Measuring the Efficiency of EU Health Systems Using Data Envelopment Analysis

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Abstract

This paper has the purpose of evaluating the Health Systems of European Union member states'. An overview of the Romanian health system will be provided, underlying the status of some the main indicators in 2008.

In achieving the goal of the research, a set of relevant health variables was chosen from Eurostat database for the countries within the European Union. An input oriented Data Envelopment Analysis model, focused on minimizing the inputs to reach maximum efficiency for the current amount of outputs obtained, has been applied to evaluate the efficiency of the Health Systems. This method compares and attributes an efficiency score to each Decision Making Unit by comparing it with a virtual frontier formed by the efficient states.

The study emphasizes that Nordic countries are more efficient than the other European countries and even though the Romanian Health System has known different types of reforms and improvements the last 20 years, the system still denotes a lack of success in providing proper healthcare for all its citizens, proven by the small efficiency score.

Key words: Data Envelopment Analysis, Romanian Health System, Efficiency.

JEL Code:C - Mathematical and Quantitative Methods; C0 – General; H51 - Government Expenditures and Health

Introduction

The progress of all societies depends on the efficiency with which natural, human and financial resources are being disposed of.

The efficiency of public spending denotes an optimal dimension of a ratio determined by the financial effort (formed by public financial resources) and measurable or estimable effects which can be obtained from the set objectives of the state (Vacarel, 2002). The literature on this topic covers a wide area, having methods that can easily assess parts of the health systems or the relation between different parts of the systems. But even so, it has some

flaws when it comes to analyzing systems as a whole (Clarke et al., 2007), (McMarthy et al., 2007) or public spending efficiency.

When assessing public sector efficiency, managers are aware and take into account that the efforts to fulfill social needs can be measured, often quantified with the value of inputs (e.g. costs of raw materials, costs of human resources, costs of information), while social effects are difficult to determine and measure and, furthermore, they are difficult to be fully forecasted. Improving public sector performance is an objective with a high importance role in the agenda of each industrialized state.

When talking about the level of efficiency, evidences show that it can be improved by increasing scale operation. This fact is shown primary in health and education sectors (Coelli et al., 2011; Curristine T, 2005; Dronkers, 2004). This is due to scale economies which are the result of the saving of additional marginal costs compared to the fixed costs of resources. Nevertheless, their impact over other areas of public sector like equity, quality or access to services has to be considered (Dooren et al., 2007).

A first simple attempt to measure these effects was made by Tanzi and Schucknecht (1997, 2000). They, they tried to assess the benefits obtained by public spending in 18 highly industrialized countries. Their method was to determine whether increased public spending in these countries could provide proves of practical, identifiable benefits which could justify the additional spending.

The efficiency of public spending became one of the essential topics in the public finance sector. For developed economies and many of the developing ones, a higher efficiency of public spending seems to be the only option to balance the pression of high costs associated with age and tax increase (Heller et Hauner, 2006). For the underdeveloped countries, an increase efficiency of public spending will have to be accompanied by increased social spending to achieve the Millennium Development Goals. Nonetheless, emerging economies are less affected by this pressure, given their economic growth, although it is a well known fact that the demand for public services increases exponentially as countries become wealthier (the so-called Wagner effect). In this case, an increased efficiency is the only way of avoiding a significant increase of the financial burden.

It is no wonder that governmental efficiency as a whole became the subject of an increased number of papers, received key contributions from Gupta et Verhoeven (2001), Tanzi et Schuknecht (1997, 2000) and Alfonso et al. (2005). These studies measure the efficiency of public sector by connecting government spending with socio-economical indicators. Those indicators are assumed to be in close connection with the objectives of

public spending, like the percentage of pupils enrolled in educational units or percentage if infant mortality, the results emphasizing substantial differences of the efficiency level between countries, regardless the level of development.

The effect of income per inhabitant can be analyzed from points of view. From the first point of view the income could reduce efficiency by increasing relative public services costs (Baumol, 1967). From the other point of view, a higher income has many times been associated with a higher level of health and education (Afonso et al., 2006)

Comparing health systems in Europe with that from the USA, Carke, A. Et al (2010), De Gooijer W. (2007) underline the strengths of the last and state that European systems should adapt the methods to optimize the results. The power of the American health system to promote health and prevent diseases induces confidence and safety to its citizens, primary factors in ensuring efficiency. Taking into account the methods of financing health systems, Powell-Jackson, T. et al.,(2007) , Scherer et al., (2010) advocate for the an active role of the state in financing the systems in order to ensure a proper development, especially since developing countries have proven an advantage in standardizing methods of persuading decision makers.

