International Journal of Business and Management Invention
ISSN (Online): 2319 – 8028, ISSN (Print): 2319 – 801X
www.ijbmi.org || Volume 5 Issue 3 || March. 2016 || PP-34-54

20 Years of Studies on Technical and Scale Efficiency in the Hospital Sector: a Review of Methodological Approaches

M. Giancotti[1], V. Pipitone[2], M. Mauro[1], A. Guglielmo[3]
[1]*(Department of Experimental and Clinical Medicine, Magna Graecia University, Catanzaro, Italy)*
[2]*(National Research Center, Mazara del Vallo, Italy)*
[3]*(Department of Legal, Historical, Economic and Social Sciences, Magna Graecia University, Catanzaro, Italy)*

ABSTRACT*:* *Background: The efficiency of health services is one of the most important issues in the current economic debate. Considerable savings can be attained by improving hospitals' efficiency. The literature availed itself of both parametric and non-parametric approaches, such as Data Envelopment Analysis or Stochastic Frontier Analysis, to measure and analyse the productive performance of health care services. There is increasing need to determine the best policies and practice for engaging hospitals' efficiency amongst the administrators of health care systems worldwide, and it is important issue for the quality of health care services. Objectives: Our purpose was to analyse the most used methodological approaches for measuring technical and scale efficiency in the hospital sector. We aimed to summarise evidence, providing a map which shows the most appropriate method related to available data (number of beds, number of physician, or input price and cost data as Diagnosis Related Groups) and to research assumptions (parametric approach requires a behavioral assumption of cost minimization; non parametric approach shows the advantage of requiring no assumption either about the functional form of the production frontier or the behavior of actors). Methods: A literature review for papers published from 1994 to 2014 on production efficiency measurements in the health care field was conducted. Given the nature of what health economists mean by efficiency, it is important to establish how efficiency has been measured in health care. To establish this, our research followed three steps: first, we introduced the theories of parametric and non-parametric approaches used in literature for hospitals efficiency measurement; second, we analysed 59 experimental articles about this topic, which are categorized by method, input and output variables, research settings, data source, and data analysis techniques; third, we presented our concluding remarks. Results: Different approaches have advantages and disadvantages and the choice of the most appropriate estimation method should depend on the type of organization under investigation, the perspective taken, and the quality of available data. Our research showed that DEA is the most used non-parametric method because it does not impose a strict functional form on the production frontier, hence it can accommodate wide-ranging actions. The most frequently used variables are number of beds and number of personnel as input variables; number of discharges as output variables. About research setting, most of articles used a sample of public hospitals, which is not unexpected given the importance of resource management in those settings. The most frequently used data source were official databases, or Ministry of Health websites. Finally, regarding primary data analysis techniques, the most frequently used software was DEAP Version 2.1, a computer program written by Tim Coelli (1996). Conclusions: The number of studies which aim to measure efficiency and productivity in health service has increased dramatically. The review provided in this article will offer an important support to future scale efficiency researchers, providing a "new" knowledge base regarding methods and variables that can be employed to evaluate hospitals' performance.*

KEYWORDS – *Scale Efficiency, Technical Efficiency, Review, Parametric methods, Non-Parametric methods, Hospitals*

I. INTRODUCTION

The efficiency of health services is one of the most important issues in the current economic debate. It has been claimed that considerable savings can be achieved by improving hospitals' efficiency [1]. The measurement of health care efficiency has lagged behind the measurement of health care quality.

The control of the efficiency in the provision of health care is a permanent concern amongst the administrators of health care systems worldwide [2].

A number of methods based on the notion of frontier have been increasingly applied to measure efficiency as the distance from a best practice frontier, which can be estimated by two alternative modeling approaches: (i) parametric approach, mostly based on the econometric estimation of the frontier and (ii) non-parametric approach, based on mathematical programming methods.

The objective of this paper is to analyze the most frequent method used in literature to estimate technical and scale efficiency in the hospital sector.

The paper is organized as follows. The next section describe the conceptual foundations of technical and scale efficiency, as well as parametric and non parametric approaches used to measure these. Then, a description of the review approach is given. Further, we present our results. Finally, our conclusion are presented.

II. MATERIALS AND METHODS

2.1 Conceptual foundations of Technical and Scale efficiency

The term “efficiency” is widely used in economics and refers to the best use of resources in production. In this section we focused on the concepts of Technical and Scale efficiency.

2.1.1 Technical Efficiency

Following the seminal work of Farrell, “Technical efficiency” is producing the maximum amount of output (for example number of inpatient admissions, outpatient visits) from a given amount of input (for example number of beds, working hours doctor), or alternatively producing a given output with minimum quantities of inputs. Thus, when a firm, in our case one hospital, is technically efficient, it operates on its production frontier. Technical efficiency is given by the ratio between output (what comes out of the production process) and inputs (what is entered in the production process):

(1) Technical efficiency : Output/Input

One Decision making unit (DMU) is much more efficient, in technical sense, all the more higher is this ratio. As regard, there was two types of evaluation: “ Output – oriented ” and “ Input – oriented ”.

When a study assumes an “Output orientation”, technical efficiency (TE) is taken to be the ability of a hospital to produce maximum output from a given level of inputs. Thus, the research question is: by how much could hospitals expand their outputs without changing the quantity of the inputs used? On the contrary, when a study assumes an “Input orientation”, TE is taken to be the ability of a hospital to produce a given level of outputs from a minimum inputs. Research question is: by how much can input quantities be proportionally reduced without changing the output quantities produced? Then, to determine technical efficiency of a sample of hospital units, there was different methods (Data Envelopment Analysis, Stochastic Frontier Analysis and others) that are used to assess if units are efficient from the technical point of view, or if using properly resources available, or if, on the contrary, there is a waste of resources (technical inefficiency).

Therefore, the score of TE is given by:

(2) TE : Input that should be used (standard)/Input actually used

2.1.2 Scale efficiency

An unsatisfactory score of TE could be given from a bad management of available resources, or from a wrong operational scale (too big or too small). Consequently, cannot be applied properly all procedures designed to maximize existing inputs. Therefore, it is necessary to determine, in addition to TE score, the scale efficiency (SE) score, and to address the problem of "economies / diseconomies of scale."

Increasing the size of an operating unit very small (assigning for example double, triple resource) occur economies of scale, i.e. the product increases more than twice or more than three times. Thus, the existence of economies of scale implies that there are efficiency gains to expanding firm size.

In other words, there are economies of scale at a given output level if no equal split of smaller hospitals can provide the same total output at a lower total cost .

Reached a specific size, begin to occur diseconomies of scale: a further increase in available resources generates increases less than proportional of the product. Consequently, unit cost of production increases.

In conclusion, the optimal size is one for which have already been exploited all economies of scale and are not yet presented diseconomies. For this feature to maximize the productivity of all inputs available, the optimal size is normally defined as the "Most Productive Scale Size" (MPSS).

2.2 Parametric and Non-Parametric Approaches measuring Technical and Scale Efficiency in Health Care

During the last twenty years, non-parametric and parametric methods have been increasingly employed to measure and analyze productive performance of health care services. The health care sector is an area in which the measurement of efficiency has burgeoned over the past few years. The control of the efficiency in the provision of health care is a permanent concern amongst the administrators of health care systems worldwide.

A number of methods based on the notion of frontier have been increasingly applied to measure efficiency as the distance from a best practice frontier, which can be estimated by two alternative modeling approaches: (i) parametric approach, mostly based on the econometric estimation of the frontier and (ii) non-parametric approach, based on mathematical programming methods. The parametric, statistical approach uses econometric techniques to estimate either a deterministic or a stochastic frontier function. Parametric analysis requires assuming a functional form and the specification of a distributional form for the inefficiency term, which means to take a restrictive assumption, it also shows an advantage as it allows identifying the statistical noise and random shocks of the data.

The most widespread approach in the parametric hospital efficiency literature is Stochastic Frontier Analysis (SFA), that uses econometric techniques to estimate efficiency of DMUs. It constructs a smooth parametric frontier and allows for the possibility of modeling and measurement error. SFA appeals to economic theory when considering the shape of the frontier and the statistical criteria that might be used to differentiate the appropriateness of alternative functional relationships for particular data sets. This approach requires (i) a behavioral assumption of cost minimization; and (ii) that input price and cost-data are available. An alternative parametric approach is the estimation of input/output distance functions, which do not require any of the former two assumptions.

On the other hand, the non-parametric approach, allows handling multiple inputs and outputs easily while showing the added advantage of requiring no assumptions either about the functional form of the production frontier or the behavior of actors. The main non – parametric technique is the method of Data Envelopment Analysis (DEA) that estimates efficiency scores by using linear programming techniques.

Building on Farrell’s seminal work, Charness et al [3] proposed the non-parametric technique of DEA for measuring the relative efficiencies of DMUs such as schools and hospitals. This method has grown in popularity in recent years, becoming the dominant approach to performance measurement in many sectors of the economy including health care sector.

The major drawback of DEA is its deterministic nature, which implies that it is more sensitive to outliers. The efficiency of a DMU is then measured relative to the efficiency of all others in the group: DMUs located at the efficiency frontier, which have maximum outputs generated by taking the same level of inputs among all DMUs, are the most efficient DMUs. This is a well-known CCR model (Charnes, Cooper and Rhodes) in the DEA literature. The overall efficiency of any DMU has two major components, that is, technical and allocative efficiency. A DMU is considered to be technically efficient if it is able to produce maximum output from a given set of inputs. A DMU is allocatively efficient, if it is able to use the inputs in optimal proportions, given their respective costs.

Banker [4] extend the CCR model to account for variable returns to scale, which is commonly named the BCC model (Banker, Charnes and Cooper) in the DEA literature.

