

Technical and scale efficiency in Romanian public hospitals: Estimating with Data Envelopment Analysis

Raluca-Elena CAUNIC

Alexandru Ioan Cuza University, Iași, Romania

raluca_caunic@yahoo.com

Abstract. *Hospitals are a major component of the health systems, due to the complexity of the medical services they deliver and the great resources consumption. They impact the performance of the health systems, the economic policies and the public health. Since performance is a multidimensional concept, the main technique used to get a proxy evaluation of performance in the healthcare sector is Data Envelopment Analysis. DEA measures the efficiency of the healthcare providers and allows comparative analysis to identify the best practice frontier. This study addresses the performance of Romanian public hospitals from the North-Eastern region of the country and measures technical and scale efficiency. DEA basic models were run under the assumptions of constant and variable returns to scale, in an input-oriented evaluation of a sample of 18 public hospitals. The results indicated that most of the hospitals are technically inefficient (89%) and these inefficiencies are in the form of scale inefficiency for 39% of the hospitals. The average efficiency scale value was of 82%, implying that the observed hospitals could have increased their outputs by 18% if they had reached the optimal scale. The conclusion of the paper is that the inefficiency of the compared hospitals is almost equally caused by the inefficient implementation of the production plan and by the divergence of the decision making units from the most productive scale size. This kind of efficiency analyses could support managers when planning hospitals activity and policy makers when planning resources allocation and implementation of new strategies for the health system governance.*

Keywords: public hospitals, Data Envelopment Analysis, technical efficiency, scale efficiency, performance

Introduction

Performance measurement of the health systems and its components is one of the strategies proposed by the World Health Organization (WHO) ever since 2000, in order to improve the quality of health services and to ensure financial sustainability of the health systems (WHO, 2000). Healthcare sector is mainly a non-for-profit one and health services have their specificity, being produced and delivered on the spot. As a result, performance measurement becomes a difficult endeavor, counting for multiple dimensions: efficiency, quality, effectiveness, accessibility.

The hospitals are the most important health facilities that provide complex medical care for the population, with great absorption of financial, human and technical resources. They have major influence on the national health system performance and on health economy. In this context, evaluation of performance by measuring the efficiency of medical facilities becomes mandatory, for better planning of resources consumption and strategic management.

As Kohl et al. (2019) have stated, the most used instrument for this purpose in healthcare industry is Data Envelopment Analysis (DEA), a mathematical programming tool “designed to evaluate how efficiently an organizational entity, called the decision-making unit or DMU, produces a mixture of outputs with an available mixture of inputs” (Ozcan, 1993, p. 1).

In Romania, the performance of public hospitals has been poorly investigated, although the country has adopted the European health policies and strategies since its accession in European Union, in 2007. Performance evaluation of public hospitals became a normative in 2008, after the public hospitals decentralization and the introduction of the western reimbursement system, based on diagnosis – related groups (DRGs). Despite all the transformations carried out both at central and local level, Romania still ranks the last in the ranking of European countries at the European Health Consumer Index (EHCI, 2019). The annual report of Organization for Economic Co-operation and Development (OECD) indicates the poor performance that the country has on population health indicators, coverage of medical services and health spending (OECD & European Observatory on Health Systems and Policies, 2019).

One major deficit that Romanian medical system is facing is the lack of health workforce, after the massive exodus of doctors and nurses into developed countries, looking for better working conditions and incomes. In 2018, the government raised the wages of the medical staff by 100% to stop the phenomenon, but the medical system still suffers from the insufficiency of health workforce (OECD & European Observatory on Health Systems and Policies, 2019).

The current study is motivated by the lack of empirical evidence in the literature, regarding the efficiency of the Romanian health facilities. Nistor et al. (2017) consider the analysis they carried out as being the first scientific investigation in the field of effectiveness of the public hospitals, with focus on inefficiency causes of the medical facilities. The authors used DEA method to estimate the efficiency of 20 county hospitals from the 4 macro-regions of the country. The results showed that 5 hospitals out of 20 in the sample were inefficient in 2014.

This study comes to enrich the existing evidence in the field and to reduce the knowledge gap regarding health facilities individual performance. The specific objectives were: (a) to estimate the technical and scale efficiency of the public hospitals from the North-Eastern region of the country in 2019; (b) to estimate the input / output reductions or increases that would have made the inefficient hospitals more efficient.