1. Data and Method

The study uses data for 2008, for all the 27 EU member states, collected from Eurostat and the WHO. There are 27 DMUs taken into account when running the analysis, each of them representing one of EU's member states. The model developed contains two variables as inputs (Non Immunized Rate and Public Health Expenditures) and two variables as outputs (Incidence of Tuberculosis and Adult Survival rate). Although there is no general rule when deciding the number of variables in a DEA model, this study is using a ratio of under 1 variable for 6 DMUs, ensuring reliability.

According to the World Bank the incidence of tuberculosis is the estimated number of new pulmonary, smear positive, and extra-pulmonary tuberculosis cases per 100.000 inhabitants. The disease is one of the communicable diseases monitored by the WHO and the main international health bodies, and its value decreases as the development of the monitored state increases.

Adult Survival is a derivate indicator, obtained from Adult Mortality Rate. It is calculated as the ratio (1000- Adult Mortality Rate). The data is harmonized across countries and has no missing values.

Non Immunized Average, which is a derivate indicator, is obtained from the immunization rate for children, and refers to the percentage of children reaching their first birthday who have not been fully immunized against measles.

Public health expenditures is an essential indicator of health systems financing. The indicator contributes to understanding different level of expenditures and it is expressed in American dollars to ease comparisons. This indicator does not include only resources channeled from governmental budgets but also health expenditures supported by parastatal and extra budgetary entities and mandatory insurances. It also refers to the resources collected and managed by public agencies and it is defined as the total amount of public expenditures per inhabitant, expressed at the average exchange rate for the year[1].

One of the most used methods in assessing the efficiency of a set of DMUsis Data Envelopment Analysis (DEA). DEA is a non-parametric method, that identifies an efficiency frontier on which only the most efficient DMUs are placed, by using linear programming techniques.

First presented in 1978 and based on the paper of Farrell, the first DEA model is known in the literature as the CCR model, after its authors, Charnes, Cooper and Rhodes. Thus, by using linear programming and by applying nonparametric techniques of frontier estimation, it can be measured the efficiency of a DMU, by comparing it with an identified frontier of efficiency. The DEA model is input or output oriented. An output oriented DEA model is channeled towards maximizing the outputs obtained by the DMUs while keeping the inputs constant whilst the input oriented models focus on minimizing the inputs used for processing the given amount of outputs.

For a given set of data, the efficiency DMU_j is measured, *n* times, where *n* represents the number of DMU to be evaluated *j* ranges over 1, 2,…, n. To obtain the scores for the weights of the inputs (v_i) (i= 1,2,…,m) and the weights of the output (u_r) (r=1,2,…, s), the following set of linear programming equations need to be solved:

$$\text{Max } \theta=\mu_1 y_{10} + \cdots + \mu_s y_{s0} \quad (1)$$

$$\text{Subject to } v_1 x_{10} + \cdots + v_m x_{m0} = 1 \quad (2)$$

$$\mu_1 y_{10} + \cdots + \mu_s y_{s0} \leq v_1 x_{10} + \cdots + v_m x_{m0} \quad (j=1,2,\ldots,n) \quad (3)$$

$$v_1, v_2, v_3, \ldots, v_m \geq 0 \quad (4)$$

$$\mu_1, \mu_2, \mu_3, \ldots, \mu_s \geq 0, \quad (5)$$

where θ is the optimal objective value and it is at most 1.

[1] World Health Organization definition available at: http://apps.who.int/gho/indicatorregistry/App_Main/view_indicator.aspx?iid=109

To compute the data and obtain the results of the analysis, we used the DEA Excel Software developed and provided by Cooper et al. (2000).In this study, a constant return to scale, input oriented DEA model is applied.

2. Results

Table 1 summarizes the main descriptive statistics of the four variables. The Health Expenditure variable varies from 278 USD for Bulgaria to 6770 USD for Luxembourg. With an average of 2385 USD spent per inhabitant and a standard deviation of 1727.46, the variable is heterogeneous. This is also showed by the relatively high coefficient of variance. The entire excomunist block is below the series average, with Slovenia (1658 USD per inhabitant) and the Czech Republic (1217 USD per inhabitant) having the highest values. Romania, with 424 USD per inhabitant is the penultimate country.

Tab 1.Descriptive Statistics

	Health Exp.	Non Immunized	Adult Survival	Incidence of Tuberculosis
Min.	278	1	2.169	4.2
1st Qu	816	2.75	4.088	7.05
Median	1845	4.5	7.957	10
Mean	2385	5.667	7.389	21.14
3rd Qu	3839	6.25	9.622	20
Max.	6770	22.5	12.177	134
SD	1727.458	5.424	3.111	27.71
Coeff. Of variance	72.43%	95.71%	42.10%	131.08%

Source: DEA Solver results, 2012.

