Technical Efficiency and Productivity Growth in the Central and Eastern European Health Systems

Summary

The aim of the paper is to investigate technical efficiency and productivity growth of the national health systems from selective Central and Eastern European countries. We employed an output-oriented Data Envelopment Analysis to measure the technical efficiency of the health systems using data on infant death and life expectancy as health outcomes for the period 1999-2009. In the second part of the study we use Malmquist Total Factor Productivity index based on data envelopment analysis to assess health productivity changes over the same period for each country. The empirical results show that the average efficiency of health production has made a progress from 1999 to 2006, as the number of countries with relative technical efficiency has increased gradually. We found that technical efficiency varies across new EU member states and this translates into potential savings. Cyprus and Slovenia have performed best in transforming money into health outcomes. Hungary and Slovak Republic have the largest margins for improving health outcomes while keeping spending constant. The results of Malmquist Total Factor Productivity index suggest that technical change has the most significant influence on the productivity change. When we employed infant death as output, we found that 23% national health systems experienced a productivity growth over the period 1999-2009. The results were different for the second model having life expectancy at birth as output – 53% of the health systems registered an increase of total productivity due to technical progress. Our results are useful for policy-makers in designing (new) long-term health reform plan aimed to improve the performance of the emerging health systems.

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1. INTRODUCTION

During the last two decades, several reforms have been implemented in the Central and Eastern European (CEE) healthcare systems. The reforms have focused on all functions of the health system – financing, provision, stewardship and resource development. The features of health care systems and reform experiences vary substantially across emerging economies from Central and Eastern Europe (see Clements et al., 2012 for a well-documented review on the reforms implemented in emerging countries). The main aim of these reforms was to improve health outcomes and to offer greater access to health services. Despite these reforms and increasing resources (financing) available, the efficiency of these health systems is still low compared to that reported for industrialized countries.

The goal of the paper is, firstly, to study the evolution of the technical efficiency of CEE health systems as a result of reforms implemented over time. A second aim is to analyze differences in productivity change over the period 1999-2009 for the same health systems. To the best of our knowledge, this is the only study in the literature that examines technical efficiency and productivity changes in CEE health systems for the period 1999-2009 using Data Envelopment Analysis (DEA) and Malmquist Total Factor Productivity (MTFP). The results of this study can be useful in the formulation of public policy regarding the improvement of health outcomes.

The rest of the paper is organized as follows. In the next section a review of the available literature on health sector efficiency is provided. In section three, an explanation of the methodology used is given. Section four introduces the variables and data used for our research. In section five, we report and discuss the results of our analyses. Section six concludes the paper and highlights the limitations of this study.

2. LITERATURE REVIEW

Measuring the efficiency of health systems is the first step in elaborating and implementing new health policies. Furthermore, regional or international comparison of efficiency is a key lever for change in health policy and in the provision of public services. According to Tandon et al. (2003), measuring efficiency in the health system over time could be also useful in assessing how reforms undertaken have impact upon the technical and allocative efficiency of the system. This is one reason for our choice to measure efficiency of CEE health systems after and during a period of reforms. Secondly, measuring and comparing efficiency represents a way to assess the rational distribution of human and economic resources.

Due to the health data provided by Organization for Economic Cooperation and Development (OECD), there are many studies regarding the efficiency of health systems focusing on developed economies. Hitiris and Possnett (1992), Babazono and Hilman (1994), Elola et al. (1995), DeRosario (1999), Or (2000a; 2000b), Berger and Messer (2002), Retzlaff-Roberts et al. (2004), Afonso and St. Aubyn (2006), Raguseo and Vlček (2007), Asiskovitch (2010), and Tchouaket et al. (2012), among others, have studied the efficiency of health systems in developed economies. Evans et al. (2000), Self and Grabowski (2003), and Rajkumar and Swaroop (2008) extended their cross-section analysis to a wider sample of both developed and developing countries.

An increasing number of studies have used DEA and/or Stochastic Frontier Analysis (SFA) in order to measure and compare efficiency across countries: Hollingsworth and Wildman (2003), Retzlaff-Roberts et al. (2004), Afonso and St. Aubyn (2006), Joumard et al. (2010), Hadad et al. (2011), and Sinimole (2012). Retzlaff-Roberts et al. (2004) used the DEA approach in order to assess the technical efficiency of the utilization of health resources of OECD countries. They found that 13 of 27 OECD countries were on the efficiency frontier and concluded that a country's health outcomes are not necessarily indicative of how efficiently it uses its health resources. Afonso and St. Aubyn (2006) undertook an analysis of health system efficiency in 21 OECD countries. The study found that countries could increase their output by 40 percent using the same resources. Joumard et al. (2010) measured the efficiency of health care spending in 29 OECD countries. They found that technically inefficient countries could improve their life expectancy at birth by more than two years on average, maintaining health care spending constant.

In the last years, a few studies have been conducted in order to measure and compare the efficiency of health care systems from developing countries. Kirigia et al. (2007), Bhalotra (2007), Mirmirani et al. (2008), Anyanwu and Erhijakpor (2009), and Gani (2009) have studied the efficiency of health systems in developing economies from different area of the world.