It is important to mention that, According to the National Institute of Statistics (INS, 2019), the healthcare units network from the North-Eastern region is the second in the country in terms of registered number of hospital beds and number of working medical staff (20358 hospital beds out of a total of 123219 at national level and 49000 medical staff, in 2018).

Literature review

Since the article focuses on estimating the technical efficiency (TE), it is necessary to begin with basic terminology for efficiency measurement and to distinguish between technical efficiency and allocative efficiency (AE). TE is „a pareto concept that does not take into consideration the prices of inputs or outputs” (Ozcan, 1993, p. 2). It represents the score computed with DEA and implies that an organization is able to obtain a maximum output

from a given set of inputs or, alternatively, to use a minimal inputs mix to obtain the same level of output (Hollingsworth, 2008). In contrast, AE considers the relative cost of inputs, refers to the combination of factors that minimizes the costs of production and requires the use of stochastic frontier analysis (SFA), the parametric technique for efficiency measurement (Huerta et al., 2008). In healthcare industry, DEA has known a very wide applicability, providing frontier efficiency measurements in multidimensional input/output context, along with SFA.

Although currently, DEA methodology includes additional techniques which raise its discrimination power or allow in-depth analyses, early models are still the most frequently applied in the majority of the studies (Kohl et al., 2018). In hospital settings, the most common objectives for carrying out efficiency studies by means of DEA are (1) identification of the sources of inefficiency, (2) ranking units by the efficiency outcomes (3) evaluation of effectiveness of programs or policies that are beyond the control of the units or (4) creating quantitative basis for reallocating resources among the units under evaluation (Golany and Roll, 1989).

The most recent review of the published literature on DEA with focus on hospitals pointed out a standard procedure, used by most studies: the two stage analysis. In the first stage hospital-level efficiency scores are estimated using DEA and in the second stage DEA estimated efficiency scores are regressed on contextual / environmental variables, using a Tobit / truncated model, in order to explain inefficiencies (Kohl et al., 2019).

The early stages of DEA are noted by important contributions from U.S. researchers with papers focused on the influence of the type of ownership/type of hospital over the efficiency scores and on the selection of the variables in measuring hospital efficiency (O'Neill et al., 2008). In contrast to U.S. papers, the European studies are distinguished by a more frequent use of panel data, costs information and subsequent techniques of DEA. They concentrate on healthcare expenditure and evaluation of hospital efficiency mostly after the introduction of the case-based reimbursement system (O'Neill et al., 2008). The DRG reimbursement system was adopted from U.S. to enhance cost control of healthcare, but many European countries had difficulties in its implementation (Mathauer & Wittenbecker, 2013). Hofmarcher et al. (2002) and Cavallieri et al. (2016) provided results that sustain the impact of the prospective payment system, based on diagnosis related-groups, over hospital and wards efficiency scores.

Garcia-Lacalle & Martin (2010) compared the rural and urban hospital performance from Andalusian Health Service, before and after the implementation of a reimbursement system based on hospital performance. They used different DEA settings and documented the hypothesis that market – driven reforms does not necessarily introduce competition in the system because patients prefer to use their local hospitals. The analyses showed a similar level of efficiency for most of the hospitals, regardless of their location, although the rural ones were more inclined to be included in the best-performing group from one period to another.

Fragkiadakis et al. (2016) compared the Greek public hospitals in a period of great reforms (2005-2009) and found large discrepancies between their efficiency scores mostly from the economic perspective. Input-oriented DEA basic models were used to assess TE and scale efficiency (SE) for two scenarios, covering the operational and economic efficiency of the hospitals. Malmquist productivity index was applied to analyze efficiency trends over

time. The reform had a negative impact on operational efficiency of the hospitals and a positive one on economic efficiency in the first 2 years after implementation.

Şahin & Ilgün (2018) used DEA efficiency scores and the Malmquist total factor efficiency index to evaluate the Turkish public hospitals 3 years before and 3 years after the implementation of Public Hospital Association (PHA), aiming resource transfer among association hospitals in order to prevent waste. Wilcoxon signed-rank test was applied to determine differences between the efficiency score averages for the two periods analyzed. They found a decrease in the efficiency score by 5% after the implementation of PHA. As a confirmation of the reliability of the obtained results, the implementation was discontinued in 2017.