An inefficient DMU in the BCC model is only benchmarked against DMUs of similar size. To evaluate hospital TE, the nonparametric DEA approach is widely adopted [5] [6] [7] [8], because it can deal with a multi-output and multi-input production frontier and is free of the behavioural assumption of profit maximization and/or cost minimization. However, these strengths also give rise to some major limitations.

For instance, when the number of observations is small relative to the sample size, efficiency scores can become inflated, while the fact that DEA ignores stochastic elements in production means that the statistical noise can distort efficiency ranking. The activity of hospitals is characterized by a set of inputs producing a set of outputs. The DEA efficiency measures can be obtained by solving K linear programs for each hospital, following either a Constant returns to scale (CRS), or Variable returns to scale (VRS) assumption.

Thus, Technical efficiencies (TE) can be calculated by solving the following linear problem:

$$\widehat{\mathrm{TE}_I(x,y)} \equiv \widehat{\theta(x,y)} = \min\{\theta \,|\, \theta > 0; y_i \le \sum_{i=1}^{n} \gamma_i y_i; x_i \ge \sum_{i=1}^{n} \gamma_i x_i \quad \text{for } \gamma_i \quad \text{such that} \sum_{i=1}^{n} \gamma_i = 1; \; \gamma_i \ge 0, i = 1, 2, \ldots, n\}$$

Assuming that the technology is VRS, we may then obtain a scale efficiency measure for each hospital. This is done by conducting both a CRS and a VRS DEA. We then decompose the TE scores obtained from CRS DEA into two components: one due to scale inefficiency and one due to ‘‘pure’’ technical inefficiency. If there is a difference in the CRS and VRS TE score for a particular hospital, then scale inefficiency is indicated, and that scale inefficiency can be approximated from the difference between the VRS and CRS TE scores. The decomposition of TE in pure TE and scale inefficiency is realized by using the following formulae introduced by Coelli et al [9]:

$$SE = TE_{CRS}/TE_{VRS}$$

The statistical limitations of DEA have been addressed by the use of Bootstrap DEA, a general method of analyzing the sensitivity of measured efficiency scores to sampling variation. Bootstrap is currently the most attractive alternative to the above mentioned problems of deterministic DEA. The essence of the bootstrap idea is to approximate the sampling distribution of interest (in our case the efficiency scores provided by DEA), by mimicking the data-generating process (DGP). In conclusion, DEA results can be used by the decision makers and administrators as inputs in making informed decisions regarding the planning, allocation, and utilization of resources. The information generated by DEA on output inefficiencies and excess inputs can be substantially utilized for the monitoring of the performance of hospitals and health systems.

Another tool employed in hospital efficiency analysis was the Malmquist productivity index (MPI), proposed by Caves et al [10].

MPI measures total factor productivity change between two data points in terms of ratios of distance functions. A Malmquist index greater than one indicates growth in productivity, while a value of less than one indicates a decline. The MPI approach does not require a priori behavioural assumptions about the production technology, nor input and output price data. These make it more appealing for measuring productivity in the public sector. Again, as part of DEA, Tobit Model was used to identify factors that influence inefficiency. Studies have shown that institutional factors at the discretion of management as well as environmental factors beyond its control affect the efficiency of a hospital [11] [12].

Some of the factors that influence the efficiency of a hospital cited in the literature include ownership (profit versus not-for-profit), location (rural/urban), teaching status (academic/non-academic), payment source, occupancy rate and quality.

Finally, many studies employees a Directional Distance Function (DDF). It is a non parametric approach, introduced by Chambers et al. [13] [14], which represents a generalization of input and output distance function. It can be viewed as additive measures efficiency. These tools, were provided to support control of the efficiency in the provision of health care, a permanent concern amongst the administrators of health care systems worldwide [2].

As regard, the next section aims to provide information about the application of these methods in studies analyzed.

2.3 Review approach

Our investigation begins by identifying all relevant papers in the field of SE of public hospital. This has required definition of a series of aspects concerning the findings process, as illustrated below (Fig. 1).

Firstly, the choice of the database from which to find papers. We chose SSCI database (*Social Science Citation Index*), incorporated in the Web of Science Internet library source. We have extracted papers by the SSCI database using in a crossed way 3 keywords related to scale efficiency (*Scale efficiency, Technical efficiency, Optimal size*) as most used in articles focused on this topic, and 2 keywords about the healthcare setting (*Hospital, Healthcare organization*), using Boolean operator AND to identify all relevant papers in the field, and to classify articles according to the covered issue. The search on the database, by selected keywords, has been extended to title, keywords and abstracts (*topics range*). The initial record was of 979 articles.

In order to overcome limits related to the choice and use of a single database we integrated papers on the topic by using Google search engine: the search has returned 10 papers. The total record was of 989 papers. This large number is not surprising given the general nature of search.

Our study has required two stage. In a first stage, we browsed those publications, removed duplicates, determined their relevance and then further downloaded the relevant ones. In particular, three members of research team examined titles and abstracts and classified papers as pertinent or not. Papers, which polled majority, were selected [15]. The initial results revealed several articles without direct connection to the precise review requirements, as it picked up all articles that contained the words *“scale efficiency”, “hospital beds”,* or *“economies of scale”*. Therefore another round of searching was carried out on these articles using the same terms in the search bar in the PDF version of the individual article, and then physically examining them to determine the extent to which they carried insights and experiences related to the scale efficiency.

According to this rule, we have selected 117 papers and we have excluded 872 papers. Of 117 articles, we included only those journals with the Thomson Reuters Impact Factor published in 2013, as a proxy of the influence of publications. According to this rule, we eliminated 37 papers. The final list consisted of 80 articles.

In a third step, in order to meet the objective of this study, or analysis of the methods used for evaluation of scale and technical efficiency, we select only empirical or experimental articles and excluded theoretical or descriptive articles (21). The final list consisted of 59 articles.

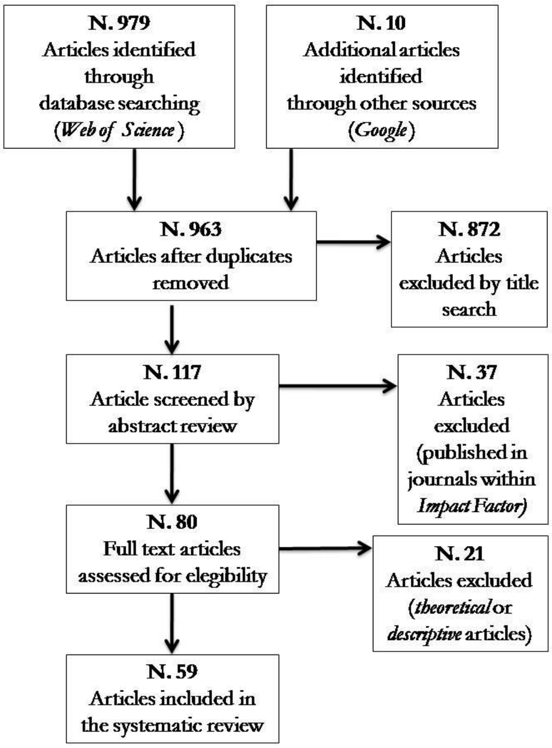

Figure 1 Flow diagram of the selection of articles included in the systematic review

Following the framework of Shields [16] - also used by Hoque [17], Chenhall and Smith [18] and Hesford et al [19] - the published articles were classified by (a) research methods, (b) input and output variables, (c) hospital setting, (d) data sources, (e) primary data analysis techniques.

The identification of the different methods, variables, research setting, data sources and primary data analysis was carried on referring to the literature of the last 20 years.

2.3.1 Temporal extension of analysis

The choice of temporal extension in our research was given by literature analysis.

Several reviews about health care performance measurement, in particular review conducted by Hollingsworth et al [20], showed an increase of empirical studies from 1995 (Figure 2).

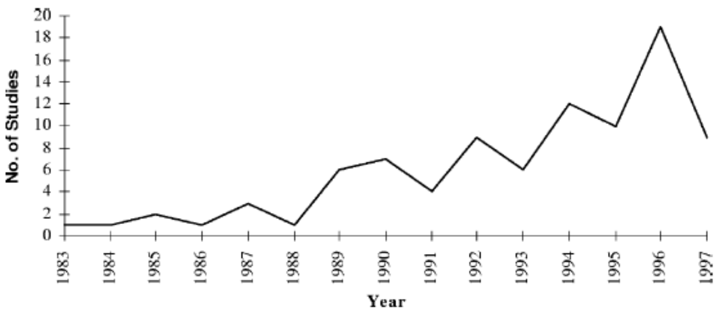

Figure 2 Number of efficiency studies 1983 – 1997. Source: *Hollingsworth et al 1999.*

This is not unexpected given that most methodological developments, such as using the efficiency score as the dependent variable in secondary regression analysis and applications of the Malmquist index, have occurred only recently. According to this, we considered literatures production about this topic of the last 20 years (1994 - 2014) published on international journals in English language with impact factor.

2.3.2 Classification of articles by methods

We classified empirical articles according to research methods used in order to calculate technical and scale efficiency of hospitals. We could distinguish between different parametric and non parametric approaches.

In general, parametric approach requires a behavioural assumption of cost minimization; non parametric approach shows the advantage of requiring no assumptions either about the functional form of the production frontier or the behaviour of actors.

Non parametric approaches included:

1. DEA analysis: The most frequently quantitative methods is DEA, a non parametric approach, that estimates efficiency scores from sample data by using linear programming techniques. DEA remains the preferred method of efficiency analysis in the non-profit sector where there is multiple-output production and it is difficult to obtain input and output price data or to set behavioral assumptions such as profit maximization or cost-minimization.

