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TECHNICAL EFFICIENCY IN THE USE OF HEALTH CARE RESOURCES: A CROSS-COUNTRY ANALYSIS

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Abstract

The aim of the paper is to assess the technical efficiency of twenty health systems from Central and Eastern Europe (CEE) and Commonwealth of Independent States (CIS). We used an output-oriented Data Envelopment Analysis (DEA) to measure the technical efficiency of the health systems using the latest data available on infant death and life expectancy as health outcomes. Our results show that technical efficiency varies across these health systems and this translates into potential savings of resources. The average efficiency scores for all heath systems were 0.98 for life expectancy at birth and only 0.821 for infant mortality. More than half of the health systems in the sample were technically inefficient in 2009 for both outputs. We found that 30% of national health systems were technically efficient for both outputs.

Keywords: Technical efficiency, health system, Data Envelopment Analysis, health outcomes, Central and Eastern Europe, Commonwealth of Independent States.
JEL classification: C14, H11, I12.

1. INTRODUCTION

The recent economic and financial crisis and their long-term consequences on public finances have reinforced the need to improve efficiency in the health care sector. Measuring and comparing efficiency across countries represents a way to assess the rational distribution of human and economic resources. Furthermore, regional comparison of efficiency is a key lever for change in health policy and in the provision of public services.

The aim of the paper is to assess technical efficiency of national health systems from twenty CEE and CIS countries. We used a Data Envelopment Analysis with life expectancy at birth and infant death as outputs. In this paper, we extend our previous research on efficiency of health systems (Anton and Onofrei, 2012) in two directions: (1) we employ another technique to model and measure the efficiency of national health systems - DEA; and (2) we extend the sample countries with three countries – Armenia, Kazakhstan, and Serbia.

This paper is organized as follows. Section two outlines other studies regarding the efficiency of health systems. Section three provides an explanation of the methodology used in our analysis. Section four presents the variables and data employed in our research. Section five discusses the empirical findings, while section six concludes the paper.

2. PREVIOUS RESEARCH ON HEALTH SYSTEM EFFICIENCY

Technical efficiency is the relationship between inputs (labour, capital, and equipment) and health outcomes (i.e., lives saved or longer lives). A health system or a hospital is considered to be technically efficient if it produces as much output as possible given existing technology and input levels. According to Häkkinen and Joumard (2007), the efficiency of health care services can be measured and compared at three levels: the disease, sub-sector, and system level. As the first two approaches for measuring and comparing efficiency across countries are plagued by severe data constraints and model limitations, a system level approach has been extensively employed for comparing health system efficiency across countries and over time (Anton and Onofrei, 2012).

The efficiency of health systems from developed economies has been extensively studied in the last two decades. Hitiris and Possnett (1992), Babazono and Hilman (1994), Elola et al. (1995), DeRosario (1999), Or (2000a; 2000b), Thornton (2002), Berger and Messer (2002), Retzlaff-Roberts et al. (2004), Afonso and St. Aubyn (2006), Raguseo and Vlček (2007), and Asiskovitch (2010), among others, have conducted comparative analyses on health care performance across developed countries and across time. Evans et al. (2000), Tandon et al. (2000), Self and Grabowski (2003), Rajkumar and Swaroop (2008), and Sinimole (2012) 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), Bhat (2005), Afonso and St. Aubyn (2006), Grosskopf et al. (2006), Spinks and Hollingsworth(2009), Joumard et al. (2010), and Hadad et al. (2011). 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.

Only a few published articles have studied health care efficiency in CIS and CEE countries, and some of them applied DEA. Verhoeven et al. (2007), Jafarov and Gunnarsson (2008), Mirmirani et al. (2008), Grigoli (2012), and Borisov et al. (2012) compared the health system performance across (some) CEE and OECD countries. 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) employed a DEA approach in order to study the efficiency of government spending on health care and education in Croatia. 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 in-inefficient in converting the low levels of health spending into health outcomes. Borisov et al. (2012) assessed the technical efficiency of the national health systems from the new member states of the EU for the period 2006-2009. Their results show that health systems from Latvia, Malta, Romania, Slovakia, and Slovenia were technically inefficient during the sample period.