In Romania, studies with DEA in healthcare were conducted at a macro level, comparing the efficiency of the Romanian health system with those from European Union (EU) countries. Popescu et al. (2014) obtained a very low efficiency score of 0.29 for the Romanian health system when compared with the systems from other 26 European countries. Romania ranked on the 23 place with a huge gap of 71% compared to the first ranked country. In contrast, Asandului et al. (2014) obtained results that sustain that Romanian health system is efficient, although the infant mortality rate, which was used as an output variable, still is one of the highest in Europe (OECD & European Observatory on Health Systems and Policies, 2019). The authors explained their surprisingly results by the fact that the resources of the Romanian health system, although limited, are efficiently used.

The Romanian public teaching hospitals efficiency was approached by Vasilache & Prejmorean (2008), with a DEA model applied under the VRS assumption in combination with Hirschman-Herfindahl index. The influence of neighboring hospitals was treated as a form of market competition and proved to have a positive effect on efficiency scores: a 10% increase in the average efficiency level of neighboring hospitals leads to a 5% increase in the efficiency level of an individual hospital. More recently, Nistor et al. (2017) conducted a two stage analysis, running a VRS input-oriented model and a Tobit regression for 20 county public hospitals. They found 75% of the hospitals to be efficient and that the number of cases (patients) has a positive influence on efficiency level.

Methodology

The current study uses a sample of 18 public hospitals from the North-Eastern region of the country, 3 input and 2 output variables. The DEA models allow efficiency measurement in a small-scale (Shahhoseini et al., 2011) but, in order to obtain discriminative power of DEA the number of DMUs has to be at least twice the number of inputs and outputs considered (Dyson et al., 2001). This study meets the above specified criterion. By choosing hospitals from a specific region, the environmental – control perspective was taken into account: hospitals serving under similar regulatory statutes, using similar amounts of resources in the local environment (Ozcan, 1993). I have also sought that the selected sample to be homogeneous in terms of hospitals capacity (number of beds), in order to avoid the effect of scale size on efficiency scores, as it was shown by Ozcan (1993). He recommended local peering in size categories whenever this is possible.

The data for the inputs were taken from the Ministry of Health reporting platform for hospitals, on which, at the time of data collection, information on specialized staff employed and the number of beds was publicly available (monitorizarecheltuieli.ms.ro). The data for

outputs are also publicly available on the website of the Romanian Center for the Evaluation and Research of Health Services (www.drg.ro).

The suitable inputs and outputs were selected according to the guidelines provided by Ozcan (see table 1) and similar to those used by other researchers in their studies, such as Cavalieri et al. (2016), Huerta et al. (2008), Hofmarcher et al. (2002). The variables chosen as inputs were: the number of beds (Input1), as a proxy for capital investment category, the number of doctors (Input2) and the number of nurses (Input3) for labor category. Labor is the second major category for hospitals inputs and it is all the more important in Romania as there is a major deficit of specialized labor force at national level (OCDE & European Observatory on Health Systems and Policies, 2019). The outputs taken into account in the analysis were the inpatient days (Output1) and the number of discharges (Output2), which was adjusted for severity with the case-mix index, as in the studies mentioned above.

Table 1: Outputs and inputs for a robust hospital DEA model

Inputs categories and corresponding indicators		Output categories and corresponding indicators	
Capital investments	Number of beds (plant size)	Inpatient	Case-mix adjusted admissions
	Service-mix (plant complexity)		
Labor	Full time equivalents (covering all nursing, diagnostic, therapy, clerks and technical personnel)	Outpatient	Outpatients visits
Operational expenses	covering medical supplies and utilities		

Source: Summarized from Ozcan (2008)

I have used only absolute data, avoiding the mix of absolute and relative data or the mix of index measure with volume measures, according to the recommendations of Dyson et al. (2001). The software package deaR was used to run the input – oriented CRS DEA and VRS DEA models, described in Table 2. The input-oriented DEA model is applied in the majority of DEA studies, since the goal in healthcare settings is to reduce inputs (resources) rather than increase the volume of services (outputs) (O'Neill et al., 2008).