2. Directional Distance Function: Chambers, Chung, and Färe [13] introduced the DDF, a non parametric approach used to obtain a measure of TE reflecting the potential for increasing outputs while reducing inputs simultaneously.

On the other hand, *parametric approaches* included:

1. Stochastic Frontier Analysis: SFA is an alternative method to examine hospital efficiency. The analysis of production and costs in the stochastic frontier framework involves two steps. Firstly, the frontier model is estimated. Secondly, the estimated model is used to construct measures of inefficiency or efficiency.

2. Cost Function Model: studies in this area used a cost function model, in order to express production costs in terms of the amount produced, through a cost function.

Mixed methods: this section included articles which used mixed methods.

2.3.3 Classification of articles by data sources

About *data sources*, authors collected data using the following sources:

1. Official database: in other words data from Ministry of health, annual statistical publications, official discharge records and casemix data.

2. Direct Contact: some studies used direct contact, such telephonic interview or questionnaire to collect data and information.

3. Mixed sources: this section included studies which used mixed sources.

4. Non specified.

This classification is been used in this paper in order to conduct the review.

III. RESULTS

3.1 Frequency distribution of articles

Figure 3 shows the frequency distribution of articles. We founded 8 empirical articles during the period from 1994 to 1998; 7 articles from 1999 to 2003, 15 articles from 2004 to 2008 and 29 articles from 2009 to 2014. Empirical study were classified by methods, input and output variables, research setting, data source and primary data analysis technique.

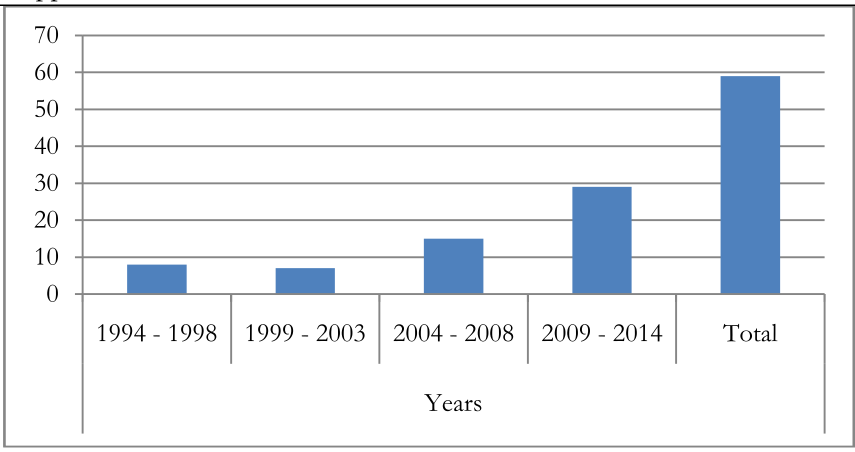

Figure 3 Frequency distribution of articles

3.2 Frequency distribution of methods.
Table 1 shows the frequency distribution of articles by methods.

Table 1. Frequency distribution of articles by methods

	Years					
Methods	1994 - 1998	1999 - 2003	2004 – 2008	2009 - 2014	**Total**	**Total %**
Non Parametric Approaches						
Dea Analysis	3	6	9	21	39	66,1
Parametric Approaches						
Cost Function	3	0	3	4	10	16,95
Stochastic Frontier Analysis	0	0	1	1	2	3,39
Directional Distance function	0	0	0	2	2	3,39
Mixed Methods	2	1	2	1	6	10,17
Total Articles	**8**	**7**	**15**	**29**	**59**	**100**

DEA has proven to be an effective and versatile tool for health care TE and SE measurement. Its use has spread throughout the world as a non-parametric method that allows the comparison of healthcare DMUs, such as physicians, hospitals, nursing homes, etc., that use multiple inputs to produce multiple outputs.

We founded 39 articles which used DEA (66,10%). 3 articles were inclused in Mixed methods.

In total, we founded 42 articles (71,18%) about TE and SE measurement with DEA.

Most frequently used DEA models are: CRS model [21] [22] [23], VRS model [21], [24] [23] and BCC model [24] [25].

Many studies (10) (17%) used a Cost function to estimate hospital productivity. In particular, Scuffham et al [26] examined the structure of cost, economies of scale and scope of 67 public hospitals , with a view to potential efficiency gains. In the study of Sinay [27], analysis was conducted to estimate Cost function Parameters and Ray economies of scale of mergers and closures for a sample of 100 pre merger hospitals. In the study of Dranove [28], semiparametric cost function was used to estimate the magnitude of economies of scale of 14 non-revenue producing cost centers in hospitals. Blank and Eggink [29] used Shadow cost function model to assess technical and allocative efficiency of 90 general hospitals. Weaver and Deolalikar [30] used Multiple product model. Data were used to estimate total variable cost as a function of multiple products, such as admissions and outpatient visits, and to estimate scale and scope economies for 654 public hospitals. Preyra and Pink [31] used a Quadratic short run cost function. The authors examine different configurations and estimate the corresponding cost functions in a sample of 210 acute care and non acute care hospitals. In the study of Kim et al [32], a cost function was used to analyse whether there are economies of scale in a sample of 204 acute care hospitals. Goncalves and Barros [33] used a translog cost function in order to evaluate economies of scale and scope in the provasion of diagnostic techniques and terapeutic services in Portuguese Hospitals. In 2012, Kristensen et al [34], used Cost function models (Quadratic cost function and Short run cost function) to estimate scale and scope efficiency of hospitals prior to the restructuring plans for a sample of 160 hospitals.

Finally, in 2014, Azevedo and Matheus [35], applied a Translog cost function to examine economies of scale in the years preceding restructuring of 69 Portuguese hospitals.

Six studies used mixed methods (10%). In the study of Frech and Mobley [36], Stigler's multivariate survivor analysis and Probit model were used to evaluate scale economies of 506 short term general hospitals. Linna [37], used parametric and non parametric panel models (SFA, DEA, Malmquist Productivity Index) to investigated about cost efficiency and productivity of 43 acute care hospitals.

During the period between 1999 – 2003 we have selected only one study [38]. In this case, authors used Fare distance function approach [39] and DEA to measure productivity change and to decompose this into technical change and efficiency change. The latter change in efficiency was also decomposed into changes in scale efficiency and input congestion for a sample of 23 hospitals.

During decade 2004 – 2014, other 3 studies used mixed methods. Arocena and Garcia-Prado [2] used the Distance function and Malmquist productivity index. Methods were applied to evaluate efficiency score of all hospitals, for a sample of 20 hospitals, whose size varies between 75 and 694 beds. In the study of Barbetta et al [40], DEA, Corrected Ordinary Least Squares (COLS), and SFA methods were applied to estimate TE of a sample of 531 hospitals boyh public and NFP. Finally, in 2009 Daidone and D'Amico [41], used Cobb Douglas and SFA to evaluate TE level of 108 hospitals.

SFA was used in 2 studies [42] [43]. 3 studies were included in mixed approaches, 1 published in 1998 [37], one in 2007 [40], one in 2009 [41]. Overall, we founded 5 articles about TE and SE measurement with SFA (8,47%).

DDF was employed in 2 studies during the period between 2009 – 2014. In particular, Ferrier et al [44] estimated a DDF to measure technical and structural efficiency for a sample of 459 hospitals. Bilsen and Davutyan [45] estimated a DDF to derive pure technical, scale and output congestion inefficiency measures and to show how they vary across size classes, for a sample of 202 rural general hospitals.

3.3 Technical and Scale efficiency estimation: the most frequently variables in parametric and non parametric approach.

It is very important to select input and output variables in studies applying parametric and non parametric methods to estimate productivity of hospitals.

Hospitals use a number of inputs to produce a wide range of services, and in studies of hospital technology researchers are forced to employ simplified models of production due to the lack of reliable data on factor prices.

Input variables are divided into three broad categories: labor (human resources; number or price), materials (services and supplies including drugs and medical - surgical supplies), and capital (buildings and equipment). So, on the input side, variables representing resource consumption by hospitals.

Regarding Output variables, it is widely acknowledged that the ultimate output in the production process of health facilities is improvement in population health . However, due to the measurement complexities and the availability of data for this type of analysis, it becomes difficult to assess the improvements in population health attributable to healthcare. Therefore, intermediate outputs are generally used as a preferred choice. Selected output variables represented the multioutput dimension of hospital production: inpatient activities (admissions and in patient days), outpatient hospital services (visits and day care), and teaching activities (residents). Butler and Li [46] classified hospital output into four broad categories: inpatient treatment, outpatient treatment, teaching and research.

This section analysis the most input and output variables as the most used in studies about this topic. In order to select the input and output variables, we used an Excel spreadsheet. In a first step, each variable was included in the spreadsheet. Secondly, variables were categorized according to the time.

Finally, variables with the same name, were grouped under a single item.

3.3.1 The most frequently variables in Dea Approaches.

The most frequently method used to estimate TE and SE in hospital sector was DEA. This section describe input and output variables used in this approach.

Articles with DEA were 39; 3 during the first period (1994 to 1998), 6 from 1999 to 2003, 9 from 2004 to 2008, 21 from 2009 to 2014.

Three studies, which used mixed methods, employed DEA; one during the first period (1994 – 1998) [37]; one during the period from 1999 – 2003 [38]; one during the third period (2004 - 2008) [40].

Overall, 42 articles used DEA. Table 2 shows the frequency distribution of input variables in DEA studies analyzed.