Kirigia et al. (2007) assessed the technical efficiency of National Health Systems of 53 African continent countries using a DEA approach and evaluated the changes in health productivity over time. The production function used two outputs (male and female life expectancies) and two inputs (per capital total health expenditure and adult literacy). They found that more than 90% of the countries analyzed run inefficiently during the period 1999-2003. Based on Malmquist Total Factor Productivity (MTFP) they reported that all the national systems registered improvements in Total Factor Productivity due to technical progress.

Only a few published articles have studied health care efficiency in CEE countries, and some applied DEA. The differences in the efficiency of health care systems between (some) CEE countries and OECD countries have been documented by Verhoeven et al. (2007), Jafarov and Gunnarsson (2008), Mirmirani et al. (2008), and Grigoli (2012). Verhoeven et al. (2007) found that CEE countries in comparison to the OECD member states achieve low health outcomes with high real resource combinations. Jafarov and Gunnarsson (2008) studied the efficiency of government spending on health care and education in Croatia by using Data Envelopment Analysis (DEA). Mirmirani et al. (2008) assessed the health care efficiency in eight transition economies from CEE and a virtual unit (OECD countries, in average) for the period 1997-2001 and found that the most efficient systems are in Albania and Armenia. On the other hand, the least efficient systems for the period 1997-2001 were Russia and Belarus, followed by Latvia and Romania. Grigoli (2012) also found that Slovak Republic is inefficient in converting the low levels of health spending into health outcomes.

This paper contributes to the extant literature through the following: first, we employed in the same time two DEA models with different outputs in order to obtain greater insight into each country situation; secondly, we investigated the technical efficiency of CEE health systems over a long period of time (1999-2009) in order to highlight the effects of reforms on the health outcomes; thirdly, we assessed the changes in health productivity over time using Malmquist Total Factor Productivity (MTFP).

3. METHODOLOGY

In the literature there are four different classes of technique to measure efficiency of health care systems, each of them having own advantages and limitations: parametric techniques (regression based approaches); non-parametric techniques; deterministic methods and stochastic methods. In order to investigate technical efficiency and productivity change of the national health systems from CEE countries, an output-oriented DEA and a DEA-based Malmquist index calculation have been employed in this paper.

Data envelopment analysis (DEA) has been introduced by Charnes et al. in 1978 and extended by Banker et al. (1984). Despite its limitations[1], DEA has become very popular in the analysis of productivity efficiency in many areas: schools, hospitals, bank branches, production plants, etc. DEA has been extensively applied in evaluating the health production efficiency at the micro level (such as hospital efficiency) and at the macro level of a country or a region.

DEA represents a linear non-parametric method used to measure efficiency of a homogenous set of Decision Making Units (DMUs). The efficiency score in the presence of multiple input and output factors can be computed as (Sinmole, 2012):

Efficiency = weighted sum of outputs / weighted sum of inputs.

Suppose that there are *n* DMUs, each with *m* inputs and *r* outputs, the relative efficiency score of a test DMU *q* is obtained by solving the following model proposed by Charnes et al. (1978):

$$E_q = \frac{\sum_{i=1}^{r} u_i y_{iq}}{\sum_{j=1}^{m} v_j x_{jq}} \to max$$

$$\frac{\sum_{i=1}^{r} u_i y_{iq}}{\sum_{j=1}^{m} v_j x_{jq}} \leq 1, q = 1,2, \dots n \quad (1)$$

$u_i > \varepsilon, v_j > \varepsilon$,where the following notation is used:

E_q – efficiency of *q*-th DMU,

y_{iq} – amount of output *i* produced by DMU *q*,

x_{jq} – amount of input *j* produced by DMU *q*,

u_i – weight given to output *i*,

v_j – weight given to input *j*,

ε – a constant which makes all weight of inputs and outputs positive.

[1] See Spinks & Hollingsworth (2009) and Jacobs (2006) for a review on DEA limitations.

For every DMU the model determines the input weight (v_j) and output weight (u_i) that maximize its efficiency scores. In general, a DMU is termed “efficient” if it obtains from DEA model a score of 1. Otherwise, the DMU is considered to be inefficient.

The most widely used DEA models are CCR and BCC. The CCR model, developed by Charnes, Cooper and Rhodes (1978), had an input orientation and assumed that production is constant return to scale (CRS). The BCC model, elaborated by Banker, Charnes and Cooper (1984), assumes that production is variable return to scale (VRS). Both models carried on and expanded the concept of “technical efficiency” introduced by Farrell (1957). According to Farrell, technical efficiency represents the ability of a firm (or an entity) to obtain maximum feasible output from a given amount of inputs, or, alternatively, to use the minimum resources to produce a given level of output. A DMU is considered technically efficient if it lies on the efficient frontier. DMUs below the frontier are considered the inefficient units.

Technical efficiency can be seen from input as well as from output perspective. In an input-oriented model, the goal is to minimize the use of inputs in order to maintain the current level of outputs constant. In an output-oriented model, the aim is to maximize the outputs with the given level of inputs.

