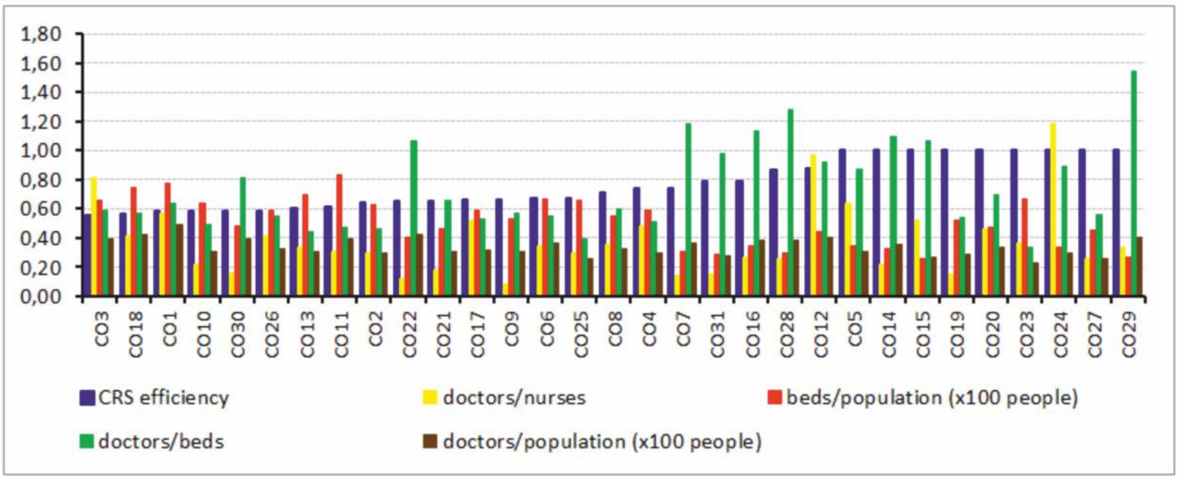

Figure 2 CRS efficiency vs ratios (doctors/nurses, beds/population, doctors/beds, doctors/population) in 2012

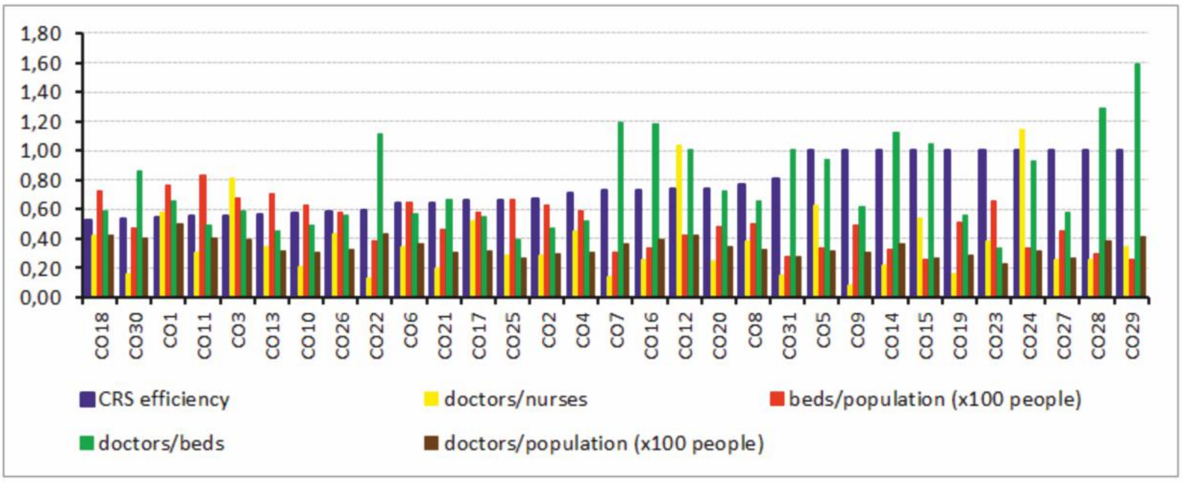

Figure 3 CRS efficiency vs ratios (doctors/nurses, beds/population, doctors/beds, doctors/population) in 2013