Table 2. Frequency distribution of input variables in Dea studies

	Years	***Total***

	1994 - 1998	1999 - 2003	2004 - 2008	2009 - 2014	Total	Total %
Dea approaches	*4*	*7*	*10*	*21*	*42*	*71,19*
Total Articles	*8*	*7*	*15*	*29*	*59*	*100%*
Input Variables						*Percentage of variable's appearance*
Number of FTE staff	2	6	10	20	38	90,48
Number of Beds	2	7	7	19	35	83,33
Hospital Expenditure	1	4	3	3	11	26,19
Supplies	-	3	2	2	7	16,67
Price of staff	-	-	1	3	4	9,52
Service	-	1	1	1	3	7,14
Total non labour costs	-	1	1	-	2	4,76
Buildings	-	-	1	1	2	4,76
Total Assets	1	-	1	-	2	4,76
Cost	1	-	-	1	2	4,76
PINDEX	1	-	-	-	1	2,38
Total labour costs	-	1	-	-	1	2,38
LPRICEs	1	-	-	-	1	2,38
Quasi fixed inputs	-	-	1	-	1	2,38
Price of beds	-	-	1	-	1	2,38
Fixed assets	-	-	-	1	1	2,38

Efficiency can be considered from two complementary perspectives, that is, production approach and cost containment approach.

Input concerning production efficiency are Number of personnel, Number of beds; input concerning cost efficiency are Costs (total labour costs, non labour costs, pharmaceutical supplies and others).

In the first case the efficiency is obtained based on non-financial activity based information seeking to contrast the raw resources used by the hospitals with the services they provide. In the second case the efficiency is assessed such that the input side of the previous model takes a financial form and thus all resources consumed are converted. We shows 16 input variables.

Each article used on average three or more input variables.

The most frequency input variable was Number of Full Time Equivalent Staff (input concerning production efficiency), used in 38 articles (90,48%). This variable included: total number of FTE physicians, nurses, administrative and other staff, excluding retirees and temporary staff.

Second variable, concerning production efficiency, was Number of Beds, used in 35 articles.

This variable was used generally as a proxy variable of capital stock employed in hospitals. A proxy is a variable not in itself directly relevant, but that serves in place of an unobservable or immeasurable variable. Number of beds was followed by Hospital Expenditure. This variable concerning cost efficiency, and was used in 11 articles (26,19%). It included the amount of operational expenses, not including payroll, capital or depreciation.

Other variables were: supplies (16,67%), including purchase of materials and other supplies; price of staff (9,52%), including salaries, or maintenance cost of staff equipment; service (7,14%), including number of diagnostic and special services, both inpatient and outpatient, provided exclusively by the hospital; total non labour costs (4,76%), input concerning cost efficiency; buildings (4,76%), a capital input variable; total assets (4,76%), as a proxy variable for capital input; cost (4,76%), or net operating costs of hospital; PINDEX (2,38%), annual price index for local government health care expenditure; total labour costs (2,38%), input concerning cost efficiency; LPRICEs (2,38%), average hourly wage rate of labour; Quasi fixed inputs (2,38%), or all types of Quasi-Fixed inputs explicitly; price of beds (2,38%), input concerning cost efficiency; and Fixed assets (2,38%), a monetary variable which included tangible assets having been used more than one year with values amounting to specific standards and with their original physical attributes not changed.

As regards output variables, measuring hospital output by such variables as inpatient days or outpatient visits, does not capture the case-mix and the quality of service rendered.

Eventhough the use of Diagnosis-related groups (DRGs) may handle the problem of hospital case-mix, the absence of data makes its use limited in most developing countries. In our analysis, we founded 28 output variables (Table 3). The most frequently output variable was outpatient visits, used in 29 studies with Dea approach (69,05%).

This variable included total number of outpatient visits or admissions. Second output variable was inpatient cases (40,48%), which included total number of inpatient admissions, followed by inpatient days (33,33%) (including total number of medicine, surgery, obstetrics, gynaecology, pediatric and psychiatry inpatient days) and inpatient discharges (16,67%) (total number of Inpatient discharges). Other output variables were: Emergencies services (16,67%), including total number of emergency visits; Case mix index (14,29%), variable used to control for differences across hospitals in the severity of illnesses or injuries treated; Surgery (14,29%), total number of surgical interventions; ALoS (9,52%), average lenght of stay; Laboratory tests (9,52%), including total number of laboratory services; VISITS (7,14%), including total sum of scheduled and follow-up visits; Patients (7,14%), including total number of patients in general medicine, surgical etc.; DRG-ADMIS (4,76%), or DRG-weighted number of total admissions; Outpatient days (4,76%); Trainees (4,76%), or number of full time equivalent trainees; Diagnoses (4,76%), including total number of medical and clinical tests; Residents (4,76 %), which is a teaching variable including number of residents receiving 1 year of training at the hospital; Hospital days care services (2,38%); Ambulatory visits (2,38%), including total number of ambulatory services ; Enrollees (2,38%), or Medicare and Medicaid Enrollees; BAD-DAYS (2,38%), or total number of bad-days; NURSE-EDU (2,38%), including total number on the job training weeks of nurses; Research (2,38%), which is a research variable including total number of impact weighted scientific publications; Total number of Clinical examinations (2,38%); Total number of External visits (2,38%); Cost (2,38%), including total hospital costs.

Table 3. Frequency distribution of output variables in Dea Analysis

	Years					***Total***
	1994 - 1998	1999 – 2003	2004 - 2008	2009 - 2014	Total	Total %
Dea approaches	*4*	*7*	*10*	*21*	*42*	*71,19*
Total Articles	*8*	*7*	*15*	*29*	*59*	*100%*
Output Variables						*Percentage of variable's appearance*
Outpatient visits	1	5	9	14	29	69,05
Inpatient cases	-	3	6	8	17	40,48
Inpatient days	2	2	4	6	14	33,33
Inpatient discharges	-	1	3	3	7	16,67
Emergencies services	1	-	2	4	7	16,67
Case - mix Index	2	-	2	2	6	14,29
Surgery	1	-	-	5	6	14,29
ALoS	-	2	1	1	4	9,52
Laboratory tests	-	1	2	1	4	9,52
VISITS	1	-	-	2	3	7,14
Patients		1	-	2	3	7,14
DRG-ADMIS	1	-	-	1	2	4,76
Outpatient days	-	-	2	-	2	4,76
Trainees	-	-	-	2	2	4,76
Diagnoses	-	-	-	2	2	4,76
Resident	1	-	1	-	2	4,76
Hospital days care services	1	-	-	-	1	2,38
Total number of Ambulatory visits	1	-	-	-	1	2,38
Enrollees	1	-	-	-	1	2,38
BED-DAYS	1	-	-	-	1	2,38
NURSE-EDU	1	-	-	-	1	2,38
Research	1	-	-	-	1	2,38
Clinical examinations	-	1	-	-	1	2,38
External visits	-	1	-	-	1	2,38
Cost	-	-	1	-	1	2,38
DRG	-	-	-	1	1	2,38
PATMORT	-	-	-	1	1	2,38
Deliveries	-	-	-	1	1	2,38

DRG (2,38%), includes DRG-value inpatients, DRG-value grey zone patients and DRG-value outpatient; PATMORT (2,38%), or Patient mortality represents an undesiderable output; Deliveries (2,38%), includes total annual number of deliveries.

3.3.2 Dea Orientation

In DEA there are two types of evaluation: “output – oriented” and “input – oriented”.

When a study assumes an “output orientation”, TE is taken to be the ability of a hospital to produce maximum output from a given level of inputs.

On the contrary, when a study assumes an “input orientation”, TE is taken to be the ability of a hospital to produce a given level of outputs from a minimum inputs.

The measure of TE preferred is input-oriented, as management is likely to have a relatively greater control of its inputs than outputs; the latter being partially determined by the utilisation behaviour of the public.

Table 4 shows the frequency distribution of DEA orientation in articles analyzed.

20 studies employed an Input orientation (47,62%); in 13 studies (30,95%) Dea orientation was not specified; 8 studies employed an Output orientation (19,05%); finally, only one study (2,38%), employed an Input and Output orientation [47].

Table 4. Frequency distribution of Dea Orientation

	Years				***Total***	
	1995 – 1998	**1999 – 2003**	**2004 - 2008**	**2009 - 2014**	**Total**	**Total %**
Dea approaches	*4*	*7*	*10*	*21*	*42*	*71,19*
Total Articles	*8*	*7*	*15*	*29*	*59*	*100%*
Dea Orientation						*Percentage of appearance*
Input orientation	2	5	4	9	20	47,62
Output orientation	-	-	3	5	8	19,05
Input and Output orientation	-	-	-	1	1	2,38
No specified	2	2	3	6	13	30,95

3.3.4 The most variables used in Stochastic Frontier Analysis

In our research, we founded five studies using SFA to estimate TE and SE in hospitals (8,47%).

In two studies SFA was the only method applied [42] [43]; in three studies SFA was included in mixed methods [37] [40] [41].

In these studies we founded 7 input SFA variables (Table 5).

The most input variables were Number of beds (100%), following by Number of FTE staff (80%) [40] [42] [41] [43].

Other output variables were: Price of staff (20%), or salary; Net operating Costs of hospital (20%); PINDEX (20%), including annual price index for local government health care expenditure [37]; LPRICEs (20%), including average hourly wage rate of labour; and Price of beds (20%).

As regard output variables, total annual number of Inpatient cases was the most variable used in studies (80%); following by total annual number of Outpatient visits (60%), Surgical intervention (40%), Residents (40%), total number of BAD-DAYS (20%); Average length of stay (ALoS) (20%), Visits (20%), DRG-ADMIS (20%), NURSE-EDU (20%); Research (20%), READMIS (20%), which included readmission rate for admissions, Cost (20%) and total number of Discharges (20%).