3. METHODOLOGY

Data envelopment analysis (DEA) has been introduced by Charnes et al. in 1978 and extended by Banker et al. (1984). Despite its drawbacks, 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). Assuming 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):

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

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

$u_i \geq \varepsilon, v_j \geq \varepsilon$,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.

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 a score of 1 from DEA model. 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 caried 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 conversely, 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. The VRS DEA model with an output orientation requires solving the following mathematical program for each DMU (country) *i* in the sample:

$$\min z = \sum_{j=1}^{m} v_j x_{jq} + \mu$$

subject to

$$\sum_{j=1}^{m} v_j x_{jq} - \sum_{i=1}^{r} u_i y_{iq} + \mu \geq 0$$

$$\sum_{i=1}^{r} u_i y_{iq} = 1$$

$$u_i, v_j \geq \varepsilon > 0$$

where μ represents a constraint. 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.

In an output-oriented DEA model, technical efficiency supposes that more output is better. One of our outputs, infant mortality, is a reverse output where a lower value is better. For this indicator we calculate the inverse of the original value before running the non-parametric analysis.

4. DATA

One of the key issues in conducting a technical efficiency study at system level using DEA is the choice of appropriate input and output variables. During the last two decades the most frequently used outputs in the efficiency studies have been life expectancy at birth, infant mortality, under-5 (child) mortality rate, and DALY (Disability-Adjusted Life Year). According to Joumard et al. (2008) and OECD (2010), there are three types of inputs that determined the population health status: health care resources measured in monetary terms or in physical terms, lifestyle factors, and socio-economic factors. Hadad et al. (2011) distinguished between inputs considered to be within the discretionary control of the healthcare system (i.e., physicians' density, inpatient bed density, and health expenditure) and inputs beyond healthcare systems' control (i.e., GDP, fruit and vegetables consumption, and health expenditure). Table 1 presents some production functions employed in the literature.

Table no. 1 Production function employed in the literature

Paper	Outputs	Inputs	Sample countries
Kirigia et al. (2007)	Male and female life expectancies	Per capital total health expenditure and adult literacy	53 African continent countries
Mirmirani et al. (2008)	Average life expectancy and infant mortality rates	Per capita health care expenditure PPP, number of inpatient hospital beds per thousand population, number of physicians, and immunization	8 CEE countries and OECD (as an average)
Hadad et al. (2011)	Life expectancy and infant survival rate	First model: physicians' density, inpatient bed density, and health expenditure (inputs that are considered to be within the discretionary control of the healthcare system)	OECD countries
	Life expectancy and infant survival rate	Second model: GDP, fruit and vegetables consumption, and health expenditure (inputs beyond healthcare systems' control)	OECD countries
Borisov et al. (2012)	Life expectancy at birth and infant mortality rate	Per capita health care expenditure PPP, number of inpatient hospital beds per thousand population, number of physicians, and immunization	12 new EU states member
Joumard et al. (2010)	Life expectancy at birth	Health care spending per capita, a proxy for the economic, social and cultural status derived from the OECD PISA Survey, and a lifestyle variable (diet)	29 OECD countries
Zhang et al. (2007)	Life expectancy	Number of doctors, number of hospital beds, and per capital health spending.	28 regions of China

In our study, three variables were taken into account as inputs in explaining cross-country differences in health status: hospital beds per 100,000 inhabitants, physicians per 100,000 inhabitants, and total health expenditure (PPP$ per capita). As in the most previous analyses at the system level (see table 1), we used two aggregate measures of health status: infant deaths per 1,000 live births and life expectancy at birth, in years. We solved a separate output model for each of the two outputs in order to obtain a greater insight into each country's situation. Table 2 presents a short description of each variable – outputs and inputs – employed in both models.