Table 2. A summary of input-oriented DEA models

Model 1. Input-oriented CRS DEA	Model 2. Input oriented VRS DEA
$TE_{CRS} = \min_{\Lambda, \theta}$	$TE_{VRS} = \min_{\Lambda, \theta}$
subject to	subject to
$-y^k + Y\Lambda \geq 0$	$-y^k + Y\Lambda \geq 0$
$\theta x^k - X\Lambda \geq 0$	$\theta x^k - X\Lambda \geq 0$
$\lambda_j \geq 0, j = 1, 2, \dots, J$	$\sum \lambda^j = 1$
	$\lambda_j \geq 0, j = 1, 2, \dots, J$

Source: Summarized from Carrington et al. (1997)

Where

θ = a scalar value, representing a proportion of current inputs that can be used to produce the chosen level of outputs;

y^k = the vector of outputs produced by DMU k ;

x^k = the vector of inputs used by DMU k ;

Y and X = matrices of observed outputs and inputs for all J DMUs in a sample;

λ_j = a weight given to DMU j in the construction of the best practice frontier;

Λ = a vector of intensity or weight variables

The technical efficiency in DEA models is computed as a solution to a linear programming problem, since the hospitals settings include multiple inputs and outputs. An important advantage of DEA is that the efficiency measure is related to best practice, not average practice (Gannon, 2005). When the constant returns to scale assumption is assumed, the objective for each hospital is to minimize inputs for a given level of outputs and the resulting model is known as CCR model (named after its authors, Charnes, Cooper & Rhodes). Thus, the optimal value of θ is “its minimum value over all possible values of θ that satisfy the set of constraints in the linear programming problem and represents the efficiency score” (Carrington et al., 1997, p. 418). A value of one (100%) indicates that the DMU under consideration is productively efficient. The value of λ_j indicates if DMU j serves as a role model or as peer for DMU k .

But the simple CRS model does not factor the size of the hospital into the process of efficiency measurement. The VRS model allows the best practice level of outputs to inputs to vary with the size of the hospitals (Gannon, 2005). A convexity constraint, $\sum \lambda^j = 1$ is added to ensures that an inefficient DMU is only benchmarked against DMUs of similar size, as Coelli has stated (in Tung, 2013, p. 4). The resulting model is known as BCC model (named also after its authors, Banker, Charnes & Cooper).

The efficiency score obtained in the VRS DEA model represents the “pure” technical efficiency (TE_{VRS}) and indicates the ability of management in implementing the production plan and converting the inputs to outputs. The efficiency score obtained in the CRS DEA model represents the overall technical efficiency (TE_{CRS}), which is the product of “pure” technical efficiency and scale efficiency (SE). The scale efficiency shows whether a DMU is operating on an optimal scale of production or not and is given by the ratio between TE_{CRS} and TE_{VRS} . Thus, the inefficiency of a DMU may be due to poor implementation of its production plan (pure technical inefficiency) or to the divergence from the most productive scale size (scale inefficiency) (García Sánchez, 2009).

In the current study, both TE_{CRS} and TE_{VRS} were computed, in order to be able to estimate scale efficiency of the hospitals in the sample, through following formulation:

$$SE = TE_{CRS} \div TE_{VRS}$$

When $SE = 1$, the combination of inputs and outputs is efficient both under CRS and VRS (Shahhoseini et al., 2011).

Results and discussions

Table 3 shows the descriptive statistics for the five variables entered in the analysis. As previously mentioned, in the selection of the DMUs (hospitals), I took into account primarily their size (number of beds), in order to have a homogeneous sample in terms of hospitals capacity. The coefficient of variation, although at the limit, indicates that the mean of the *Beds* variable is representative for the sample in the study. This is not the case for the other factors, where the variability of data is quite large, although in Romania the employed staff is

regulated according to the number of beds, so that I expected the sample to be homogeneous in this regard, too.

Table 3. Descriptive Statistics of the variables

Variables	Min	Max	Mean	Std. Dev	Coefficient of variation
Inputs					
Beds (number)	310	811	469.56	164.58	0.35
Doctors (number)	17	136	72.10	30.64	0.43
Nurses (number)	76	596	311.47	142.98	0.46
Outputs					
Case-mix adjusted discharges (number)	1431.17	33790.86	18453.06	8496.35	0.46
Inpatient days (number)	12672	153815	81623.06	37538.93	0.46

Source: Authors' own computation, based on data from monitorizarecheltuieli.ms.ro & drg.ro