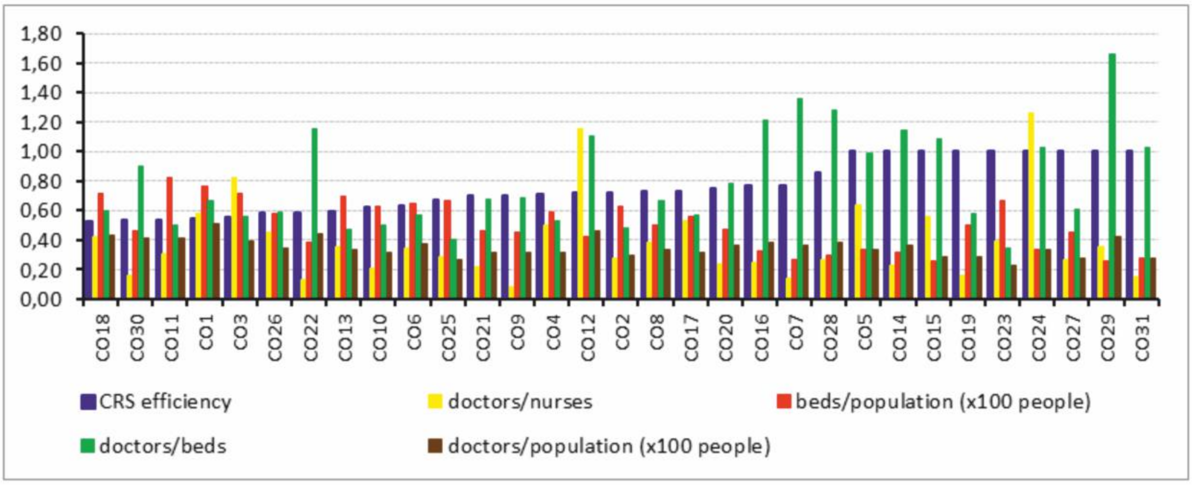

Figure 4 CRS efficiency vs ratios (doctors/nurses, beds/population, doctors/beds, doctors/population) in 2014

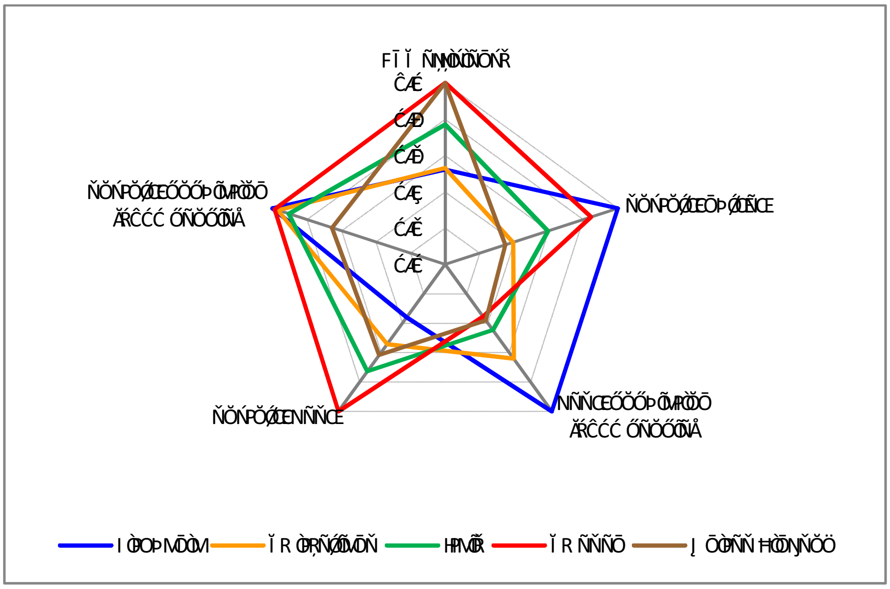

Figure 5 Efficiency vs ratios analysis for a restricted number of countries in 2014

Finally, Table 4 presents the outcome of the super-efficiency analysis relative to the healthcare systems in the 31 countries. The super-efficiency analysis is limited to countries whose healthcare system was 100% efficient in the CRS efficiency analysis. The healthcare system of one of the countries – Iceland – is always placed first in the ranking, while that of Portugal moved from the second (in 2011 and 2012) to the third rank (in 2013 and 2014). For some countries the position in the ranking has improved (i.e., Cyprus) while for others it has worsened to the extent their healthcare system is no longer among the best ones (i.e., Malta). Additionally, the relative distance between the healthcare systems efficiencies diminished as the highest score achieved by Iceland was 2.714 in 2011 and 1.721 in 2014. However, even though this insight may have important implications for the analysis, it is difficult to understand if there has been either a relative improvement of the healthcare systems of more inefficient countries or a relative worsening of the healthcare systems which scored high in 2011.