Table no. 2 Short description of variables (outputs and inputs) employed

Variable	Short description
Life expectancy at birth, in years	The variable is computed by WHO/EURO for all countries using Wiesler's method. Age disaggregation of mortality data: 0, 1-4, 5-9, 10-14, etc, 80-84, 85+.
Infant deaths per 1,000 live births	The variable represents a measure of the yearly rate of deaths in children less than one year old. The denominator is the number of live births in the same year. Infant mortality rate = [(Number of deaths in a year of children less than 1 year of age) / (Number of live births in the same year)] *1000 (ICD-10).
Hospital beds per 100,000 population	The variable is a measure of hospital capacity. A hospital bed represents a regularly maintained and staffed bed for the accommodation and full-time care of a succession of inpatients. It is situated in wards or areas of the hospital where continuous medical care for inpatients is provided. Joint definition used by WHO, OECD and EUROSTAT.
Physicians per 100,000 population	A physician is a person who has completed studies in medicine at the university level. To be legally licensed for the independent practice of medicine (comprising prevention, diagnosis, treatment and rehabilitation), (s)he must in most cases undergo additional postgraduate training in a hospital (from 6 months to 1 year or more). The number of physicians at the end of the year includes all active physicians working in health services (public or private), including health services under other ministries than the Ministry of Health. Joint definition used by WHO, OECD and EUROSTAT.
Total health expenditure, PPP$ per capita	Total health expenditure is the sum of general government and of private expenditure on health. Estimates for this indicator were produced by WHO. The estimates are, to the greatest extent possible, based on the National Health Accounts classification.

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

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 for twenty CEE and CIS countries. The sample consists of the following countries: Armenia, Belarus, Bulgaria, Croatia, Czech Republic, Estonia, Georgia, Hungary, Kazakhstan, Latvia, Lithuania, Malta, Montenegro, Poland, Republic Moldova, Romania, Serbia, Slovak Republic, Slovenia, and Ukraine.

The descriptive statistics of the variables are shown in Table 3. We observed that there is great variation across countries in every dimension of the health production model, as indicated by the standard deviations. Perhaps the most striking differences concern the input variables: total health spending at PPP, hospital beds, and number of physicians. Armenia is the country that spends less on health per capita ($241.02 PPP). At the opposite extreme, Malta spends $4,264.32 PPP, followed by Slovenia with $2,475.92 PPP. However, these high values of total health spending do not mean that this money is being spent efficiently on the production of relevant health outcomes in any of these countries. The average number of hospital beds per 100,000 inhabitants is 618.1475, and varies from 309.08 in Georgia to 1,106.72 in Belarus. The number of physicians per 100,000 inhabitants, however, varies significantly across countries: from 207.48 in Montenegro to 510.75 in Belarus.

Table no. 3 Descriptive statistics of inputs and outputs

	Infant deaths (per 1,000 live births)	**Life expectancy at birth (years)**	**Hospital beds (per 100,000 population)**	**Physicians (per 100,000 population)**	**Total health expenditure (PPP$ per capita**
Mean	7.491000	74.22900	618.1475	319.8805	1250.730
Maximum	18.22000	80.46000	1106.720	510.7500	4264.320
Minimum	2.400000	68.67000	309.0800	207.4300	241.0200
Std. Dev.	4.066157	3.072825	180.8808	76.86779	917.2779
Skewness	1.128838	0.032228	0.657848	0.784167	1.846613
Observations	20	20	20	20	20

There are also large differences across countries regarding the level of outputs. The average level of infant mortality is 7.49 deaths at 1,000 inhabitants. Kazakhstan registered the highest number of infant deaths per 1,000 births, while the Czech Republic has the lowest value. On average, life expectancy at birth is 74.22 years for the sample countries. Life expectancy at birth for the whole population has increased in the past decade in the sample countries. However, the lowest life expectancy is registered in Kazakhstan (68.67 years), while the higher life expectancy is in Malta (80.46 years). All of the series have positive skewness (i.e. the mean of the series is greater than the median).