Table 1 gives an overview if the main DEA models in a linear programm. Under the constant return to scale assumption, the two models will provide the same set of efficient DMU’s irrespective of the input or output oriented approach (Charnes et al., 1978). The value of z ($z \leq 1$) obtained represents the efficiency score for each DMU. A score of 1 will indicate an efficient DMU situated on the frontier, while a score less than 1 implies that the DMU is inefficient.

Table 1. Overview of the main DEA models

INPUT ORIENTED MODEL – CRS (2)	OUTPUT ORIENTED MODEL – CRS (3)
$\max z = \sum_{i=1}^{r} u_i y_{iq}$ subject to	$\min z = \sum_{j=1}^{m} v_j x_{jq}$ subject to

$\sum_{i=1}^{r} u_i y_{iq} - \sum_{j=1}^{m} v_j x_{jq} \leq 0$ $\sum_{j=1}^{m} v_j x_{jq} = 1$ $u_i, v_j \geq \varepsilon > 0$	$\sum_{j=1}^{m} v_j x_{jq} - \sum_{i=1}^{r} u_i y_{iq} \geq 0$ $\sum_{i=1}^{r} u_i y_{iq} = 1$ $u_i, v_j \geq \varepsilon > 0$
INPUT ORIENTED MODEL – VRS (4)	OUTPUT ORIENTED MODEL – VRS (5)
$\max z - \sum_{i=1}^{r} u_i y_{iq} + \mu$ subject to $\sum_{i=1}^{r} u_i y_{iq} - \sum_{j=1}^{m} v_j x_{jq} + \mu \leq 0$ $\sum_{j=1}^{m} v_j x_{jq} = 1$ $u_i, v_j \geq \varepsilon > 0$	$\min z - \sum_{j=1}^{m} v_j x_{jq} + \mu$ subject to $\sum_{j=1}^{m} v_j x_{jq} - \sum_{i=1}^{r} u_i y_{iq} + \mu \geq 0$ $\sum_{i=1}^{r} u_i y_{iq} = 1$ $u_i, v_j \geq \varepsilon > 0$

The dual formulation for the variables returns to scale (Banker et al, 1984) is presented also in the table 1. The VRS models include a constraint μ. If μ<0, the model uses decreasing returns to scale (an increase in the amount of inputs consumed would lead to an increase less than proportionally in the amount of outputs produced); if μ>0, the model uses increasing return to scale (an increase in the amount of inputs consumed would lead to an increase more than proportionally in the amount of outputs produced), and if μ=0 variable returns to scale are the same as CRS. Another important difference between these models is that VRS models provide efficiency scores greater or equal to those obtained using the CRS model. The VRS model will provide a larger set of efficient DMU's that the VRS model. According to Coelli et al. (2005), output and input-oriented models will provide the same set of efficient DMU's (the same frontier), but the efficiency scores associated with the inefficient DMU's may differ between the two models. In our paper we employ an output-oriented BCC model for efficiency evaluation because we consider that policy makers should put more emphasis on the maximization of outputs (for example, life expectancy) by using given amounts of input.

In order to assess the changes in health productivity over the period 1999-2009 we employed Malmquist Total Factor Productivity (MTFP) index, one of the most frequently used techniques to measure productivity changes over time. This technique was first introduced by Caves, Christensen, and Diewert (1982a, 1982b) and later operationalized in the DEA by framework Färe et al. (1992 and 1994).

In the output-oriented model the Malmquist productivity index was defined as the geometric mean of two period's productivity indices (Caves et al., 1982). It reflects the productivity change (growth, decline, or stagnation) between two periods (t and t+1) and it can be useful in decomposing the productivity change into Technical Change (TC) and Technical Efficiency Change (TEC). According to Coelli et al. (2005), technical change implies advances in technology (new products or new health technologies) that may be represented by an upward shift in the production frontier.

Färe et al. (1994) specified an output-based Malmquist productivity change index as:

$$M_0(Y_{t+1}, X_{t+1}, Y_t, X_t) = \left[\frac{D_0^t(X_{t+1}, Y_{t+1})}{D_0^t(X_t, Y_t)} \times \frac{D_0^{t+1}(X_{t+1}, Y_{t+1})}{D_0^{t+1}(X_t, Y_t)}\right]^{1/2} \quad (6).$$

Where: M_0 = Malmquist index;

X = Input matrix

Y = Output Matrix;

Do = distance function (output oriented);

T = time.

Equation (6) represents the productivity of the production point (X_{t+1}, Y_{t+1}) relative to the production point (X_t, Y_t) by using the technology of period t and the period t+1 (Coelli, 1996). In fact, M_0 is a geometric mean of two output-based Malmquist indices: the first one uses period t technology, while the second period t+1 technology. If M_0 is greater than 1, it will indicate a positive TFP growth from period t to period t+1. An increase in the total productivity of factors from one period to another can be the result of either growth in technical efficiency or technological progress or even the product of both. If M_0 is lower than 1, it will indicate a decline in TFP relative to the previous year.

