Evaluating technical efficiency and the effect of innovative healthcare delivery on Italian hospitals: A two stage DEA approach

Lorenzo Magherini*, Emanuele Lettieri, Tommaso Agasisti****

**Department of Industrial Engineering, University of Florence, Viale Morgagni, 40, 50134, Firenze – Italy (lorenzo.magherini@unifi.it)*

*** Department of Management, Economics and Industrial Engineering, Politecnico di Milano, Milano – Italy (emanuele.lettieri@polimi.it, tommaso.agasisti@polimi.it)*

Abstract: The last few years have shown a growing trend in healthcare efficiency measurement. Very often this topic deals on production and not on the innovative aspects because of measurement difficulties. The goal of this work is to develop a model for evaluating the technical efficiency by considering different organizational and management aspects and to understand whether the presence of differences on management, information technology, financial and innovation on healthcare delivery can affect the efficiency level. The model was built starting from a literature review and on empirical experiences. The results of a survey show the implementation status of the guidelines of the Italian "Patto per la Salute 2014 – 2016", to verify if some of the levers proposed by the survey can positively influence the efficiency. The analysis performed have been carried out in two stages. In the first stage, healthcare efficiency is measured via bootstrapped Data Envelopment Analysis. In the second stage, the impacts of organizational and environmental variables on efficiency are investigated. Results show an increase of the efficiency gap between the best practice and small hospital due to economies of scale and low reachability.

Keywords: Second-stage DEA, Tobit regression, Hospital efficiency, Organization, Innovation, Regression

1. Introduction

The evaluation of technical efficiency of existing hospitals is necessary to understand how hospital performances can be improved. Performance evaluation plays a strategic role in healthcare organizations, in order to optimize the use of resources and demand planning and scheduling (Fabbri, 2002). The purpose of this paper is to compare the technical efficiency of Italian hospitals among 3 years and to examine, through a second stage DEA analysis, if differences in technical efficiency could be correlated to innovation in Hospitals.

1.1 Health system challenges

Health systems across Europe are faced with critical issues (i.e. multimorbidity, chronic diseases, aging population, rising expenditures). In particular, policymakers necessitate evidence on the optimal balance of healthcare resources and functions to help prioritize strategies to increase the sustainability of healthcare (Mitton and Donaldson, 2004).

Primary care must play a key role in improving the economic sustainability, quality of care and improve outcomes of healthcare systems. An increasing body of scientific literature recognizes that primary care is the first point of contact with healthcare services (Pelone, 2012).

1.2 Italian healthcare system

Italian healthcare system is organized in three administrative tiers: National, Regional and local. Healthcare is provided to all citizens and resideynts by a mixed public-private system. The public part is the national health service, named "Sistema Sanitario Nazionale" (SSN), which is organized under the Ministry of Health and is administered on a regional basis. The national level is responsible to allocate healthcare resources and ensuring a uniform level of service. The central government sets the general objectives and fundamental principles for the national healthcare system.

Recent reforms have delegated administrative, financial and organizational responsibility to the 20 Italian Regions. The SSN is controlled by regional governments and is administered by local health authorities ("Azienda Sanitaria Locale"/ASL - often referred to by their former name "Unità Sanitaria Locale"/USL) (De Nicola and Gitto, 2013). Regional governments are responsible for legislative and administrative health functions, planning health care activities, organizing supply and monitoring quality, appropriateness and efficiency of the services provided (Lo Scalzo, 2009).

1.3 Healthcare efficiency

Technical efficiency can be defined as the ability of a unit to transform their inputs into outputs. When an operating unit is technically efficient, it works on its production

frontier (Farrell, 1957). Following this definition, a hospital is considered to be efficient if it produces the maximum amount of output from a given amount of inputs (this is called output-oriented efficiency) or alternatively, if it produces a given output with a minimum consumption of resources (input-oriented efficiency). Most studies in healthcare use an input-oriented model because it is assumed that hospitals cannot reject their patients' demands, while they can reduce resource allocation and consumption levels. Alternatively, if hospitals are required to improve the appropriateness of healthcare procedures, an output-oriented model can better explain the real efficiency of that unit. (Barbetta et al. 2007).

1.4 Researche Objectives

The purpose of this study is to compare the technical efficiency of Italian hospitals and to examine if differences could be explained by organisational and contextual factors like innovation in healthcare or positive engagement of human resources.