5. EMPIRICAL FINDINGS AND DISCUSSION

We have chosen output-oriented BCC model and used DEAP 2.1 software to calculate the technical efficiency of selective health systems from CEE and CIS. The first model used infant deaths per 1,000 live births as output, while the second employed life expectancy at birth as output. The average efficiency score is 0.98 for life expectancy at birth and only 0.821 for infant mortality. In the case of the first model, estimates of technical efficiency suggest that 8 countries out of 20 perform best in transforming money into health outcomes. Margins for improving outcomes while keeping spending constant are the largest in Kazakhstan, Malta, and Bulgaria. When we employed life expectancy at birth as output, we obtained that only 7 countries (35 percent of the sample) were situated on the efficient frontier in 2009.

Table 4 shows that 6 (30 percent) of 20 countries had a DEA score equal to 1 and therefore were on the efficiency frontier for both outputs. Each of these 6 countries - Armenia, Georgia, Montenegro, Republic of Moldova, Romania, and Slovenia - was using its inputs efficiently to produce its current levels of both infant mortality and life expectancy. These dominant countries include those with both good health outcomes such as Montenegro and Slovenia, as well as those with poor health outcomes such as Romania, Republic of Moldavia, Georgia, and Armenia. It is possible for countries with poor health outcomes, such as Georgia, to be on the frontier due to their low consumption of resources.

Table no. 4 Output oriented DEA results (2009)

Country	DEA scores		Percent improvement in output		Health outcomes	
	Infant mortality	Life exp.	Infant mortality	Life exp.	Infant mortality	Life exp.
Armenia	1	1	0	0	10,22	73,85
Belarus	1	0,941	0	5,9	4,68	70,62
Bulgaria	0,491	0,974	50,9	2,6	9	73,77
Croatia	0,697	0,992	30,3	0,8	5,27	76,43
Czech Republic	0,985	0,993	1,5	0,7	2,88	77,5
Estonia	1	0,982	0	1,8	3,55	75,31
Georgia	1	1	0	0	14,91	73,77
Hungary	0,703	0,969	29,7	3,1	5,13	74,45
Kazakhstan	0,35	0,92	65	8	18,22	68,67
Latvia	0,653	0,969	34,7	3,1	7,75	73,28
Lithuania	0,831	0,964	16,9	3,6	4,93	73,23
Malta	0,453	1	54,7	0	5,3	80,46
Montenegro	1	1	0	0	5,79	75,63
Poland	0,888	0,998	11,2	0,2	5,57	75,91
Republic of Moldova	1	1	0	0	12,08	69,44
Romania	1	1	0	0	10,12	73,61
Serbia	0,903	0,986	9,7	1,4	7	74,07
Slovakia	0,51	0,967	49	3,3	5,65	75,42
Slovenia	1	1	0	0	2,4	79,46
Ukraine	0,958	0,94	4,2	6	9,37	69,7
Mean	0,821	0,98	17,9	2	7,491	74,229

Further, three (15 percent) of the sample countries (Belarus, Estonia, and Malta) are efficient for one output, but inefficient for the other. Belarus and Estonia are efficient for infant mortality and inefficient for life expectancy. In other words, they perform 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, Malta performs much better for life expectancy than for infant mortality. Our results show that Malta could improve its infant mortality by 54.7% with the same consumption of resources.