Table 4 reports the findings from CRS and VRS analyses of the hospitals data. The results indicate that 16 hospitals out of 18 were technical inefficient in 2019. The average index of TE was situated at 74.93%, implying that these hospitals could reduce the use of all their inputs by 25.07% (since an input-oriented model was run) without any reduction in the amount of outputs. The lowest TE score was of 0.37 and it was found for the Pneumophthisiology Hospital from Bisericani – Neamț. If only this result is interpreted, it can be stated that this DMU used only 37% of its resources (beds, doctors and nurses) to provide services in 2019. But TE can be examined by decomposing it into pure technical efficiency and scale efficiency. Thus, the hospital proves to be pure technically efficient, being, surprisingly, the only DMU in the sample with zero slacks in inputs and outputs, when VRS model is run. Its inefficiency is clearly only scale inefficiency (it did not operated on its optimal size) and is not determined by a poor management of the resources.

The average index of pure technical efficiency was situated at 91.93% and the average index of scale efficiency was 81.75%. Thus, the decomposition of TE indicated that 9 hospitals out of 18 were technically inefficient. Seven hospitals (38.8%) which were technical inefficient in the CCR model, became efficient in the BCC model (such as Pneumophthisiology Hospital from Bisericani–Neamț), demonstrating pure technical efficiency. The inefficiency of these hospitals proves to be in the form of scale inefficiency. The average scale efficiency of 82%, demonstrates that the observed hospitals could have increased their outputs by 18% if they had reached the optimal scale.

Table 4.CCR and BCC – efficiency index for Romanian public hospitals in NE region

Hospitals (DMUs)	Technical efficiency (CRS scores – input oriented)	Pure technical efficiency (VRS scores – input oriented)	Scale efficiency
DMU1 Infectious Diseases Hospital (Iași)	100.00%	100.00%	100.00%
DMU2 Pneumophthisiology Hospital (Bisericani - Neamț)	37.82%	100.00%	37.82%
DMU3 C.F.R. University Hospital (Iași)	55.28%	96.88%	57.06%
DMU4 Neurosurgery Hospital (Iași)	100.00%	100.00%	100.00%
DMU5 Regional Oncology Institute (Iași)	88.99%	96.13%	92.57%

Hospitals (DMUs)	Technical efficiency (CRS scores – input oriented)	Pure technical efficiency (VRS scores – input oriented)	Scale efficiency
DMU6 Pneumophthisiology Hospital (Iași)	59.80%	88.57%	67.52%
DMU7 Municipal Hospital (Dorohoi – Botoșani)	74.62%	84.24%	88.58%
DMU8 Municipal Hospital (Fălticeni – Suceava)	72.41%	81.58%	88.75%
DMU9 Hospital of Obstetrics and Gynecology “Cuza-Vodă” (Iași)	71.80%	75.89%	94.62%
DMU10 Municipal Hospital (Pașcani – Iași)	67.57%	75.61%	89.36%
DMU11 Municipal Emergency Hospital (Moinești – Bacău)	87.04%	100.00%	87.04%
DMU12 Municipal Hospital (Rădăuți – Suceava)	83.76%	100.00%	83.76%
DMU13 Rehabilitation Hospital (Iași)	44.65%	58.53%	76.29%
DMU14 Municipal Hospital (Onești – Bacău)	84.57%	100.00%	84.57%
DMU15 Pediatric Hospital Iași	77.40%	97.33%	79.52%
DMU16 Municipal Emergency Hospital (Roman – Neamț)	82.59%	100.00%	82.59%
DMU17 County Emergency Hospital (Vaslui)	80.68%	100.00%	80.68%
DMU18 Municipal Emergency Hospital (Bârlad)	79.69%	100.00%	79.69%
Average efficiency	74.93%	91.93%	81.69%
Efficiency units	2	9	2
Inefficiency units	16	9	16

Source: Authors' own computation for DEA method, CRS and VRS models, using deaR

The results indicated which hospitals are the efficient ones in the sample:

(i) 2 hospitals (11.11%) are technical efficient (pure technical and scale efficient), forming the best practice frontier. These units are the Infectious Diseases Hospital from Iași and the Neurosurgery Hospital from Iași. However, the slacks analysis in the BCC input-oriented model revealed that these two hospitals are weakly efficient, having positive values for slacks in the outputs. This result suggests that the overall TE of those two hospitals on the efficient frontier is due to scale efficiency;

(ii) 7 hospitals (38.89%) are pure technical efficient: Pneumophthisiology Hospital from Bisericani– Neamț, Municipal Emergency Hospital from Moinești – Bacău, Municipal Hospital from Rădăuți – Suceava, Municipal Hospital from Onești – Bacău, Municipal Emergency Hospital from Roman – Neamț, County Emergency Hospital from Vaslui and Municipal Emergency Hospital from Bârlad. For these hospitals, the inefficiency is due to divergence from the most productive scale size (scale inefficiency) and it is not due to the poor management of the resources;

(iii) the average scale efficiency score of 81.69% implies potential input savings, on average, of 18.31% if restructure would be possible.