2 Methodology

Literature is full of models developed proposed in order to find an optimal solution to the problem to improve healthcare efficiency. In this paper, the concept of efficiency is measured by Data Envelopment Analysis (DEA). DEA is a well know non-parametric method developed by Charnes, Cooper, and Rhodes (1978) that identifies a production frontier and determines the efficiency scores of a set of decision making units (DMU), with the common set of inputs and outputs (Heidari and Mohammadi, 2012; Lin et al., 2009). DEA model works under the assumption of Constant Returns to Scale (CRS) and Variable Returns to Scale (VRS): a linear relationship between inputs and outputs is assumed in the production process. As it was assumed that not all units of analysis were operating at an optimal scale, in this analysis the VRS model was considered in order to assess the extent to which the scale of operations affected productivity (Banker et al., 1984).

DEA defines (technical) efficiency of a Decision Making Unit (DMU) as the ratio of the weighted sum of its outputs to the weighted sum of its inputs and it uses linear programming techniques to compute relative technical efficiency scores. A range of DEA models have been developed that measure efficiency and capacity in different ways. These largely fall into the categories of being either input-oriented or output-oriented models. In this paper input-oriented efficiency analysis is used, because it's interesting to explore how each DMU could reduce its inputs given the amount of output moving to an efficient production point (in relation to the frontier determined by the bootstrapping method). In addition, an input-oriented model seemed more appropriate because it was assumed that hospitals have control over utilization of resources rather than over demand. (Banker et al., 1984)

DEA efficiencies are sensitive to the sampling variations of the obtained frontier. In order to overcome this problem, Simar and Wilson (2007) proposed a bootstrap procedure to approximate the sampling distribution of the efficiency scores. Halkos and Tzeremes (2012), Gitto and Mancuso (2011 and 2012) apply the bootstrap-DEA methodology for their studies.

The methodology used in the paper is composed by two different stages; the first deals with bootstrapped DEA technique while the second concerns the use of the Tobit regression in order to analyze the correlation between technical efficiency and the level of innovation of the health unit.

2.1 Bootstrapped DEA

The DEA approach allows each DMU to choose the optimum weightings for the outputs and inputs. Each DMU is considered in turn and its most favourable weights are selected (Marshall, 2011). The bootstrap technique corrects the results obtained in order to exclude endogenous factors between these variables and autocorrelation between the residuals.

The efficiency scores of DEA approach are an estimate of the unknown production frontier. As discussed by Simar and Wilson (2000), DEA estimator can only be biased. The model can't determine whether the efficiency values are real. In a context of two-stages procedure as proposed in this paper, the use of biased scores can lead to misleading results (Simar and Wilson, 2007). Consequently, bootstraping techniques, based on the idea that the frontier can be estimated by using the given sample, has used to obtain unbiased results. In this paper the bootstrap introduced by Efron (1993) has been used as an attractive tool to analyze the sensitivity measured efficiency scores to sampling variation. Bootstrapping is based on the idea of repeatedly simulating the Data Generating Process (DGP), usually through resampling, and applying the original estimator to each simulated sample so that resulting estimates mimic the sampling distribution of the original estimator (Simar and Wilson, 1998).

This paper does not highlight the formulations of Bootstrapped DEA, already widely covered in the literature. The number of sampling iterations applied in this paper for the bootstrap methodology is 2000.

2.2 Tobit Regression

In the second stage of the research the bias-corrected efficiency scores has been compared with a set of variables potentially affecting the production process of the DMU (Matranga et al. 2014). DEA efficiency scores were used as a dependent variable in a Tobit regression analysis, where a set of contextual variables were chosen as independent variable.

Predicted efficiency scores (Stage II DEA scores) reflected the amount of efficiency that was predicted by organisational and contextual characteristics. As a result, the presence of some systematic links between efficiency and structural and organizational characteristics of hospitals have been examined thanks to a survey.

2.3 Hospital efficiency

In order to collect data regarding the hospital efficienty, a research from the Italian Ministry of Health and from the "Health for All" databases has been done, covering the years 2010-2012. Four inputs (physicians, nurses, administrative employers and number of beds) and two outputs (number of admissions and number of days of recovery, weighted for case mix index of the DMU) have beed identified. Case mix index takes account for the severity of illness treated by the healthcare providers (Mobley and Magnussen, 1998). The inputs and outputs are expressed in terms of physical quantities, because no reliable price data were available. Number of payed employers are used as a proxy for the production factor labour, number of bed as a proxy for capital investment (Grosskopf et al., 2004) The literature regarding the estimation of efficiency in healthcare suggests that the number of admitted patients is a reliable measure of output (De Nicola and Gitto, 2013). The number of hospital days used as an output, takes into account that a healthcare unit required a daily use of resources to carry out recovery activities. Since the latter variable is much debated in recent years because of the tendency to reduce days of recovery, it has been chosen to weigh this variable to the Case Mix Index (CMI), so as to penalize those structures that, despite a lower CMI, take the person being treated more days than necessary.