4. VARIABLES AND DATA

One of the most important issues in conducting a technical efficiency study using DEA is the choice of the **appropriate health production input and output variables**. The most frequently used outputs (or health status) variables are life expectancy at birth, infant mortality and the under-5 (child) mortality rate (the probability of dying between birth and age five years expressed per 1,000 live births). In addition, some studies are using other health outcomes such as QALY (Quality-Adjusted Life Year), DALY (Disability-Adjusted Life Year), HYE (Healthy-Years Equivalent), HALE (Health-Adjusted Life Expectancy), SDR (standardized death rates), maternal mortality rate and incidence of tuberculosis. For example, Elola et al. (1995) employed as dependent variables infant mortality and life expectancy and premature mortality by sex. Or (2000a, 2000b) used in his studies potential years of life lost (PYLL). Self and Grabowski (2003) and Evans et al. (2000) selected DALE (Disability-Adjusted Life Expectancy) as the most representative dependent variables.

The main categories of input that determined the population health status as resulted from the most important previous studies (Joumard et al., 2008 and OECD, 2010) are: health care resources measured in monetary terms or in physical terms; lifestyle factors; socio-economic factors.

In this study, we have selected the input and output variables based on three restrictions. First, we have chosen variables that can be influenced easily and directly through a policy reform: number of physicians, number of beds and total health expenditure at PPP$ per capita. These three input variables represent two important resources for health sector: human resources and financial resources. Secondly, as in the most previous analyses at the system level, we used two outputs: infant deaths per 1,000 live births and life expectancy at birth, in years. Infant mortality represents an outcome of a health system and, in the same time, an indicator of inequality in access to resources. Life expectancy at birth reflects the global result of the health system of a country. Thirdly, lack of data influenced both the choice of input and output variables and the number of countries from CEE region. Due to the lack of data for some countries, we restricted our sample at the new 11 members of the European Union. An additional reason for this choice is given by the fact that the data for these countries are probably the most complete and comparable and are available for a long period of time (1999-2009).

In our study, we develop two models in which three variables were taken into account as inputs in explaining cross-country differences in health status: hospital beds per 100,000 population, physicians per 100,000 population, and total health expenditure (PPP$ per capita). Similar to Retzlaff-Roberts et al. (2004) we solved a separate output model for each of the two outputs of infant deaths per 1,000 live births and life expectancy at birth, in years. In our models health status outputs are dependent upon the inputs of healthcare resources which reflect the results of reforms implemented by the national authorities.

The data used come from the European Health for All Database (HFA-DB) developed by the World Health Organization (WHO) Regional Office for Europe. Our analysis uses annual data regarding health system inputs and outputs for eleven Central and Eastern European countries, (new) members of the European Union and two virtual units – EU27 (all members of the European Union) and EU15 (refers to EU members before May 2004). We exclude Malta from our sample due to the lack of data for some years and, as a result, the sample consists of the following countries: Bulgaria, Cyprus, Czech Republic, Estonia, Hungary, Lithuania, Latvia, Poland, Romania, Slovak Republic, and Slovenia. Similar to other studies (Mirmirani et al., 2008 and Borisov et al., 2012) we employed two virtual units in order to compare the results for CEE countries with those of EU27, respectively EU15 countries as a group.

5. RESULTS AND DISCUSSION

5.1. Technical efficiency of health systems from CEE countries

We have chosen output-oriented BCC model and used DEAP 2.1 software to calculate the technical efficiency of CEE health systems. The results for the output oriented models are shown in tables 2 and 3. The first model used infant deaths per 1,000 live births as output, while the second employed life expectancy at birth as output.

As can be observed in Table 2, two countries (Cyprus and Slovenia) were technically efficient in every year of the period 1999-2009. These countries are followed by Czech Republic, which is situated on the efficient frontier in ten years from the period. On the other hand, some countries, such as Slovak Republic and Hungary, lie only once on the efficient frontier. Other countries, such as

Table 2. Output oriented DEA results (output: infant deaths per 1,000 live births)

Country/Year	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Bulgaria	0.900	0.913	1.000	1.000	1.000	1.000	1.000	0.938	0.928	0.954	1.000
Cyprus	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
Czech Republic	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	0.990	1.000	1.000
Estonia	0.947	0.958	1.000	1.000	1.000	0.964	0.985	0.990	0.969	1.000	0.990
Hungary	0.983	0.947	0.948	0.982	0.959	1.000	0.969	0.979	0.988	0.969	0.969
Latvia	0.959	1.000	0.917	0.968	0.942	0.932	1.000	0.958	1.000	0.966	1.000
Lithuania	1.000	0.962	0.958	1.000	0.969	0.977	0.978	0.969	0.989	0.990	1.000
Poland	0.958	0.958	0.962	0.958	1.000	1.000	0.977	1.000	1.000	0.969	0.969
Romania	0.853	0.853	0.844	0.854	0.865	1.000	1.000	1.000	1.000	1.000	0.918
Slovakia	0.974	0.958	0.969	0.958	0.958	0.975	0.983	1.000	0.959	0.975	0.969
Slovenia	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
EU27	0.979	1.000	0.984	0.979	0.979	0.970	1.000	1.000	0.979	0.979	0.981
EU15	1.000	1.000	0.995	0.990	1.000	0.981	0.995	1.000	0.994	1.000	0.990

Table 3. Ouput oriented DEA results (output: life expectancy at birth)