Table 5. Frequency distribution of input variables in SFA approaches

	Years				***Total***	
	1994 - 1998	**1999 - 2003**	**2004 – 2008**	**2009 – 2014**	**Total**	**Total %**
SFA approaches	*1*	*0*	*2*	*2*	*5*	*8,47*
Total Articles	*8*	*7*	*15*	*29*	*59*	*100%*
Input Variables						*Percentage of appearance*
Number of Beds	1	-	2	2	5	100
Number of FTE	-	-	2	2	4	80

staff						
Price of staff	-	-	1	-	1	20
Cost	1	-	-	-	1	20
PINDEX	1	-	-	-	1	20
LPRICEs	1	-	-	-	1	20
Price of beds	-	-	1	-	1	20

Table 6 shows the frequency distribution of output variables in SFA.

We founded 13 output variables.

The most frequently output variable was Inpatient cases (80%), followed by outpatient visits (60%), surgery and residents (40%), bad-days, ALos and visits, DRG-admis, Nurse-EDU (20%) and others.

Table 6. Frequency distribution of output variables in SFA approaches

	Years					*Total*
	1994 - 1998	**1999 - 2003**	**2004 – 2008**	**2009 – 2014**	**Total**	**Total %**
SFA approaches	*1*	*0*	*2*	*2*	*5*	*8,47*
Total Articles	*8*	*7*	*15*	*29*	*59*	*100%*
Output Variables						*Percentage of appearance*
Inpatient cases	-	-	2	2	4	80
Outpatient visits	1	-	1	1	3	60
Surgery	-	-	-	2	2	40
Residents	1	-	1	-	2	40
BED-DAYS	1	-	-	-	1	20
ALoS	-	-	-	1	1	20
Visits	1	-	-	-	1	20
DRG-ADMIS	1	-	-	-	1	20
NURSE-EDU	1	-	-	-	1	20
Research	1	-	-	-	1	20
READMIS	1	-	-	-	1	20
Cost	-	-	1	-	1	20
Discharges	-	-	1	-	1	20

3.3.5 Mixed methods

In our review, we founded seven studies which applied mixed methods to examine technical and scale efficiency of hospitals. In this section we analyzed these studies.

Frech and Mobley [36] analyzed scale efficiency of public and private hospitals in California. Sample was constituted by 506 short-term general hospitals, during the period from 1983 to 1989. They applied Stigler's multivariate survivor Analysis and Probit Model.

Variables used in models were: GROWSHR (change in market share, 1983-89); ADC (Output - bed days or average daily census); SYSS (whether affiliated - owned or leased - with a chain at the end of the period – 1989); HERF (Herfindahl Index, 1983); PCONTRACT (change in local market-level proportion of hospital revenues under discount contracts, 1983-1989, where losses are bed debt plus charity care less gifts designated for charity care); GROWMCARE (change in the proportion of gross revenue accounted for by Medicare charges 1983-89); GROWMCAL (change in the proportion of gross revenue accounted for by Medical charges 1983-89). Their results showed that the existence of scale economies in hospitals is important for both public and managerial policy.

Linna M [37] applied SFA and DEA to investigated about development of hospital cost efficiency and productivity in Finland. Sample was composed by 43 acute care hospitals (five university teaching hospitals and 38 other public hospitals).

Variables used in DEA were: COST (Net operating costs of a hospital), LPRICES (Average hourly wage rate of labour) and PINDEX (Annual price index for local government health care expenditure) as input variables; EMVIS (total number of emergency visits), VISITS (total sum of scheduled and follow-up visits), DRG-ADMIS (DRG-weighted number of total admissions), BED-DAYS (total number of bed-days exceeding the cutoff point defined in the outlier analysis), RESIDENTS (number of residents receiving 1 year of training at the hospital), NURSE-EDU (total number of on-the-job training weeks of nurses) and RESEARCH (total number of impact-weighted scientific publications) as output variables.

Variables used in SFA were : COST (Net operating costs of a hospital) as cost variable; BEDS (total number of beds) as fixed factor; LPRICES (average hourly wage rate of labour) and PINDEX (Annual price index for local government health care expenditure) as price variable; TEACHING (teaching dummy indicating the teaching status of the hospital), READMIS (Readmission rate for the admissions) and TIME (Year of the observation - 1...,7) as control variables.

Output variables used were: EMVIS (total number of emergency visits); VISITS (total sum of scheduled and follow-up visits); DRG-ADMIS (DRG-weighted number of total admissions); BED-DAYS (total number of bed-days exceeding the cutoff point defined in the outlier analysis); RESIDENTS (number of residents receiving 1 year of training at the hospital); NURSE-EDU (total number of on-the-job training weeks of nurses) and RESEARCH (total number of impact-weighted scientific publications).

Results revealed a 3–5% annual average increase in productivity, half of which was due to improvement in cost efficiency and half due to technological change.

McCallion et al [38] applied Fare distance Function approach [39] and DEA to analyze productive efficiency of 'larger' and 'smaller' Northern Ireland hospitals. Authors used a sample of 23 hospitals in period from 1986 to 1992. Methods used was employed to measure productivity change and to decompose this into technical change and efficiency change. The latter change in efficiency was also decomposed into changes in scale efficiency and input congestion.

Input Variables used were: Nursing staff; administrative staff; ancillary staff (full time equivalent staff member for each category); Specialist (annual expenditure on specialists); Bed complement (number of beds).

Output variables were: General surgery; General medical; Maternity; Accident and Emergency (total number of inpatient and outpatient for each category).

Findings indicated that smaller hospitals achieved greater productivity gains than larger hospitals over 1986-92. For smaller hospitals, this was due to progressive shifts in the best practice frontier outweighing a substantial decline in efficiency.

Barbetta et al [40] applied DEA, COLS, and SFA to estimate TE and SE of a sample of 531 public and NFP hospitals over 1995 - 2000, in order to identified differences between public and private not-for-profit hospitals after the introduction of the DRG-based payment system.

Variables used were Beds; Beds for DH; Physicians; Nurses; Teaching staff; Other personnel as input variables; Inpatient days; Discharged patients; DH treatments; Emergency room treatments as output variables.

Results showed that public and private nonprofit hospitals differ in their response to the introduction of the new payment system, with the latter responding more promptly than the former to PPS introduction.

Arocena and Garcia-Prado [2] applied Distance Function approach and MPI to provide insights into how Costa Rican public hospitals responded to the pressure for increased efficiency and quality introduced by the reforms carried out over the period 1997–2001.

Sample was composed of 20 hospitals, whose size varies between 75 and 694 beds, over 1997 – 2001.

Variables used were Number of physician, Number of nurses, Expenditure in goods and services and Number of beds as input variables; Case-mix adjusted discharged patients, Case-mix adjusted outpatient hospital services, Case-mix adjusted hospital re-admissions as output variables.

Results showed an improvement in hospital performance mainly driven by quality increases. The adoption of management contracts seems to have contributed to such enhancement, more notably for small hospitals.

Further, productivity growth is primarily due to technical and scale efficiency change rather than technological change.

Finally in the study of Daidone and D’amico [41], authors applied SFA and Cobb Douglas models to analyze impact of productive structure and level of specialization of hospital on TE and SE for a sample of 108 hospitals (2000 – 2005).

Input variables used were: number of Beds, Physicians, Nurses and Other Personnel (teaching plus ancillary staff). Output variables were: ER Treatments; HIV and Tumors; General Surgery; General Medicine.

3.3.6 The most frequently variables in Directional Distance Function Approaches

3 studies employed a DDF.

It is a a non parametric approach, introduced by Chambers et al. [13] [14], which represents a generalization of input and output distance function.

It can be viewed as additive measures efficiency.

Table 7 shows a frequency distribution of input variables in DDF approach.

Table 7. Frequency distribution of input variables in DDF approaches

	Years					Total
	1994 - 1998	**1999 - 2003**	**2004 - 2008**	**2009 - 2014**	**Total**	**Total %**
DDF approaches	*0*	*0*	*1*	*2*	*3*	*5,08*
Total Articles	*8*	*7*	*15*	*29*	*59*	*100%*
Input Variables						*Percentage of appearance*
Number of FTE staff	-	-	1	2	3	100
Number of Beds	-	-	1	2	3	100
Hospital Expenditure	-	-	1	1	2	66,67

From 1994 to 2003, in our research, we not founded articles about this theme which employed Directional distance function.

On the contrary, from 2004 to 2014, we founded 3 articles.

In particular, Arocena and Garcia-Prado [2] estimated a DDF to evaluate efficiency score of Costa Rica public hospitals. Input variables used were Number of FTE staff, Number of beds and Hospital expenditure.

Ferrier et al [44], used a DDF to estimate technical and structural efficiency for a sample of 459 hospitals (1994 – 2002) in the United States. On the other side, authors analyzed the efficacy of certificate of need (CON) regulations.

Input variables used were: Number of beds and Number of FTE staff. Authors founded that, on average, industry level efficiency is higher in CON states than in NOCON states. The superior performance of CON states is due to higher aggregate technical and mix efficiencies; NOCON states, however, have higher scale efficiency. Therefore, two opposite effects play out in the assessment of structural inefficiency. On one side, the CON regulation seems to improve the mix allocation among hospitals, but on the other side it also seems to constrain the size of hospitals, which have difficulty achieving most productive scale size. On net, structural efficiency is higher in CON states.

Third study with DDF approach was by Bilsel and Davutyan [45].

Authors employed a DDF to analyze the operational performance of 202 Turkish rural general hospitals deriving pure technical, scale and output congestion inefficiency measures.

Input variables were: Number of FTE staff, Number of Beds and the amount of operational expenses, not including payroll, capital or depreciation expenses (Hospital Expenditure).