Table 4 Super-efficiency analysis

rank	DMU	Score	rank	DMU	Score
	Year 2011			Year 2012	
1	CO14	2.714	1	CO14	2.124
2	CO24	1.281	2	CO24	1.312
3	CO20	1.195	3	CO20	1.197
4	CO15	1.090	4	CO27	1.133
5	CO5	1.063	5	CO15	1.099
6	CO23	1.052	6	CO23	1.050
7	CO29	1.039	7	CO5	1.046
8	CO27	1.034	8	CO29	1.031
9	CO19	1.019	9	CO19	1.019
	Year 2013			Year 2014	
1	CO14	1.940	1	CO14	1.721
2	CO5	1.224	2	CO5	1.273
3	CO24	1.211	3	CO24	1.225
4	CO15	1.108	4	CO15	1.107
5	CO23	1.055	5	CO23	1.059
6	CO29	1.025	6	CO29	1.045
7	CO19	1.020	7	CO27	1.039
8	CO27	1.015	8	CO19	1.021
9	CO9	1.008	9	CO31	1.001
10	CO28	1.004			

Conclusions

This study has provided empirical evidence about relative efficiency in the management of the healthcare services across 31 countries in Europe, covering the period from 2011 to 2014. Data Envelopment Analysis (DEA) was implemented to generate an efficiency measurement. Particularly, two DEA model specifications adopting a slack-based measurement of efficiency have been developed to perform the benchmarking analysis. Data retrieved from the Eurostat dataset have been used. A technical efficiency measure rather than cost efficiency was utilized in the benchmarking analysis, privileging resource usage as inputs and health quality performance measurements as outputs instead of expenditure or cost data to avoid any measuring drawbacks related to currency conversion and different purchasing power rates across countries.

Results emphasize that there is a widespread inefficiency in the management of healthcare systems across Europe. From 2011 to 2014, the minimum efficiency measurement is between 52.3% (in year 2014) and 55.8% (in year 2012). In 2011, only 9 countries had a full efficient healthcare system, while the countries included in the study having an inefficient healthcare system achieve a mean efficiency measurement of about 66% under the assumption of constant returns to scale. From 2012 to 2014, mean efficiency of underperforming countries remains between 64% and 67%. Mean efficiency of the whole sample is between 75.7% and 76.6% and between 84.5% and 87.1% respectively under the assumption of constant and variable returns to scale. The graphical analysis of efficiency and some ratios (doctors/nurses, beds/population, doctors/beds, doctors/population) provides insight about variables of the healthcare system that may affect its efficiency, i.e. "number of medical doctors to number of available beds" and "number of hospital beds to population". However, different configurations of the healthcare system may be associated to high efficiency as well as the same configuration may be associated to low and high efficiency rates at the same time. Finally, the super-efficiency analysis has showed that the relative distance between the higher-rank healthcare systems is diminishing. These systems should be more in depth investigated as individual or multiple case studies and, eventually, assuming them as benchmarks to identify best practices that can be transferred to low efficient country healthcare systems by adopting an organizational behavior perspective able to grasp the specific effects of context, cultural, and personal variables more in depth.

References

Afonso, A. and St. Aubyn, M., 2006. Relative efficiency of health provision: a DEA approach with non-discretionary inputs. Department of Economics at the School of Economics and Management (ISEG). Lisbon: Technical University of Lisbon.

Amado, C. and Santos, S. 2009. Challenges for performance assessment and improvement in primary health care: The case of the Portuguese health centres. Health Policy, 91, pp. 43-56.

Anton, S.G. and Onofrei, M., 2012. Health care performance and health financing system in selective countries from Central and Eastern Europe. A comparative study. Transylvanian Review of Administrative Sciences, 35E, pp. 22-32.