Country/Year	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Bulgaria	0.923	0.921	1.000	1.000	1.000	1.000	0.911	0.900	1.000	0.921	0.917
Cyprus	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
Czech Republic	0.949	0.971	1.000	1.000	1.000	0.949	0.962	0.950	1.000	0.971	1.000
Estonia	0.908	0.897	1.000	1.000	0.899	0.941	0.911	1.000	0.931	0.936	1.000
Hungary	0.989	0.910	0.911	0.994	0.911	1.000	0.924	0.913	0.913	0.949	0.944
Latvia	1.000	1.000	1.000	0.964	0.886	0.935	0.899	0.875	1.000	0.906	1.000
Lithuania	1.000	0.932	0.899	1.000	0.938	1.000	0.899	0.942	1.000	1.000	0.939
Poland	0.936	0.936	0.937	0.944	0.980	0.937	0.949	0.942	0.946	0.939	0.963
Romania	0.908	0.919	0.899	0.896	0.899	0.899	0.911	0.900	0.989	1.000	0.931
Slovakia	0.984	0.941	0.924	0.924	0.924	0.954	0.937	0.926	0.942	1.000	0.954
Slovenia	0.962	1.000	0.997	1.000	0.962	1.000	1.000	1.000	1.000	1.000	1.000
EU27	1.000	1.000	0.994	1.000	0.975	0.987	0.987	1.000	0.993	0.992	0.999
EU15	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000

Bulgaria, Estonia, Latvia, Lithuania, Poland and Romania, were on the production frontier only in a few years (3 to 6) over the period 1999-2009. The number of countries with relative technical efficiency increased gradually until 2006 and remained stable in the last 3 years of the analysis. As a result, the average efficiency of health production has made a progress from 1999 to 2009.

The evolution of Romania' health production efficiency is worth to be noted. Romania showed up far from the production frontier during the period 1999-2003 and achieved efficiency scores below the average of the new EU member states. These values can be interpreted in two ways. Firstly, Romania was inefficient in the process of transforming health care resources into health outcomes (lower infant deaths per 1,000 live births). Secondly, Romania could reach the same outcome level using fewer resources. For example, in 2009, Romania achieved an efficiency score of 0.918, which mean that it could have saved up to 8.2% of its financial resources if it would have operated at the same efficiency level of the most efficient countries in the sample (Bulgaria, Cyprus, Czech Republic, Lithuania, Latvia, and Slovenia). Starting with the year 2004, the technical efficiency of Romanian health system has improved considerably. One of the determinants of this evolution was the increasing resources (both public and private) allocated to health systems during the period 2004-2008. Even if the total health expenditure has increased from $410 in 2003 to $839 in 2008, Romania has the lowest health expenditure per capita in the European Union and the lowest level of health expenditure as percentage of GDP.

Another important finding of our study is that countries on the production frontier include both countries with high and low outputs. However, countries with the best health outcomes (Slovenia, Czech Republic and Cyprus) were almost all the time on the efficiency frontier. Our results show also that countries with a low health level, such as Romania, Bulgaria and Latvia, can reach the efficient level under the input constraints.

We also ran a DEA with life expectancy at birth as the output indicator. As it can be observed in table 3, estimates of technical efficiency suggest that Cyprus, EU15 (as an average) and Slovenia performed best in transforming money into health outcomes during the period 1999-2009. Margins for improving outcomes while keeping spending constant are the largest in Hungary, the Slovak Republic, Poland, and Romania. As in the previous model, Cyprus has lied on the efficient frontier in all the years analyzed.

Our results permit also the comparative analysis of the technical efficiency at a given point in time. Table 4 shows the results for the two output oriented models for the latest year available (2009). Only 4 (30.7 percent) out of 13 countries had a score equal to 1 and therefore were on the efficiency frontier for both outputs. Each of these 4 countries (Cyprus, Czech Republic, Latvia, and Slovenia) was using its inputs efficiently to produce its current levels of both infant mortality and life expectancy. These dominant countries included those with both good health outcomes such as Cyprus, Czech Republic, and Slovenia, as well as those with poor health outcomes such as Latvia. It is possible for countries with poor health outcomes, such as Latvia, to be on the frontier due to their low consumption of resources.

Table 4 Output oriented DEA results (2009)

Country	**DEA scores**		**Percent improvement in output**		**Outcomes**	
	Infant mortality	**Life expectancy**	**Infant mortality (%)**	**Life expectancy (%)**	**Infant mortality (at 1,000 live births)**	**Life expectancy (years)**
Bulgaria	1.000	0.917	-	8.3	9	73,77
Cyprus	1.000	1.000	-	-	3,33	81,37
Czech Republic	1.000	1.000	-	-	2,88	77,5
Estonia	0.990	1.000	1	-	3,55	75,31
Hungary	0.969	0.944	3.1	5.6	5,13	74,45
Latvia	1.000	1.000	-	-	7,75	73,28
Lithuania	1.000	0.939	-	6.1	4,93	73,23
Poland	0.969	0.963	3.1	3.7	5,57	75,91
Romania	0.918	0.931	8.2	6.9	10,12	73,61
Slovakia	0.969	0.954	3.1	4.6	5,65	75,42
Slovenia	1.000	1.000	-	-	2,4	79,46
EU27	0.981	0.999	1.9	0.1	4,23	79,79
EU15	0.990	1.000	1	-	3,68	80,98
Mean			**3.05**	**4.5**	5,48	75,75

Three of the 11 countries (Bulgaria, Lithuania, and Estonia) are efficient for one output, but inefficient for the other. Bulgaria and Lithuania are efficient for infant mortality and inefficient for life expectancy. In other words, they are performing better for infant mortality than for life expectancy. These two countries could produce higher levels of life expectancy given their level of inputs (financial and health-related inputs). On the other hand, Estonia is performing better for life expectancy than for infant mortality.