Our results show that eleven countries (55 percent of the sample) 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 the countries with good health outcomes (such as Croatia, Czech Republic, Hungary, Lithuania, Poland, and Slovakia) and those with relatively poor health outcomes (such as Bulgaria, Kazakhstan, Latvia, Serbia, and Ukraine). If we had employed both outputs simultaneously in a model, we would have obtained that only these eleven countries are inefficient. Employing each output individually, we reached a greater insight into each country's situation. 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 utilizes 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, life expectancy at birth can be improved by 2% for those countries where improvement is indicated. Infant mortality can be improved on average by 17.9%, which means that on average there is more room for improvement of infant mortality, given the level of health resources. For the eleven countries that are inefficient for both outputs, greater improvements are possible in infant mortality than in life expectancy, by utilizing their resources in a more efficient manner.

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 health systems on average can reduce infant mortality by 17.9% without using more resources. At the same time, they can increase life expectancy by 2% without increasing resource use. Based on these results, we consider that efforts to decrease infant mortality appear to have more potential as a public health goal for the inefficient countries as a whole than attempts to increase life expectancy. Every country can also use these findings to choose their respective path to the efficiency frontier. For example, results indicate that Malta's best course of action would be to focus on decreasing infant mortality by employing its current levels of resources in a more efficient manner. Kazakhstan, on the other hand, is the most inefficient country in its use of resources and because the level of health outcomes is very low, there is more room for enhancing both health outcomes.

6. CONCLUSIONS

The aim of the paper is to assess which countries from CEE and CIS are utilizing their healthcare inputs in a technically efficient manner, given the level of the most frequently used health outcomes - infant mortality and life expectancy. We have employed an output oriented DEA model in order to investigate the possible paths to the efficiency frontier defined by the most efficient countries.

We have found that technical efficiency varies substantially across health systems and this translates into potential savings of resources. The average efficiency score is 0.98 for life expectancy at birth and only 0.821 for infant mortality. Our empirical results show that only six health systems (30% of total sample) were using their resources efficiently. Many of the technically efficient countries from the region, such as Slovenia and Montenegro, have registered good health outcomes compared to the average of the sample countries. Some countries with poor health outcomes such as Armenia, Georgia, and Republic of Moldova, proved to be on the efficiency frontier because they use their health resources in an efficient manner.

Eleven countries (55% of the total sample) are found to be technically inefficient for both outputs. Some of these countries register good health outcomes but are using their resources inefficiently. We found that these countries have greater potential for improvement in infant mortality than in life expectancy. The results of our research are similar to those obtained by other studies (Mirmirani et al., 2008 and Grigoli, 2012). We conclude that, even if CEE and CIS countries have implemented during the last two decades several reforms that aim to improve the way resources are allocated and used in the health sector, several changes remain and there is room for improving the efficiency of health systems.

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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.

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.

Asiskovitch, S., 2010. Gender and Health Outcomes: The Impact of Healthcare Systems and Their Financing on Life Expectancies of Women and Men. *Social Science and Medicine*, 70, pp. 886-895.

Babazono, A. and Hilman, A.L., 1994. A Comparison of International Health Outcomes and Health Care Spending. *International Journal of Technology Assessment in Health Care*, 10(3), pp. 376-381.

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(9), pp. 1078-92.

Berger, M.C., and Messer, J., 2002. Public Financing of Health Expenditures, Insurance, and Health Outcomes. *Applied Economics*, 34(17), pp. 2105-2113.

Bhat, V., 2005. Institutional Arrangements and Efficiency of Health Care Delivery Systems. *The European Journal of Health Economics*, 6(3), pp. 215-222.

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.

Charnes, A., Cooper, W.W. and Rhodes, E., 1978. Measuring the efficiency of decision making units. *European Journal of Operational Research*, 2(6), pp. 429-444.

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.

Elola, J., Daponte, A. and Navarro, V., 1995. Health Indicators and the Organization of Health Care Systems in Western Europe. *American Journal of Public Health*, 85(10), pp. 1397-1401.

Evans, D.B., Tandon, A., Murray, C.J.L. and Lauer, J.A., 2000. The Comparative Efficiency of National Health Systems in Producing Health: An Analysis of 191 Countries. *GPE Discussion Paper Series*, No. 29, Geneva: World Health Organization.