As regards output, Outpatient visits was the most used variable [44] [45], following by Surgery [44] [45]; Inpatient cases [45], Emergency services [44], Case mix – Index [44], D/S Ratio, or number of deaths divided by total number of surgeries [45] and Trainees [44] (Table 8).

Table 8. Frequency distribution of output variable in DDF approach

	Years					Total
	1994 – 1998	**1999 – 2003**	**2004 - 2008**	**2009 - 2014**	**Total**	**Total %**
DDF approaches	*0*	*0*	*1*	*2*	*3*	*5,08*
Total Articles	*8*	*7*	*15*	*29*	*59*	*100%*
Output Variables						*Percentage of appearance*
Outpatient visits	-	-	-	2	2	66,67
Surgery	-	-	-	2	2	66,67
Inpatient cases	-	-	-	1	1	33,33
Emergencies services	-	-	-	1	1	33,33
Case - mix Index	-	-	-	1	1	33,33
D/S Ratio	-	-	-	1	1	33,33
Trainees	-	-	-	1	1	33,33

3.3.7 The most frequency variables in studies with a Cost Function

Of 59 studies analyzed, 10 estimated a Cost Function to analyze technical and scale efficiency in hospital sector. This section describe input and output variable used in these studies.

The most frequently input variable was Number of beds (90%), used in 9 articles.

4 studies used Supplies as input variable (40%), following by Price of staff (30%), Number of FTE staff (30%), Hospital expenditure, Total non labour costs, Case mix, Cost, Fixed resource and Total costs (10%) (Table 9).

Table 9. Frequency distribution of input variables in Cost Function

	Years				Total	
	1994 - 1998	**1999 - 2003**	**2004 – 2008**	**2009 - 2014**	**Total**	**Total %**
Cost Function approaches	*3*	*0*	*3*	*4*	*10*	*16,95*
Total Articles	*8*	*7*	*15*	*29*	*59*	*100%*
Input Variables						*Percentage of appearance*
Number of Beds	3	-	2	4	9	90
Supplies	2	-	2	-	4	40
Price of staff	1	-	1	1	3	30
Number of FTE staff	1	-	1	1	3	30
Hospital Expenditure	-	-	1	-	1	10
Total non labour costs	-	-	-	1	1	10
Cost	-	-	1	-	1	10
Case mix	1	-	-	-	1	10
Fixed Resource	-	-	1	-	1	10
Total cost	-	-	-	1	1	10

On the other side, most frequency output variable was Outpatient visits (50%), used in 5 studies. Others output variables were: Number of Inpatient days (40%), Case – mix Index (30%), number of Discharges (20%), Number of Inpatient cases (20%), Average length of stay (20%), number of Emergency services (10%), Research (10%), Inpatient discharges (10%) , Cost (10%) and DRG (10%).

Table 10 shows the frequency distribution of output variables.

Table 10. Frequency distribution of output variables in Cost Function approach

	Years				Total	
	1995 - 1998	**1999 - 2003**	**2004 - 2008**	**2009 - 2014**	**Total**	**Total %**
Cost Function approaches	*3*	*0*	*3*	*4*	*10*	*16,95*
Total Articles	*8*	*7*	*15*	*29*	*59*	*100%*
Output Variables						*Percentage of appearance*
Outpatient visits	2	-	1	2	5	50
Number of Inpatient days	1	-	2	1	4	40
Case - mix Index	-	-	1	2	3	30
Discharges	1	-	1	-	2	20
Inpatient cases	1	-	1	-	2	20
ALoS	1	-	-	1	2	20
Emergencies services	-	-	-	1	1	10
Research	-	-	1	-	1	10
Inpatient discharges	-	-	-	1	1	10
Cost	1	-	-	-	1	10
DRG	-	-	-	1	1	10

3.4 The research setting.

Detail of hospital studies are in figure 4 which shows the type of hospital studies during period from 1994 to 2014.

41 studies analyzed TE and SE using a sample composed of Public hospitals (45,76%); also called Acute/general hospitals. Acute care is a level of health care in which a patient is treated for a brief but severe episode of illness, for conditions that are the result of disease or trauma, and during recovery from surgery. Acute care is generally provided in a hospital by a variety of clinical personnel using technical equipment, pharmaceuticals, and medical supplies.

An acute care hospital is defined as a short-term hospital that has facilities, medical staff and all necessary personnel to provide diagnosis, care and treatment of a wide range of acute conditions.

In particular, we founded 3 studies during the period 1994 – 1998, 6 studies from 1999 to 2003, 11 studies during the third period (2004 – 2008) and 21 studies from 2009 – 2014. This is not unexpected given the importance of resources management in public hospitals.

In this context, Bilodeau et al [48] proposed an approach to measure allocative and technical efficiency of Quebec hospitals using a sample of 121 Short-term acute care hospitals from 1981 to 1993. Over the 1981 through 1993 period, 37% of hospitals were efficient. Inefficiency resulted in large part from technical rather than allocative inefficiency. This suggested that inefficient hospitals combined their inputs efficiently but used more resources to achieve similar production levels.

A mixed sample was used to compare different type of hospitals (public and private for example) and to analyze differences in their efficiency level. We founded 3 studies during the first period (1994 – 1998), 1 study from 1999 to 2003, 3 studies during the third period (2004 – 2008) and 2 studies from 2009 to 2014.

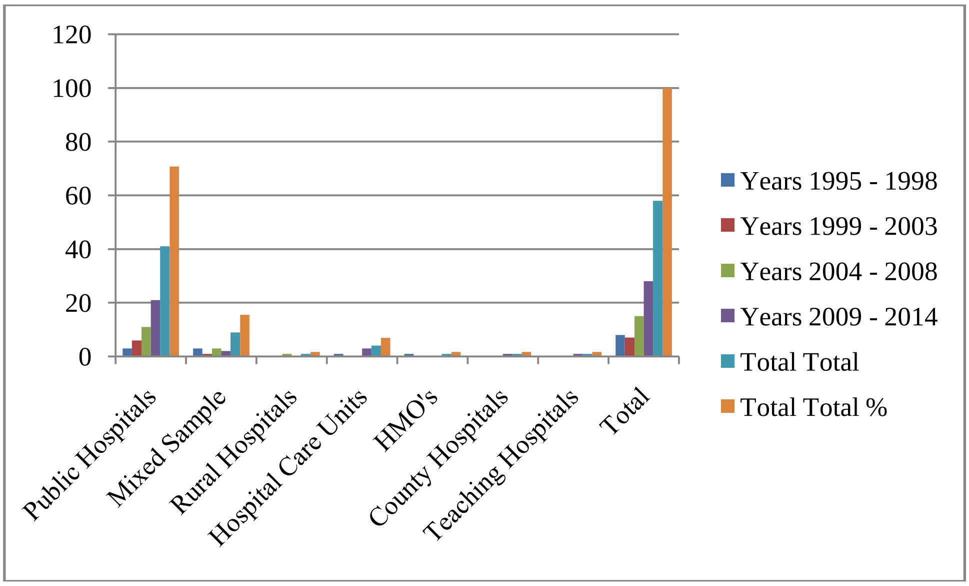

Figure 4 Frequency distribution of sample

Rural hospitals are generally defined related to the size of communities (population) and, in terms of distance.

Efficiency of this type of hospitals was measured in only one study [46].

4 studies conducted analysis in terms of Hospital Care Units. For example, Dranove [28], analyzed examine the magnitude of economies of scale in 14 Non-revenue producing cost centers in hospitals. Findings suggested that small hospitals, which average only about 2500 discharges, may potentially reap substantial benefits from scale economies. Also Ancarani et al [49] used a sample of 48 Hospital wards in Italy to analyse the impact of managerial and organizational aspect on hospital wards efficiency. Dea was employed to evaluate technical efficiency of wards.

Results showed that both decisions internal to the ward and exogenous re-organizations affect the ward's efficiency, and suggested that these variables are more significant in explaining efficiency than environmental ones.

Efficiency measurement and comparison between operational units, rather than between hospitals in their entirety, allows to compare units homogeneous between them.

About other types of sample, Rosenman et al [50] analyzed TE and SE of 28 Health maintenance organizations in Florida using DEA. Results shows that large HMOs are more efficient and HMOs with Medicaid patients are significantly less efficient than other HMOs.

Gai et al [51] assessed trends in the productive efficiency of China's county hospitals during the economic transition using data from 1993 to 2005. County hospitals were inefficient due to their enlarged scale and the reduced amount of health care services they provide.

Finally, in only one study the sample was composed of only teaching hospitals.

In particular, Goudarzi et al [43] examined TE of 12 teaching hospitals affiliated with Tehran University of Medical Sciences (TUMS) between 1999 and 2011. The mean level of TE was 59% (ranging from 22 to 81%).

During the study period the efficiency increased from 61 to 71%. Concerning the CRS, an optimal production scale was found, implying that the productions of the hospitals were approximately constant. Findings of this study showed a remarkable waste of resources in the TUMS hospital during the decade considered.

3.5 Data source

This section provided information about data source used for data collection (Input and Output variables). Table 11 shows the frequency distribution of data sources.

Table 11. Frequency distribution of data sources

	Years				***Total***	
Data Source	**1994 - 1998**	**1999 - 2003**	**2004 - 2008**	**2009 - 2014**	**Total**	**Total %**
No Specified	-	-	1	-	1	1,69
Official Database	8	7	10	22	47	79,66
Mixed Sources	-	-	3	5	8	13,56
Direct contact	-	-	1	2	3	5,08
Total	**8**	**7**	**15**	**29**	**59**	**100**

Only one study non specified data source (1,60%). 47 studies used Official database (79,66%), or Ministry of Health websites.