Table 5 summarizes the main sources of inefficiency amongst inputs and outputs for the hospitals taken into analysis.

Table 5. Potential average input reductions and output increases (BCC input-oriented model)

<i>Input and output variables entered in the analysis</i>	<i>Percentage variation (slacks)</i>
Beds	-1.50%
Doctors	-6.24%
Nurses	-7.72%
Average inputs' slacks	-5.15%
Case-mix adjusted discharges	9.64%
Inpatient days	8.38%
Average outputs' slacks	9.01%

Source: Authors' own computation for DEA method, VRS model, using deaR

Hospitals could reduce their inputs by an average of 5.15% to get the same amount of outputs. Also, the amount of outputs could be increased by an average of 9.01%, using the same level of inputs. Using the given amount of inputs, in terms of plant size and labor the evaluated hospitals could have treated 9.64% more patients in 2019.

Conclusion

Hospitals are facing pressure to improve efficiency through good management, medical protocols of best practices and best quality services. The need for efficiency improvement, not only in the healthcare sector, drew researcher's interest for developing methods and techniques for efficiency and productivity measurement, such as DEA. This technique became one of the preferred tools to measure the efficiency of healthcare providers due to its main feature: is able to manage complex production processes, with multiple inputs and outputs. The magnitude of DEA applications in healthcare is impressive and aims to refine the method in order to provide reliable results for policymakers, health economists and managers and thus to adapt it for practice.

This paper is an attempt to arouse the interest of Romanian health researchers for DEA, since it was very poorly used to evaluate the efficiency in the national healthcare sector, despite its strengths. I used the DEA basic models, CCR and BCC input-oriented, in order to estimate the technical efficiency of a small sample of Romanian public hospitals, decomposed into pure technical efficiency and scale efficiency.

The results indicated that only 11.11% of the hospitals were technical efficient in 2019. The technical efficient hospitals proved to be in fact "weakly efficient", having positive slack values in outputs, which recommends an increase of outputs, given the amount of inputs. Other 38.88% of the hospitals showed scale inefficiency, meaning that they did not operate at their optimal size (being too small or too large). The rest of 50% of the investigated hospitals were inefficient in 2019 (pure and scale inefficiency). These results indicate that the inefficiency of the hospitals in the sample was almost equally caused by inefficient implementation of the production plan (poor management) and by the divergence from the most productive scale size. Future researches should pursue an extended application of DEA methodology on a larger sample of hospitals, allowing peering in size categories and in depth analysis of size effect (comparisons of DEA outputs, using increasing and decreasing returns to scale) and also the inclusion of cost variables in the analysis.