Farrell, M. J., 1957. The Measurement of Productive Efficiency. *Journal of the Royal Statistic Society*, 120(III), pp. 253-281.

Grigoli, F., 2012. Public Expenditure in the Slovak Republic: Composition and Technical Efficiency. *IMF Working Paper*, WP 173, Washington: International Monetary Fund.

Grosskopf, S., Self, S. and Zaim, O., 2006. Estimating the efficiency of the system of healthcare financing in achieving better health. *Applied Economics*, 38(13), pp. 1477-1488.

Hadad, S., Hadad, Y. and Simon-Tuval, T., 2011. Determinants of healthcare system's efficiency in OECD countries. *The European Journal of Health Economics*, DOI: 10.1007/s10198-011-0366-3Online First™.

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.

Hitiris, T. and Posnett, J., 1992. The Determinants and Effects of Health Expenditure in Developed Countries. *Journal of Health Economics*, 11(2), pp. 173-181.

Hollingsworth, B. and Wildman, J., 2003. The efficiency of health production: re-estimating the WHO panel data using parametric and non-parametric approaches to provide additional information. *Health Economics*, 12(6), pp. 493-504.

Kirigia, J.M., Zere, E., Greene, A.W. and Emrouznejad, A., 2007. Technical Efficiency, Efficiency Change, Technical Progress and Productivity Growth in the National Health Systems of Continental African Countries. *Eastern Africa Social Science Research Review*, 23 (2), pp. 19-40.

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.

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.

Joumard, I., Andre, C., Nicq, C. and Chatal, O., 2008. Health Status Determinants: Lifestyle, Environment, Health Care Resources and Efficiency. *OECD Economics Department Working Papers*, No. 627, Paris: Organization for Economic Cooperation and Development.

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. 47-55.

OECD, 2010. Health Care Systems: Getting More Value for Money. *OECD Economics Department Policy Notes*, No. 2, Paris: Organization for Economic Cooperation and Development.

Or, Z., 2000a. Exploring the Effects of Health Care on Mortality across OECD Countries. *Labour Market and Social Policy Occasional-Papers*, No. 46, Paris: Organization for Economic Cooperation and Development.

Or, Z., 2000b. Determinants of Health Outcomes in Industrialised Countries: A Pooled, Cross-Country, Time-Series Analysis. *OECD Economic Studies*, No. 30, Paris: Organization for Economic Cooperation and Development.

Raguseo, D. and Vlček, P., 2007. The Health Care in Europe: A Multi-Criteria Approach. *International Archives*, 70(3), pp. 46-55.

Rajkumar, A.S. and Swaroop, V., 2008. Public Spending and Outcomes: Does Governance Matter?. *Journal of Development Economics*, 86(1), pp. 96-111.

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.

Self, S. and Grabowski, R., 2003. How effective is Public Health Expenditure in Improving Overall Health? A Cross-country Analysis. *Applied Economics*, 35(7), pp. 835-845.

Sinimole, K.R., 2012. Evaluation of the efficiency of national health systems of the members of World Health Organization. *Leadership in Health Services*, 25(2), pp.139 – 150.

Spinks, J. and Hollingsworth, B., 2009. Cross-Country Comparisons of Technical Efficiency of Health Production: A Demonstration of Pitfalls. *Applied Economics*, 41(4-6), pp. 417-427.

Thornton, J., 2002. Estimating a health production function for the US: some new evidence. *Applied Economics*, 34, pp. 59–62.

Tandon, A., Murray, C. J. L., Lauer, J. A. and Evans, D., 2000. Measuring overall health system performance for 191 countries, *GPE discussion Paper Series 30*, Geneva: World Health Organization.

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

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.

Zhang, N., Hu, A., and Zheng, J., 2007. Using Data Envelopment Analysis approach to estimate the health production efficiencies in China. *Frontiers of Economics in China*, 2 (1), pp. 1-23.