Four countries (Hungary, Poland, Romania, and Slovakia) and one virtual unit are inefficient for both outputs and thus can be considered inefficient overall in their consumption of inputs to produce health outcomes. In this group we have both countries with good health outcomes (such as Hungary, Poland, and Slovakia) and those with relatively poor health outcomes (such as Romania). Similar to Retzlaff-Roberts et al. (2004), we found that the current level of a country's health outcomes is not necessarily indicative of how efficiently the system is utilizing its resources. Some countries can obtain high health outcomes with high level of inputs, while others can reach the same level of outcomes with a lower consumption of inputs.

In table 4 we have also computed the **possible percent improvement in output**. On average, infant mortality can be improved by 3.05% for those countries where improvement is indicated. Life expectancy can be improved on average 4.5%, which mean that on average there is more room for improvement of life expectancy, given the level of health resources. For three countries that are inefficient for both outputs (Hungary, Poland, and Slovakia), greater improvements are possible in life expectancy than in infant mortality, by utilizing their resources in a more efficient manner. As expected, Romania shows improvement possible for life expectancy and infant mortality.

The results of our analysis have at least two important implications for policy-makers. First, we highlighted which path to the frontier offers greater potential improvement for technically inefficient countries. Secondly, for each country we identified which output provides the greater improvement potential.

According to our results, the technically inefficient CEE countries on average can reduce infant mortality by 3.05% without using more resources. At the same time, they can increase life expectancy by 4.5% without increasing resource use. Based on these results, we consider that efforts to increase life expectancy appear to have more potential as a public health goal for the inefficient countries as a whole than attempts to reduce infant mortality.

Every country can also use these findings to choose their respective path to the efficiency frontier. For example, results indicate that Lithuania's best course of action would be to focus on increasing life expectancy by employing its current levels of resources in a more efficient manner. Romania, on the other hand, was the most inefficient country in its use of resources and because the level of health outcomes is still very low, there is more room for enhancing both health outcomes.

We conclude that the best performers in CEE during the period 1999-2009 were Cyprus and Slovenia, which registered the best results in both models. For these two countries technical efficiency was positively and significantly associated with high levels of total health expenditure (PPP$ per capita). Our results show that Hungary and Slovak Republic have the most inefficient health systems, which means that there are more opportunities for improvement. These findings are broadly in line with those obtained by Verhoven et al. (2007) and Giglio (2012).

5.2. Productivity Growth in the CEE Health Systems

The Malmquist TFP index based on DEA has been used to measure the productivity change over the period 1999-2009 for each country. In order to compute Malmquist index the overall production frontier is estimated based on the data from all 11 countries and 2 virtual units. The production frontier used the same two models with two outputs (infant deaths per 1,000 live births and life expectancy at birth, in years) and three inputs (hospital beds per 100,000 population, physicians per 100,000 population, and total health expenditure at PPP$ per capita).

The Malmquist index calculation returns five results: technical efficiency change, technical change, pure technical efficiency change, scale efficiency change, and total factor productivity change. All these indexes can have a value greater, equal or smaller than 1, reflecting improvement, respectively stagnation or deterioration of the measured efficiency (Coelli et al., 2005). The change in total factor productivity is determined by technical efficiency change and by technical change (sometimes called an innovation). In other words, the Malmquist productivity index for every health system can be decomposed to isolate the specific contributions of pure efficiency change, scale efficiency change, and the technical change towards the overall productivity change.

Table 5 summarizes the Malmquist index summary of annual geometric means. The year 1999 has been taken as the technology reference when employing the MTFO index to analyze differences in productivity over time. In the last row, we observed that, on average MTFP index decreased slightly by 1.1 percent over the period 1999-2009 for the sample. On average, the deterioration in MTFP was due to technical change, while the technical efficiency and also its determinants (pure technical efficiency and scale efficiency) remained constant over the period. MTFP change was the highest in 2009 (MTFP=1.024) and the lowest in 2008 (MTFP=0.958).