2.4 Innovative healthcare delivery

In order to collect information regarding the innovation elements in healthcare delivery, an empirical research has been conducted, using an online survey. The survey consists of questions about the implementation of Telemedicine, Health Technology Assessment (HTA), process and logistics optimization, layout analysis (i.e. if the structures have been taken special care when planning, designing, and renovating like minimize the distance traveled by the patient or by the staff, and special layout of the operating rooms), IT implementation level, new project development, Electronic Health Record (HER) and Personal Health Record (PHR). The survey has been distributed to 350 partecipants. The response rate has been the 19%. Unfortunately it's impossible to refer the sample of the answers to the I stage analysis because in some cases the management refers to a set of structures, not only to a unit. In order to overcome this problem this aggregate sample is homogenised considering the first stage clusterization: all small hospitals (rural, without intensive care) has been deleted.

3 Main results

I Stage analysis. A statistical summary of the first stage analysis results (computed input-oriented hospital technical efficiency scores, original and bias-corrected) for each separate financial year is provided in Table 1. Computed efficiency values are by definition between 0 and 1 and may be interpreted in two ways. Firstly, if a DMU under consideration has an efficiency value of 65,5%, the DMU reaches 65,5% of the efficiency of its best practice peers. Secondly if the DMU performed as efficiently as its best practice peers, it theoretically could reduce all inputs by 34,5% while maintaining the samel level of output. It is important to remark that using the DEA technique implies that inputs and outputs in different DMUs are of the same quality; thus it is assumed that the reduction of inputs by 34,5% does not deteriorate the quality of care provided (Hofmarcher et al., 2002).

The analysis shows that the average efficiency for 2010 is 0.655 of a maximum of 1. In 2011, the efficiency appears to decrease by 5 percentage points before returning back in 2012 on the levels of 2010. The rising trend reported from 2011 to 2012 is given by some economic and organizational factors like the decreasing of the number of beds (5,000 beds less than the previous year).

The sample of hospitals that has been used for this application was collected with the most recent data available on the public Italian national databases. Many hospitals have missing values in the variables required. In particular, the final sample consists of 581 productive units equally distributed in Italian Regions. Missing hospitals do not affect the relative nature of the computed efficiency scores (Chua et al. 2011). In the model, input-oriented approach and VRS spercifications are used. Specifically, 184 belong to the north part of Italy, 169 to the centre, 228 to South and Islands.

Table 1: Efficiency scores (2010-2012)

	Year	VRS	VRS (Bias)
Mean	2010 2011 2012	0.655 0.608 0.652	0.591 0.545 0.593
Std Dev	2010 2011 2012	0.172 0.159 0.150	0.138 0.125 0.124
Top quartile	2010 2011 2012	0.523 0.496 0.542	0.485 0.458 0.498

The same sample of Table 1 is classified by organizational, dimensional, fiscal, and financial models considering BIAS values.

National healthcare system identifies 7 different organizational tiers: Direct Management by ASL, Polyclinics, IRCCS, Research Institutes, University Hospitals, Classified Hospitals (clerical hospitals), Qualified Institutes managed by ASL. Some of those are private, others are public (different financial model). Moreover, some of those are rural or have intensive care or multi-specialistic, others not (dimensional aspect). This way, in Table 2 some determinats have been chosen, in order to summarize if there are differencies in efficiency through aspects mentioned above. For example, structures with intensive care and those without has been separated in order to have a proxy of the size of the unit and to identify high complexity structures. It's useful to make this separation in order to account the economies of scale of smaller hospitals: the availability of the staff is not necessarily correctly dimensioned in relation to the number of accesses and therefore could be more

inefficient. Another classification has been made by dividing mono-specialist production units (e.g. long-term nursing, rehabilitation, psychiatric facilities, etc.) from multi-specialist ones. Third division deals with rural and non-rural hospitals in order to take account of hospitals more difficult to reach. Another distinction which required some changes to the classification given by the Ministry of Health is about university hospitals. In this paper the headquarters of Medicine and Surgery University courses of Italian University have been included in the sample. The last distinction refers to management types: Public or Accredited Private Hospitals. The first case refers to the ASL direct management facilities, public polyclinics, public foundations, IRCCS (research institutions). Other categories are part of the accredited private hospitals.