Athanassopoulos, A. and Gounaris, C, 2001. Assessing the technical and allocative efficiency of hospital operations in Greece and its resource allocation implications. European Journal of Operational Research, 133(2), pp. 416-431.

Banker, R.D., Charnes, A. and Cooper W.W., 1984. Some models for estimating technical and scale inefficiencies in data envelopment analysis. Management Science, 30, pp. 1078–1092.

Berger, M.C., and Messer, J., 2002. Public financing of health expenditures, insurance, and health outcomes. Applied Economics, 34(17), pp. 2105-2113.

Bhat, R., 2001. Methodology note: Data Envelopment Analysis (DEA). Journal of Health Management, 3(2), pp. 309-328.

Borisov, D., Cicea, C. and Turlea, C., 2012. DEA model for assessing efficiency in providing health care. Management Research and Practice, 4(1), pp. 5-18.

Butler, T.W. and Li, L., 2005. The utility of returns to scale in DEA programming: An analysis of Michigan rural hospitals. European Journal of Operational Research, 161(2), pp- 469-477.

Charnes, A. and Cooper W.W., 1962. Programming with linear fractional functional. Naval Research Logistics Quarterly, 9, pp. 181–186.

Charnes, A., Cooper, W.W. and Rhodes, E., 1978. Measuring the efficiency of decision making units. European Journal of Operational Research, 2, pp. 429–444.

Chilingerian, J., 1995. Evaluating physician efficiency in hospitals: A multivariate analysis of best practices. European Journal of Operational Research, 80, pp. 548- 574.

Coyne, J. S., Richards, M.T., Short, R., Schultz, K. and Singh, S.G., 2009. Hospital cost and efficiency: Do hospital size and ownership type really matter? Journal of Healthcare Management, 54(3), pp. 163-176.

Davis, K., Schoen, C., Schoenbaum, S., Audet, A., Doty, M. and Tenney. K., 2004. Mirror, mirror on the wall: Looking at the quality of American health care through the patient's lens. The Commonwealth Fund, Boston.

Davis, K., Schoen, C., Schoenbaum, S., Doty, M., Holmgren, A., Kriss, J. and Shea, K. 2007. Mirror, mirror on the wall: An international update on the comparative performance of American health care. The Commonwealth Fund, Boston.

DeRosario, J.M., 1999. Healthcare system performance indicators: A new beginning for a reformed Canadian healthcare system. Journal for Healthcare Quality, 21(1), pp. 37-41.

Giokas, D., 2002. The use of goal programming, regression analysis and Data Envelopment Analysis for estimating efficient marginal costs of hospitals. Journal of Multicriteria Decision Analysis, 11(4-5), pp. 261-268.

Giuffrida, A. and Gravelle, H., 2001. Measuring performance in primary care: econometric analysis and DEA. Applied Economics, 33, pp. 163-175.

Goncalves, A.C., Noronha, C.P., Lins, M.P.E. and Almeida, R., 2007. Data envelopment analysis for evaluating public hospitals in Brazilian state capitals. Revista De Saude Publica, 41(3), pp. 427-435.

Häkkinen, U. and Joumard, I., 2007. Cross-country analysis of efficiency in OECD health care sectors: Options for research. OECD Economics Department Working Papers, No. 554, Paris: Organization for Economic Cooperation and Development.

Hofmarcher, M.M., Paterson, I., and Riedel, M., 2002. Measuring hospital efficiency in Austria - a DEA approach. Health Care Management Science, 5 (1), pp. 7-14.

Hollingsworth, B., 2003. Non-parametric and parametric applications measuring efficiency in health care. Health Care Management Science, 6, pp. 203-218.

Hollingsworth, B., 2008. The measurement of efficiency and productivity of health care delivery. Health Economics, 17, pp. 1107-1128.

Jacobs, R., Street, A. and Smith, P. 2006. Measuring efficiency in health care. Cambridge, Mass USA): Cambridge University Press.

Jafarov, E. and Gunnarsson, V., 2008. Government spending on health care and education in Croatia: Efficiency and reform options. IMF Working Paper, WP 136, Washington: International Monetary Fund.