Table 5.Malmquist index summary of annual means (output: infant deaths per 1,000 live births)

Year	Technical efficiency change (1) = (3)*(4)	Technical change (2)	Pure technical efficiency change (3)	Scale efficiency change (4)	Total factor productivity change (5) = (1) * (2)
2000	1.005	0.989	0.999	1.007	0.994
2001	0.995	0.989	0.997	0.997	0.984
2002	0.988	0.994	0.993	0.995	0.983
2003	0.994	0.996	1.006	0.988	0.99
2004	1.01	0.986	0.994	1.016	0.995
2005	0.999	1.002	1.007	0.992	1.001
2006	0.992	0.984	0.997	0.995	0.976
2007	1	0.984	1.002	0.998	0.983
2008	1.017	0.942	1.003	1.013	0.958
2009	1.001	1.024	0.998	1.003	1.024
Mean	1	0.989	1	1	0.989

Table 6 presents a summary of the annual geometric mean values of the MTFP index and it components for each country. In the case of the first model, our results revealed that 3 (23.07 percent) out of 13 countries had a total factor productivity scores greater than one, indicating growth in productivity over the period 1999-2009. For Cyprus and EU27 (as an average) the increase in productivity is due to innovation (technical change greater than 1), while for Latvia an increase in technical efficiency by 1.5% determined the growth of productivity.

Table 6. Malmquist index summary of health systems' means (output: infant deaths per 1,000 live births)

Country\Results	Technical efficiency change (1) = (3)*(4)	Technical change (2)	Pure technical efficiency change (3)	Scale efficiency change (4)	Total factor productivity change (5) = (1) * (2)
Bulgaria	0.994	0.974	0.998	0.996	0.968

Cyprus	1.000	1.002	1.000	1.000	1.002
Czech Republic	0.992	0.988	1.000	0.992	0.980
Estonia	1.004	0.984	1.000	1.004	0.987
Hungary	1.005	0.993	1.001	1.004	0.998
Latvia	1.015	0.990	1.000	1.015	1.005
Lithuania	1.009	0.979	1.000	1.009	0.987
Poland	1.000	0.994	1.000	1.000	0.994
Romania	1.000	0.954	1.000	1.000	0.954
Slovakia	0.991	0.990	0.998	0.994	0.982
Slovenia	1.000	0.996	1.000	1.000	0.996
EU27	0.996	1.006	1.000	0.996	1.002
EU15	0.994	1.006	0.999	0.995	1.000
Mean	1.000	0.989	1.000	1.000	0.989

*Malmquist index averages are geometric means

EU15, as an average, has registered stagnation, while the rest 9 (69.23 percent) countries showed a decrease in productivity. Bulgaria, Czech Republic, Estonia, Hungary, Lithuania, Poland, Romania, Slovakia, and Slovenia registered a decrease in the productivity determined by the technical regress – the value of technical change is lower than one. Among the above-mentioned countries three (Estonia, Hungary, and Lithuania) had an increase of technical efficiency, while Poland, Romania, and Slovenia showed a stagnation in technical efficiency.

The technical efficiency change is composed of pure technical efficiency change and scale efficiency change. From the three countries with productivity growth during the period 1999-2009 only Latvia reflected a positive contribution of the productivity scale to the efficiency change. For all EU member states, as an average, the scale efficiency contributed negatively to the efficiency change. Latvia and Cyprus have no change in pure efficiency change over the period 1999-2009. Overall the pure efficiency change reflected stagnation, only Bulgaria, Slovakia and EU15 showed a decrease of pure efficiency. The results of the first model suggest that productivity regression in the CEE health systems was due to technical regress.

We also ran a Malmquist index calculation with life expectancy at birth as the output indicator. Table 7 presents the Malmquist index summary of annual geometric means. In the last row, we observed that, on average MTFP index increased by 2.7 percent over the period 1999-2009 for the sample. On average, the growth in MTFP was determined, firstly, by technical innovation – technical change increased by 2.2 percent – and, secondly, by an increase of technical efficiency of 0.5 percent. The technical efficiency growth was attributed to an increase in scale efficiency by 0.4 percent and an improvement of pure technical efficiency by 0.1 percent. MTFP growth was the highest in 2007 (MTFP=1.520), while the higher decrease in productivity was observed in 2006 (MTFP=0.645).

Table 7.Malmquist index summary of annual means (output: life expectancy at birth)

Year	Technical efficiency change (1) = (3)*(4)	Technical change (2)	Pure technical efficiency change (3)	Scale efficiency change (4)	Total factor productivity change (5) = (1) * (2)
2000	0.868	1.302	0.99	0.877	1.13
2001	1.073	1.016	1.011	1.062	1.09
2002	1.027	1.058	1.013	1.014	1.086
2003	0.991	0.976	0.972	1.019	0.967
2004	0.935	1.233	1.019	0.917	1.152
2005	0.808	1.314	0.975	0.828	1.062
2006	1.171	0.551	1.004	1.166	0.645
2007	1.193	1.274	1.03	1.158	1.52
2008	0.938	1.198	0.992	0.946	1.124
2009	1.119	0.667	1.003	1.116	0.746
Mean	1.005	1.022	1.001	1.004	1.027

Table 8 provides a summary of the annual geometric mean values of the MTFP index and it components for each country. The results suggest that seven (53.84 percent) out of the 13 selected countries showed a productivity growth (Bulgaria, Czech Republic, Estonia, Latvia, Lithuania, Romania, and EU15), while for the rest of 6 countries (46.15 percent) a decrease of productivity has been observed. The productivity increase is due to technical progress, only in the case of Romania the growth is caused by an increase of technical efficiency. The Latvian health system is the only one in the CEE region that registered a productivity growth over the period 1999-2009 in both models.