8 studies used Mixed source (13,56%).

In particular, Aletras et al [52], employed data from Official database (Greek NHS Hospitals) and Direct contact (electronic and ordinary mailing of letters to managers of hospitals).

Kibambe and Kocht [53], collected data using official websites (Gauteng Department of Health) and through direct contact with hospitals. Finally, Masiye [54], collected data from Official database of Ministry of Health and through direct visits to individual hospital.

We founded that data collection from direct contact with hospitals, often involves the lack of some data. For this reason, many studies used unbalanced panel.

This is a limitation in researches.

However, in three studies data collection was carried out by direct contact with hospitals (5,08%). In particular, in the study of Kirigia et al [55], one author visited the entire population of 28 municipal hospitals in Angola and reviewed their input and output records.

Yusafzadeh et al [56] collected data from direct funding, or available documents in hospitals. Finally Jehu-Appiah et al [57] collected data thought one questionnaire sent to hospitals.

3.6 The primary data analysis technique

The purpose of this section is to review the most frequency software used to calculate TE and SE score in hospital sector using parametric or non parametric approach, providing a brief description of these. Table 12 shows the frequency distribution of software.

39 articles non specified software used (66,10%).

The most frequency software was DEAP Version 2.1, used in four articles (6,78%). DEAP is a computer program written by Tim Coelli (1996). This program is used to construct DEA frontiers for the calculation of technical and cost efficiencies and also for the calculation of Malmquist Indices.

The program has three principle DEA options: standard CRS and VRS DEA models that involve the calculation of TE and SE (where applicable); the extension of the above models to account for cost and allocative efficiencies; the application of Malmquist DEA methods to panel data to calculate indices of total factor productivity (TFP) change, technological change, TE change and SE change.

All methods are available in either an input or an output orientation (with the exception of the cost efficiencies option). The output from the program includes, where applicable, technical, scale, allocative and cost efficiency estimates; slacks; peers; and TFP indices.

Table 12. Frequency distribution of software

	Years				***Total***	
Software	**1994 - 1998**	**1999 - 2003**	**2004 - 2008**	**2009 - 2014**	**Total**	**Total %**
No specified	7	4	11	17	39	66,1
DEAP 2.1	0	2	1	1	4	6,78
STATA 5	1	0	0	0	1	1,69
STATA 7	0	0	1	0	1	1,69
STATA 8.2	0	0	1	0	1	1,69
STATA 9.2	0	0	1	1	2	3,39
STATA 10	0	0	0	3	3	5,08
STATA 11	0	0	0	1	1	1,69
EMS 1.3	0	0	0	2	2	3,39
IDEAS 5.1	0	1	0	0	1	1,69
SAS 9.1.3	0	0	0	1	1	1,69
DEA Frontier	0	0	0	1	1	1,69
FEAR software	0	0	0	1	1	1,69
Frontier 4.1	0	0	0	1	1	1,69
Total	**8**	**7**	**15**	**29**	**59**	**100**

DEAP was followed by STATA, which is a general-purpose statistical software package created in 1985 by StataCorp.

Most of its users work in research, especially in the fields of economics, sociology, political science, biomedicine and epidemiology. Stata's capabilities include data management, statistical analysis, graphics, simulations, regression analysis (linear and multiple), and custom programming.

In our research we founded different version of STATA software: STATA 10, used in 3 articles (5,08%); STAT 9.2 used in 2 articles (3,39%); STATA 8.2, used in one article; STATA 7, used in one article; STATA 5, used in one article and STATA 11,used in one article (1,69%).

Another software was Efficiency Measurement System (EMS) 1.3, which is a software for Windows 9x/NT which computes DEA efficiency measures. Input and output data should be collected in one worksheet. It was used in 2 articles (3,39%).

One study (1,69%) used IDEAS 5.1 software to achieve TE and SE measurement. IDEAS is a concept-mapping software. It helps to visualize and analyze complex ideas by building multilevel interactive maps.

SAS (Statistical Analysis System) 9.1.3 is version of a software suite developed by SAS Institute for advanced analytics, business intelligence, data management, and predictive analytics. It is the largest market-share holder for advanced analytics.

It was used in one study (1,69%).

DEA Frontier was used in one study (1,69%) during the period from 2009 to 2014.

This software was developed based upon Professor Zhu's years of DEA research and teaching experience (2010). It is a Microsoft Excel Add-In for solving DEA models.

FEAR is a software package for frontier efficiency analysis, or for computing nonparametric efficiency estimates, making inference, and testing hypotheses in frontier models, developed by Wilson (2006). This software was used in one study (1,69%).

FEAR consists of a software library that can be linked to the general-purpose statistical package. The routines included in FEAR allow the user to compute DEA estimates of technical, allocative, and overall efficiency while assuming either variable, non-increasing, or constant returns to scale.

Routines are highly flexible, allowing measurement of efficiency of one group of observations relative to a technology defined by a second, reference group of observations. Consequently, the routines can be used to compute estimates of Malmquist indices and their components in any of the decompositions that have been proposed, scale efficiency measures, super-efficiency scores.

Finally, one study (1,69%) used Frontier 4.1 during the period from 2009 to 2014. This software is a package for estimating of stochastic production frontiers and inefficiency, written by Tim Coelli (1996). It is used to obtain maximum likelihood estimates of the parameters of a variety of stochastic production and cost frontiers, and estimates of mean and individual technical or cost efficiencies. The software can accommodate:

cross- sectional or panel data; half-normal or truncated normal distributions; any functional form which is linear in parameters; time-invariant or time-varying efficiencies; and inefficiency effects can be explicitly influenced by a number of firm-specific factors.

IV. CONCLUSION

The efficiency of health services is one of the most important issues in the current economic debate. The control of the efficiency in the provision of health care is a permanent concern amongst the administrators of health care systems worldwide. Considerable savings can be achieved by improving hospitals' efficiency.

According to this, the number of studies which seek to measure health service efficiency and productivity has increased dramatically and there is now an extensive literature that reflects this growing interest. A number of methods based on the notion of frontier have been increasingly applied to measure efficiency of hospitals.

This research aimed to analyze the most frequency methodological approach for technical and scale efficiency measurement in hospital sector. We can draw some conclusions.

First, the choice of an appropriate model is an important methodological issue. Different approaches have advantages and disadvantages and the choice of the most appropriate estimation method should depend on the type of organizations under investigation, the perspective taken, and the quality of available data. DEA is the most used non-parametric method because does not impose a functional form on the production frontier and hence can accommodate wide-ranging behavior.

However, measurement errors can bias results and DEA may be best employed in applications having relatively small potential measurement errors.

Second, many problems about technical and scale efficiency measurement in hospital sector, regards the inability to measure real outputs in the health care industry, changes in health status and the low quality of data. It is almost certain that health industry studies suffer from omitted variable bias. It is very important to select input and output variables in studies applying parametric and non parametric methods to estimate productivity of hospitals. Hospitals use a number of inputs to produce a wide range of services, and in studies of hospital technology researchers are forced to employ simplified models of production due to the lack of reliable data on factor prices.

However, measuring hospital output by such variables as inpatient days or outpatient visits, does not capture the case-mix and the quality of service rendered.

Eventhough the use of Diagnosis-related groups (DRGs) may handle the problem of hospital case-mix, the absence of data makes its use limited in most developing countries.

To complicate matters, the estimated results may be sensitive to changes in basic assumptions or specifications of the models used, the characteristics of the environment in which the units operate, and the results may only be valid for the specific units under investigation.

In conclusion, the accuracy of the estimated performance measures depends on the use of appropriate and well-specified models, the inclusion of relevant inputs and outputs, and the use of accurate data.

Our review of results should be treated with caution. The first limitation of this article was the lower number of articles (only 59). However, we focused our research on technical and scale efficiency measurement in hospital sector, with the aim to discuss about the optimal dimension of hospitals.

According to this rule, we excluded articles about technical efficiency with the exclusive aims to measure the use of resources (input/output ratio). In this articles, analysis not extended to scale efficiency measurement.

Anyway, our research aims to support researches with interest in this area.

REFERENCES

[1] S. Ketabi, Efficiency Measurement of Cardiac Care Units of Isfahan Hospitals in Iran, *Journal of Medical Systems, 35,* 2011, 143-150.
[2] P. Arocena, A. Garcia-Prado, Accounting for quality in the measurement of hospital performance: evidence from Costa Rica, *Health Economics, 16,* 2007, 667-685.
[3] A. Charnes, WW. Cooper, E. Rhodes, (1978) Measuring the efficiency of decision making units, *European Journal of Operational Research,2,* 1978, 429-444.
[4] RD. Banker, (1984) Estimating most productive scale size using data envelopment analysis, *European Journal of Operational Research, 17,* 35-44.
[5] P. Nayar, YA. Ozcan, Data Envelopment Analysis Comparison of Hospital Efficiency and Quality, *Journal of Medical Systems, 32,* 2008, 193-199.
[6] T. Kristensen, P. Bogetoft, KM. Pedersen, Potential gains from hospital mergers in Denmark, *Health Care Management Science, 13,* 2010, 334-345.
[7] M. Asmild, B. Hollingsworth, S. Birch, The scale of hospital production in different settings: one size does not fit all. *Journal of Productivity Analysis, 40,* 2013, 197-206.