Non Immunized rate ranges from 1% of non immunized children in Hungary, Slovakia and Greece to 22.5% non immunized in Malta. The series is highly heterogeneous, having a 95.71% coefficient of variance. What is interesting to mention for this variable is that east European countries have a lower rate of non immunized children than western states.

Adult Survival Rate is the most homogenous variable of the chosen set, having a coefficient of variance of 42.1% and ranging from 2.169 for Lithuania to 12.176 for Sweden. Similar to Health Expenditures, the ex communist countries are below average (7.389), having Slovenia (6.488) and the Czech Republic (5.975) as the best situated eastern countries. Romania's adult survival rate is 4.058.

The Incidence of Tuberculosis is the most heterogeneous variable of the series, with the mean of 21.13 new cases of tuberculosis per 100.000 inhabitants and a standard deviation

of 27.71. The minimum of the series is 4.2 new cases per 100.000 inhabitants for Cyprus and the maximum is 134 new cases for Romania.

Analyzing the correlations between the variables from the dataset, it was observed that the two input variables were not correlated statistically significant one to another. Thus, it can be concluded that each variable influenced differently the efficiency score. In other words, the information regarding efficiency contained by non immunization rate is not doubled by the information connected to governmental expenditures. On the other hand, health expenditures and incidence of tuberculosis are negatively correlated, statistically significant (-0.487). In economic terms, this correlation can be explained by the fact that as public health expenditures increase, the incidence of tuberculosis decreases. It can be noted that public health expenditures and the adult survival rate are positively correlated, statistically significant. The correlation sustains empirical evidences as well as the international reports, being a well known fact that higher public health expenses improve the health status of the population and contributes to decreasing mortality.

Tab 2. Efficiency Scores and Rankings

DMU	Score	Rank
Denmark	1	1
Finland	1	1
Greece	1	1
Luxembourg	1	1
Sweden	1	1
Germany	0.949	6
Netherlands	0.816	7
Italy	0.612	8
Spain	0.609	9
Belgium	0.586	10
Ireland	0.572	11
Austria	0.555	12
France	0.514	13
Slovakia	0.477	14
Czech Republic	0.461	15
United Kingdom	0.415	16
Hungary	0.381	17
Cyprus	0.362	18
Portugal	0.318	19
Poland	0.299	20
Slovenia	0.298	21
Malta	0.150	22
Romania	0.134	23
Estonia	0.104	24
Lithuania	0.088	25
Bulgaria	0.088	26
Latvia	0.085	27

Source: DEA Solver, 2012.

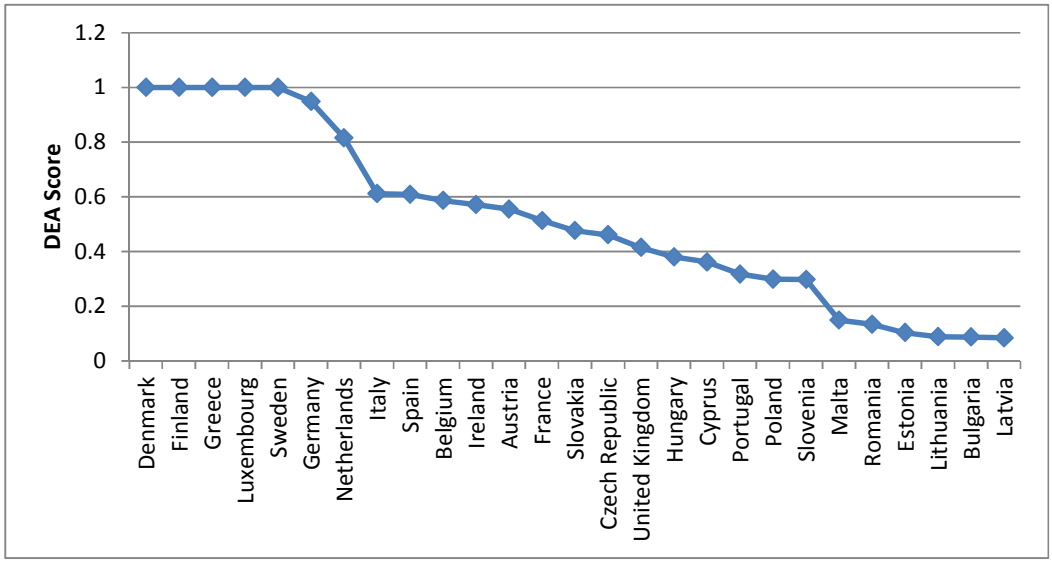
Table 2 provides the efficiency scores and the ranking the ranking of EU countries by the efficiency scores.