Table 8. Malmquist index summary of health systems' means (output: life expectancy at birth)

Country\Results	Technical efficiency change (1)= (3)*(4)	Technical change (2)	Pure technical efficiency change (3)	Scale efficiency change (4)	Total factor productivity change (5)= (1) * (2)
Bulgaria	0.984	1.177	0.999	0.985	1.159
Cyprus	1.000	0.900	1.000	1.000	0.900
Czech Republic	1.033	1.135	1.005	1.027	1.172
Estonia	1.024	1.048	1.010	1.014	1.073

Hungary	0.981	0.977	0.995	0.985	0.958
Latvia	1.000	1.057	1.000	1.000	1.057
Lithuania	0.987	1.131	0.994	0.993	1.116
Poland	1.028	0.970	1.003	1.025	0.998
Romania	1.015	1.007	1.002	1.012	1.022
Slovakia	0.986	0.929	0.997	0.989	0.916
Slovenia	1.025	0.962	1.004	1.021	0.986
EU27	1.000	0.991	1.000	1.000	0.990
EU15	1.003	1.038	1.000	1.003	1.041
Mean	1.005	1.022	1.001	1.004	1.027

*Malmquist index averages are geometric means

The decrease of productivity was due for all 6 countries to technical regress. Cyprus and EU27 showed stagnation in efficiency change, while Poland and Slovenia improved their technical efficiency over the period 1999-2009. For Czech Republic, Estonia, Poland, Romania, Slovenia, and EU15 the scale efficiency change had a positive influence on the technical efficiency change, while in the case of Bulgaria, Hungary, Lithuania, and Slovakia scale efficiency change had a negative contribution to the technical efficiency change. Latvia and Cyprus registered stagnation both for pure efficiency and scale efficiency change.

Similar to the first model, we found that technical change had the most important influence on total factor productivity change over the period 1999-2009. The lack of technological innovation determined a decrease of productivity in both models. We consider that policy makers should put more emphasis on the technological innovation in designing policy reforms aimed to improve the efficiency of health systems on long term. Technological progress can be achieved through introduction of improved health technologies into health service production process, by better organization of health services, and also by improved skills and motivation of health workforce.

Measuring relative efficiency among countries has the potential of revealing best practices for policy makers. Technically inefficient countries could learn from best performers and develop comprehensive long-term strategies for the health sector based on a deep understanding of the sources of current inefficiencies. Efficiency-raising reforms in health sector are highly needed in many CEE countries in order to reduce spending and ensure the provision of high-quality public services at lower cost.

6. CONCLUSIONS

Health care systems from Central and Eastern Europe have faced profound reforms after the 1990s in the context of political, social, and economic changes that have marked these countries. These reforms were expected to improve the efficiency and quality of the health care systems in this region and to provide better care for the citizens. The aim of this paper is to evaluate the efficiency of CEE health systems using DEA in the light of reforms undertaken in the last two decades. In the second part of the paper we assessed the changes in health productivity over time determined by the reforms adopted in the last fifteen years. In this regards, our models used inputs considered to be within the discretionary control of the health systems (number of physicians, number of hospital beds, and health expenditure).

We found that technical efficiency varies substantially across new EU member states and this translates into potential savings. According to the first model, Cyprus and Slovenia were on the efficiency frontier for all eleven years, maintaining a high level of efficiency in health production. Czech Republic was on production frontier for ten years. On the contrary, Slovak and Hungary lie only once on the efficient frontier.

We also ran a DEA model with life expectancy at birth as the output indicator. As in the previous model, Cyprus and Slovenia performed best in transforming money into health outcomes. Margins for improving outcomes while keeping spending constant were the largest in Hungary, the Slovak Republic, Poland, and Romania. Both models showed that best performers in CEE are Cyprus and Slovenia, while other two countries – Hungary and Slovak Republic – proved to be technically inefficient during the period 1999-2009. Our results are broadly in line with those obtained by Verhoven et al. (2007) and Giglio (2012).

We have also computed the Malmquist index for both models in order to assess the productivity change over the period 1999-2009. In the case of the first model, we have found that only two countries (Cyprus and Latvia) and EU27 (as an average) experienced an increase of the productivity. The other countries registered a decrease in the total productivity due to the technical regress. In the case of the second model (life expectancy at birth as the output) our results show that 6 countries and EU15 experienced a productivity growth due to the technical progress rather than efficiency increase. The rest of 5 countries and EU27 has registered a decrease of productivity due to technical regress. For both models, we found that the main source of inefficiencies in the CEE health systems was the lack of technological innovation.

The results of our analysis have at least three important implications for policy-makers. First, we highlighted which path to the frontier offers greater potential improvement for technically inefficient countries. Secondly, for each country we identified which output provides the greater improvement potential. Thirdly, we examined the determinants of productivity change over the period 1999-2009 for each country.

Our study suffers from two types of limitations: DEA methodology limitations and health data related limitations. First type of limitations derives from the drawback of DEA models, often cited in the literature by Retzlaff-Roberts et al. (2004), Spinks & Hollingsworth (2009), and Jacobs (2006). As explanatory variables selection was influenced by lack of some data, we consider that our analysis could be extended with other determinants of health status and other CEE countries as soon as the data will be available.

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