[8] A. De Nicola, S. Gitto, P. Mancuso, V. Valdmanis, Healthcare reform in Italy: an analysis of efficiency based on nonparametric methods, *The International Journal Of Health Planning and Management, 29,* 2014, 48-63.
[9] T. Coelli, D.S.P. Rao, G.E. Battese, *An Introduction to Efficiency and Productivity Analysis* (Boston: Kluwer Academic Publishers, 1998).
[10] D.W. Caves, L.R. Christensen, W.E. Diewert, The Economic Theory of Index Numbers and the Measurement of Input, Output and Productivity, *Econometrica, 50,* 1393-1414.
[11] G.D. Ferrier, V.G. Valdmanis, Rural hospital performance and its correlates, *Journal of Productivity Analysis, 7,* 1996, 63-80.
[12] M.D. Rosko, J.A. Chilingerian, J.S. Zinn, W.E. Aaronson, The effects of ownership operating environment, and strategic choices on nursing home efficiency, *Medical Care, 33,* 1995, 1001-1021.
[13] R.G. Chambers, Y. Chung, R. Färe, Benefit and Distance Functions, *Journal of Economic Theory, 70,* 1996, 407-419.
[14] R.G. Chambers, 1998. Profit, Directional Distance Functions, and Nerlovian Efficiency. *Journal of Optimization Theory and Applications 98,* 1998, 351-364.
[15] T. Hutzschenreuter, I. Kleindienst, Strategy-Process Research: What Have We Learned and What Is Still to Be Explored, *Journal of Management, 32,* 2006, 673-720.
[16] M.D. Shields, Research in management accounting by North Americans in the 1990s, *Journal of Management Accounting Research, 9,* 1997, 3-62.
[17] Z. Hoque, 20 Years of Studies on the Balanced Scorecard: Trends, Accomplishments, Gaps and Opportunities for Future Research, *The British Accounting Review, 46,* 2014, 33-59.
[18] R.H. Chenhall, D. Smith, A review of management accounting research: 1980–2009, *Accounting Finance, 51,* 2011, 173-206.
[19] J.W. Hesford, S.H. Lee, W.A. der Stede, M.S. Young, (2009) Management accounting: a bibliographic study, in C.S. Chapman, A.G. Hopwood, M.D. Shields (Ed.), *Handbook of management accounting research,* 1 (Elsevier, Oxford, 2009) 3-26.
[20] B. Hollingsworth, P.J. Dawson and N. Maniadakis, Efficiency measurement of health care: a review of non-parametric methods and applications, *Health Care Management Science, 2,* 1999, 161-172.
[21] J. Harris, H. Ozgen, Y. Ozcan, Do mergers enhance the performance of hospital efficiency? *Journal of the Operational Research Society, 51,* 2000, 801-811.
[22] T.S. Gruca, D. Nath, The technical efficiency of hospitals under a single payer system: the case of Ontario community hospitals, *Health Care Management Science, 4,* 2001, 91-101.
[23] E. Zere, D. McIntyre, T. Addison, Technical efficiency and productivity of public sector hospitals in three South African provinces, *South Africa Journal of Economics, 69(2),* 2001, 336-358.
[24] D. Prior, M. Solà, Technical efficiency and economies of diversification in health care, *Health Care Management Science 3,* 2000, 299-307.
[25] E. Dalmau-Matarrodona, J. Puig-Junoy, (1998) Market Structure and Hospital Efficiency: Evaluating Potential Effects of Deregulation in a National Health Service, *Review of Industrial Organization, 13,* 1998, 447-466.
[26] P.A. Scuffham, N.J. Devlin, M. Jaforullah, The structure of costs and production in New Zealand public hospitals: An application of the transcendental logarithmic variable cost function, *Applied Economics, 28,* 1996, 75-85.
[27] T. Sinay, Hospital mergers and closures: Survival of rural hospitals, *Journal of Rural Health, 14,* 1998, 357-365.
[28] D. Dranove, Economies of scale in non-revenue producing cost centers: Implications for hospital mergers, *Journal of Health Economics, 17,* 1998, 69-83.
[29] L.T. Blank Jos, E. Eggink, The decomposition of cost efficiency: an empirical application of the shadow cost function model to Dutch general hospitals, *Health Care Management Science, 7,* 2004, 79-88.
[30] M. Weaver, A. Deolalikar, Economies of scale and scope in Vietnamese hospitals, *Social Science & Medicine, 59,* 2004, 199-208.
[31] C. Preyra, G. Pink, Scale and scope efficiencies through hospital consolidations, *Journal of Health Economics, 25,* 2006, 1049-1068.
[32] K.H. Kim, K. Carey, J.F. Burgess Jr, Emergency department visits: the cost of trauma centers, *Health Care Management Science, 12,* 2009, 243-251.
[33] R. Goncalves, P.P. Barros, Economies of scale and scope in the provision of diagnostic techniques and therapeutic services in Portuguese hospitals, *Applied Economics, 4,* 2011, 415-433.
[34] T. Kristensen, K.R. Olsen, J. Kilsmark, J.T. Lauridsen, K.M. Pedersen, Economies of scale and scope in the Danish hospital sector prior to radical restructuring plans, *Health Policy, 106,* 2012, 120-126.
[35] H. Azevedo, C. Mateus, Cost effects of hospital mergers in Portugal, *European Journal of Health Economics, 15,* 2014, 999-1010.
[36] H. Frech, L.R. Mobley, Resolving the Impasse on Hospital Scale Economies - A New Approach, *Applied Economics, 27,* 1995, 286-296.
[37] M. Linna, Measuring hospital cost efficiency with panel data models, *Health Economics, 7,* 1998, 415-427.
[38] G. McCallion, J.C. Glass, R. Jackson, C.A. Kerr, D.G. McKillop, Investigating productivity change and hospital size: a nonparametric frontier approach, *Applied Economics, 2,* 2000, 161-174.
[39] R. Färe, S. Grosskopf, C.A.K. Lovell, *Production Frontiers* (Cambridge University Press, Cambridge, 1994).
[40] G.P. Barbetta, G. Turati, A.M. Zago, Behavioral differences between public and private not-for-profit hospitals in the Italian National Health Service, *Health Economics, 16,* 2007, 75-96.
[41] S. Daidone, F. D'Amico, Technical efficiency, specialization and ownership form: evidences from a pooling of Italian hospitals, *Journal of Productivity Analysis, 32,* 2009, 203-216.
[42] A. Herr, Cost and technical efficiency of German hospitals: Does ownership matter? *Health Economics, 17,* 2008, 1057-1071.
[43] R. Goudarzi, A. Pourreza, M. Shokoohi, R. Askari, M. Mahdavi, J. Moghri, Technical efficiency of teaching hospitals in Iran: the use of Stochastic Frontier Analysis, 1999–2011, *International Journal of Health Policy & Management, 3(2),* 2014, 91–97.
[44] G.D. Ferrier, H. Leleu, V.G. Valdmanis, The impact of CON regulation on hospital efficiency, *Health Care Management Science 13,* 2010, 84-100.
[45] M. Bilsel, N. Davutyan, Hospital efficiency with risk adjusted mortality as undesirable output: the Turkish case, *Annals of Operations Research,* 2011, 1-16.
[46] T.W. Butler, L. Li, The utility of returns to scale in DEA programming: An analysis of Michigan rural hospitals, *European Journal of Operational Research, 161,* 2005, 469-477.
[47] G. Rego, R. Nunes, J. Costa, The challenge of corporatization : the experience of Portuguese public hospitals. *European Journal of Health Economics, 11,* 2010, 367-381.
[48] D. Bilodeau, P.Y. Cremieux, B. Jaumard, P. Ouellette, T. Vovor, Measuring hospital performance in the presence of quasi-fixed inputs: An analysis of Quebec hospitals, *Journal of Productivity Analysis, 21,* 2004, 183-199.

[49] A. Ancarani, C. Di Mauro, M.D. Giammanco, The impact of managerial and organizational aspects on hospital wards' efficiency: Evidence from a case study, *European Journal of Operational Research, 194,* 2009, 280-293.
[50] R. Rosenman, K. Siddharthan, M. Ahern, Output efficiency of health maintenance organizations in Florida, *Health Economics, 6,* 1997, 295-302.
[51] R. Gai, C.C. Zhou, L.Z. Xu, M. Zhu, X.Z. Wang, S.X. Li, W.G. Zheng, P.P. Song, X.L. Yang, L.Y. Fang, Y. Zhen, W. Tang, Health resource allocation and productive efficiency of Chinese county hospitals: Data from 1993 to 2005, *Bioscience Trends, 4,* 2010, 218-224.
[52] V. Aletras, N. Kontodimopoulos, A. Zagouldoudis, D. Niakas, The short-term effect on technical and scale efficiency of establishing regional health systems and general management in Greek NHS hospitals, *Health Policy, 83,* 2007, 236-245.
[53] J.N. Kibambe, S.F. Kocht, DEA applied to a Gauteng sample of public hospitals, *South African Journal of Economics, 75(2),* 2007.
[54] F. Masiye, Investigating health system performance: An application of data envelopment analysis to Zambian hospitals, *BMC Health Services Research, 7(58),* 2007.
[55] J.M. Kirigia, A. Emrouznejad, B. Cassoma, E.Z. Asbu, S. Barry, A Performance Assessment Method for Hospitals: The Case of Municipal Hospitals in Angola, *Journal of Medical Systems, 32,* 2008, 509-519.
[56] H. Yusefzadeh, H. Ghaderi, R. Bagherzade, M. Barouni, The Efficiency and Budgeting of Public Hospitals: Case Study of Iran, *Iranian Red Crescent Medical Journal, 15,* 2013, 393-399.
[57] C. Jehu-Appiah, S. Sekidde, M. Adjuik, J. Akazili, S. D Almeida, F. Nyonator, R. Baltussen, E.Z. Asbu, J.M. Kirigia, Ownership and technical efficiency of hospitals: evidence from Ghana using data envelopment analysis, *Cost Effectiveness and Resource Allocation, 12(9),* 2014.