IRCCS, clerical hospitals, Qualified Institutes are not summarized in this table. Results for the university hospital and for Azienda Ospedaliera show the best results in efficiency and appear quite similar in scores and in organizational and financial aspects. Direct management by ASL seems the least efficient, yielding a gap efficiency of almost 20 points.

Table 2: Clusterization (2012)

2012	Mean	VRS (BIAS) St. Dev	Median
Rural	0.577	0.119	0.543
Non Rural	0.596	0.109	0.609
Universit	0.740	0.119	0.766
Not U	0.578	0.115	0.561
Multi-Special	0.594	0.126	0.572
Mono-special	0.576	0.094	0.569
Public	0.588	0.122	0.567
Private	0.625	0.126	0.625
Polyclinic	0.692	0.122	0.715
Direct mgmt ASL	0.562	0.109	0.551
Intensive care	0.610	0.13	0.596
Without int care	0.545	0.117	0.536

II Stage analysis. Analyzing the survey results, Telemedicine is used – or tested – in 25% of units, while HTA is adopted by the 50% of respondents. In 65% of cases there is not a dedicated budget item concerning R&D. In the 40% of cases respontents pay attention to layout issues.

Only 5 structures trace the patient flow (8%), and 15 are studying implementation projects (24%). There are critical issues regarding the online view of bed availability and access to the list of reservations or the IT management of treatment plans. EHR is used by 13 structuresn (20%), whilst PHR is adopted in 38% of cases. Regarding the doctor and nurses engagement a few interesting answers reveals that, even if this is a quite new topic, an interest is growing in the healthcare structure. This result confirms the assumptions of Barello et al. (2012).

It seems that some factors can positively influence the efficiency. Table 3 shows that a statistically significant (at 99.9 per cent significance level) positive relationship exists between positive engagement by health staff and the estimated hospital efficiency.
With significance level of 99%, structures that have electronic health records (EHR) or personal health records and a budget item dedicated to R&D seem to have a higher efficiency than others ones.
Also in this case the variable is positively correlated with the efficiency.
Note, however, that the values show potisive correlation but they are not statistically significant according to Ward management, HTA, Telemedicine, Traceability issues.

Table 3: II stage analysis

	Estimate	Std.Error	z value		
Intercept	0.517	0.031	16.76	***	
R&D	0.121	0.033	3.72	***	
Ward management	0.018	0.035	0.516		
Traceability	0.047	0.03	1.569		
Telemedicine	0.046	0.0295	1.565		
HTA	0.03	0.02	1.469		
EHR	0.131	0.041	3.231	**	
PHR	0.096	0.042	-2.364	*	
HR Engagement	0.131	0.031	4.226	**	
Log (scale)	-3.172	0.129	-24.57	***	
Level of significance	0 ***	0.001 **	0.01 *	0.05 .	0.1

4 Conclusions and future work

This paper investigates the performance of all italian care facilities and the linkages with organizational and innovation elements by using DEA and regression analyses. Examining the system at the level of single units, this analysis was conducted by applying a two-stage DEA model. The analysis reveals that the most efficient organizational model is related to University Hospitals showing the greatest healthcare technical efficiency during the analyzed time span, 2010-2012.

Moreover, results show that a high level of innovation in healthcare is pretty correlated to high efficiency scores. The role of management in improving efficiency could be very important. It will be important to reduce the partitioning of information systems and the need for organising in a more structured way the information sharing and knowledge exchange between healthcare units accross italian territory. It is necessary to create a sense of trust in new technologies like telemedicine and provide sufficient information in order to involve patients in the cure record, thus ensuring both effectiveness and efficiency. If patients are involved in terms of participation and feel the closeness of doctors, it much more likely that they respond in a positive way to

treatments and indirectly contribute to reduce financial expenditures because of decreasing of unnecessary re-admissions.

The main limitation of this study is that the samples considered in the 1st stage and in the 2nd stage analysis differ. Because the fact that the survey does not cover all the dataset, it was only possible to explain the calculated DEA efficiency scores of 65 units by corresponding demand-side data. DEA is a promising tool for benchmarking both aspects of performance: efficiency and quality of hospitals. The choice of an appropriate composite quality measure has to be addressed in future research. In fact, incorporating quality in to DEA models would be a better reflection of the hospital product.

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