Jamison, D. and Sandbu, M., 2001. Global health: WHO ranking of health system performance. Science, 293(5535), pp. 1595-1596.

Joumard, I., André, C. and Nicq, C., 2010. Health care systems: Efficiency and institutions. OECD Economics Department Working Papers, No. 769, Paris: Organization for Economic Cooperation and Development.

lo Storto, C., 2016. Ecological efficiency based ranking of cities: A combined DEA cross-efficiency and Shannon's entropy method. Sustainability, 8, p. 124.

Kirigia, J.M., Emrouznejad, A., Sambo, L.G., Munguti, N. and Liambila, W., 2004. Using data envelopment analysis to measure the technical efficiency of public health centers in Kenya. Journal of Medical Systems, 28(2), pp. 155-166.

Mirmirani, S., Li, H.C. and Ilacqua, J.A., 2008. Health care efficiency in transition economies: An application of Data Envelopment Analysis. International Business & Economics Research Journal, 7(2), pp. 47-56.

OECD, 2010. Health care systems: Getting more value for money. OECD Economics Department Policy Notes, No. 2.

OECD, 2015. Focus on health spending-OECD health statistics 2015, July, www.oecd.org

Osei, D., d'Almeida, S., George, M., Kirigia, J., Mensah, A. and Kainyu. L., 2005. Technical efficiency of public district hospitals and health centres in Ghana: a pilot study. Cost Effectiveness and Resource Allocation, 3(9), http://doi.org/10.1186/1478-7547-3-9.

Ozcan, Y.A., 2008. Health care benchmarking and performance evaluation: an assessment using data envelopment analysis (DEA). Springer.

Rebba, V. and Rizzi, D., 2007. Measuring hospital efficiency through Data Envelopment Analysis- when policy-makers' preferences matter: An application to a sample of Italian NHS hospitals. Politica Economica, 23(3), pp. 233-257.

Retzlaff-Roberts, D., Chang, C.F. and Rubin, R.M., 2004. Technical efficiency in the use of health care resources: a comparison of OECD countries. Health Policy, 69(1), pp. 55-72.

Roemer, M.I., 1991. National Health Systems of the World, Vol. 1: The Countries. New York: Oxford University Press.

Santos, S.P., Amado, C.A. and Santos ,M.F. 2012. Assessing the efficiency of mother-to-child HIV prevention in low- and middle-income countries using data envelopment analysis. Health Care Management Science, 15 (3), pp. 206-222.

Scheel, H., 2001. Undesirable outputs in efficiency valuations. European Journal of Operational Research, 132, pp. 400–410.

Siciliani, L., Sivey, P. and Street, A., 2013. Differences in length of stay for hip replacement between public hospitals, specialised treatment centres and private providers: Selection or efficiency? Health Economics, 22, pp. 234-242.

Skinner, J., 1994. What do stochastic frontier cost functions tell us about inefficiency? Journal of Health Economics, 13, pp. 323–8.

Spinks, J. and Hollingsworth, B., 2009. Cross country comparisons of technical efficiency of health production: a demonstration of pitfalls. Applied Economics, 41(4), pp. 417-427.

Tone, K., 2001. A slacks-based measure of efficiency in data envelopment analysis. European Journal of Operational Research, 130, pp. 498–509.

Tone, K., 2002. A slacks-based measure of super-efficiency in data envelopment analysis, European Journal of Operational Research, 143, pp. 32-41.

Verhoeven, M., Gunnarsson, V. and Lugaresi, S., 2007. The health sector in the Slovak Republic: Efficiency and reform. IMF Working Paper, WP 226, Washington: International Monetary Fund.

Wei, C.K., 2006. Measuring efficiency and productivity change in Taiwan hospitals: A nonparametric frontier approach. The Journal of American Academy of Business, 10(1), pp. 317-323.

WHO, 2012. European health for all database. World Health Organization-Regional Office for Europe, http://www.euro.who.int/en/what-we-do/data-and-evidence/databases/european-health-for-alldatabase-hfa-db2.

Yang, H. and Pollit, M.G., 2009. Incorporating both undesirable outputs and uncontrollable variables into DEA: The performance of Chinese coal-fired power plants. European Journal of Operational Research, 197, pp. 1095–1105.