The model identified five countries on the efficiency frontier: Denmark, Finland, Greece, Luxembourg and Sweden were all given a general efficiency score of 1.

Sweden's health system is mostly public, which benefited from large and constant investments over the time, fact that led to a very good infrastructure and adequate procedures of public money allocation.

Close to the frontier, with a score of 0.949 was identified Germany, who should reduce the amount of inputs used to the current level of 94.87% in order to become as efficient as Denmark and Luxembourg, its reference set. Within this model, the first Eastern European country was identified Slovakia, with an efficiency score of 0.477. Romania was the 23rd, with a score of 0.134, being situated before Estonia, Lithuania, Latvia and Bulgaria. When forming the optimal weights and thus the efficiency score for Romania, the Non Immunized indicator was the only one taken into account. Thus, the model underlines the low level of public health expenditures of Romania. Moreover, some other countries of the eastern block had the score based 100% on this indicator[2].

Fig 1. DEA Efficiency Scores



Source: DEA Solver, 2012.

The model identified three trends in the scores of the data. Thus, excluding the fully efficiency countries, there are two countries with high efficiency score (Germany and Netherlands) with scores 0.948 and 0.815. The second group is formed by countries with moderate efficiency (Italy, Spain, Belgium, Ireland, Austria, France and Slovenia) with scores

[2]Bulgaria, Czech Republic, Hungary, Poland and Slovakia.

ranging from 0.611 to 0.298 and the third group that comprises the highly inefficient states (Malta, Romania, Estonia, Lithuania, Bulgaria and Latvia) with scores from 0.149 to 0.084. Given the two sudden drops in the results, it would be interesting to investigate what caused the high discrepancy between Netherlands and Italy and Slovenia and Malta. A first reason is that both Italy and Malta have the general scores given by the health expenses, the non immunization rate being a drawback for the countries. By comparison, both the Netherlands and Slovenia have weights that take into account non immunization rate in a higher proportion that health expenditures.

The model underlined that, except the countries on the efficiency frontier, all states should reduce the non immunized rate to some extent, from 20.05% for Malta to 0.26% for Lithuania. For the other input variable, health expenses, the model did not identify any needed changes. The explanation is that for the countries on the frontier the changes are not needed whilst for the others the change in the non immunization would be sufficient for the inputs to be projected on the frontier.

For the outputs, the model identified five countries that would have to improve their Adult Survival Rate in order to become fully efficient. Belgium, Cyprus, France, Germany and Italy, would have to improve with different levels the Adult Survival Rate, from an improvement of 0.38% for Cyprus to an increase of 105.61% for Germany.

Similar for the Incidence of Tuberculosis, several countries should reduce the value of the indicator, the biggest problem being flagged for Romania, who should reduce almost 10 times the level of this indicator to be projected on the frontier. It is interested to mention that all the eastern European countries should reduce its extent. From the western states, only Malta, Portugal and United Kingdom should reduce the Incidence of Tuberculosis to be fully efficient.

Conclusions

Although public sectors have a significant number of reforms meant to enhance their efficiency, the impact of these reforms on the systems if difficult to evaluate. First of all, the researches in the area are extremely difficult to perform due to data availability, measurement difficulties and the potential effect of some external factors over efficiency and productivity. Secondly, most of the times reforms are adopted out of ideological and political reasons rather than efficiency related reasons. Lastly, there are substantial differences between the effects of reforms on short term and the effects on long term.

This article emphasized the importance of efficiency and assessing the level of health systems' efficiency. Given that the topic is very wide and sensitive but its importance to society is essential, it was underlined that it is critical to decide what aspect of the system is being investigated.

With the chosen variables set, it was shown that eastern European countries still have to recover a significant gap in providing efficient health services to their citizens. The low level of health expenditures compared to western countries would be a start point for doing so. Nonetheless, some western societies should also focus on some aspects of health services, especially for the Immunization of children (e.g. case of United Kingdom or Portugal).

The results of the output variables could be a factor for decision makers when assessing new reforms in the systems. Thus, taking the case of Tuberculosis, states should channel resources towards decreased the extent of the disease; it was emphasized that Romania has to decrease 10 times the Incidence of Tuberculosis to align to the rest of Europe.

A harmonization of the efficiency methods should be put in stage so that the comparison of certain aspects (e.g. the functioning of the educational or health system) at international level could be performed. This would allow the identification of socio-politico-economical area which once reformed or restructured, would enhance efficiency.

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