References

- Asandului, L., Roman, M., Fătulescu, P. (2014). The efficiency of healthcare systems in Europe: a Data Envelopment Analysis approach. *Procedia Economics and Finance*, 10, 261-268.
- Carrington, R., Puthuchear, N., Rose, D., & Yaisaeearng, S. (1997). Performance measurement in government service provision: the case of police services in New South Wales. *Journal of Productivity Analysis*, 8(4), 415-430.
- Dyson, R.G., Allen, R., Camanho, A.S., Podinovski, V.V., Sarrico, C.S. & Shale, E.A. (2001). Pitfalls and protocols in DEA. *European Journal of Operational Research*, 132 (2), 245-259.
- Fragkiadakis, G., Doumpos, M., Zopounidis, C., & Germain, C. (2016). Operational and economic efficiency of public hospitals in Greece. *Annals of Operations Research*, 247(2), 787-806.
- Gannon, B. (2005). Testing for Variation in Technical Efficiency of Hospitals in Ireland. *The Economic and Social Review*, 36(3), 273-294.
- Garcia-Lacalle, J., & Martin, E. (2010). Rural vs urban hospital performance in a 'competitive' public health service. *Social Science & Medicine*, 71(6), 1131-1140.
- García Sánchez, I.M. (2009). Technical and Scale Efficiency in Spanish Urban Transport: Estimating with Data Envelopment Analysis. *Advances in Operations Research*, Article ID 721279, 15 pages.
- Golany, B., & Roll, Y. (1989). An application procedure for DEA. *Omega*, 17(3), 237-250.
- Health Consumer Powerhouse (2019). *Euro Health Consumer Index 2018*. Retrieved from <https://healthpowerhouse.com/media/EHCI-2018/EHCI-2018-report.pdf>
- Hofmarcher, M., Paterson, I., & Riedel, M. (2002). Measuring hospital efficiency in Austria – a DEA approach. *Healthcare Management Science*, 5(1), 7-14.
- Hollingsworth, B. (2008). The measurement of efficiency and productivity of health care delivery. *Health Economics*, 17(10), 1107-1128.
- Huerta, T.R., Ford, E.W., Peterson, L.T., & Brigham, K.H. (2008). Testing the hospital value proposition: An empirical analysis of efficiency and quality. *Health Care Management Review*, 33(4), 341-349.
- Institutul Național de Statistică (2019). *Activitatea unităților sanitare. Anul 2018*. Retrieved from https://insse.ro/cms/sites/default/files/field/publicatii/activitatea_unitatilor_sanitare_anul_2018.pdf
- Kohl, S., Schoenfelder, J., Fügner, A., & O. Brunner, J. (2019). The use of Data Envelopment Analysis (DEA) in healthcare with a focus on hospitals. *Health Care Management Science*, 22(2), 245-286.
- Mathauer, I., & Wittenbecker, F. (2013). Hospital payment systems based on diagnosis-related groups: experiences in low- and middle-income countries. *Bulletin of the World Health Organization*, 91(10), 746-756A.
- Nistor, C.S., Ștefănescu, C.A., Sintejudanu, M.A., & Crișan, A.R. (2017). Performance through efficiency in the public healthcare system – a DEA approach in an emergent country. *Studia Universitatis Babeș-Bolyai Oeconomica*, 62(1), 31-49.
- O'Neill, L., Rauner, M., Heidenberger, K., & Kraus, M. (2008). A cross-national comparison and taxonomy of DEA-based hospital efficiency studies. *Socio-Economic Planning Sciences*, 42(3), 158-189.
- Organisation for Economic Co-operation and Development & European Observatory for Health Systems and Policies (2019). *România: Profilul de țară din 2019 în ceea ce privește sănătatea. State of Health in the EU*. Paris: OECD Publishing / Bruxelles: European Observatory on Health Systems and Policies. Retrieved from https://ec.europa.eu/health/sites/health/files/state/docs/2019_chp_romania_romanian.pdf

- Ozcan, Y.A. (1993). Sensitivity analysis of hospital efficiency under alternative output/input and peer groups: a review. *International Journal of Knowledge and Policy*, 5(4), 1-29.
- Ozcan, Y.A. (2008). HealthCare benchmarking and performance evaluation. An assessment using Data Envelopment Analysis (DEA). New York, NY: Springer Science & Business Media
- Popescu, C., Asandului, L., & Fatulescu, P. (2014). A Data Envelopment Analysis for Evaluating Romania's Health System. *Procedia – Social and Behavioral Sciences*, 109, 1185-1189.
- Shahhoseini, R., Tofighi, S., Jaafaripooyan, E., & Safiaryan, R. (2011). Efficiency measurement in developing countries: application of data envelopment analysis for Iranian hospitals. *Health Services Management Research*, 24(2), 75-80.
- Şahin, B., & Ilgün, G. (2018). Assessment of the impact of public hospital associations (PHAs) on efficiency of hospitals under the ministry of health in Turkey with data envelopment analysis. *Health Care Management Science*, 22(3), 437-446.
- Tung, D.T. (2013). Changes in the technical and scale efficiency of rice production activities in the Mekong delta, Vietnam. *Agricultural and Food Economics*, 1(1), 16.
- Vasilache, S., & Prejmerean, M.C. (2008). Estimation of Romanian hospitals efficiency in relation to hospital market competition. *Management & Marketing*, 3(3), 97-106.
- World Health Organization (2000). *The World health report 2000. Health Systems: improving performance*. Retrieved from https://www.who.int/whr/2000/en/whr00_en.pdf?ua=1