FINANCIAL ENGINEERING LABORATORY
Technical University of Crete

Evaluation of the Efficiency of Greek Hospitals: A Non-Parametric Framework and Managerial Implications

George Fragkiadakis
Michael Doumpos
Constantin Zopounidis
Christophe Germain

Working Paper 2013.02

April 2013

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EVALUATION OF THE EFFICIENCY OF GREEK HOSPITALS: A NON-PARAMETRIC FRAMEWORK AND MANAGERIAL IMPLICATIONS

George Fragkiadakis[1], Michael Doumpos[1], Constantin Zopounidis[1, 2*], Christophe Germain[2]

[1] Technical University of Crete, Dept. of Production Engineering and Management, Financial Engineering Laboratory, University Campus, 73100 Chania, Greece

[2] Audencia Group, School of Management, Nantes, France

Abstract

The continuous growth of hospital costs has driven governments in many countries, as well as in Greece, to encourage hospitals to increase their efficiency. In response to this need the knowledge and the continuous evaluation of the National Health System (NHS) hospitals' efficiency level is certainly a precondition for planning, implementing and monitoring any promising reform. In this paper, we seek to develop and apply a research framework concerning the assessment of the efficiency in public sector hospital operations in Greece, especially after the implementation of the reforms that took place in the Greek NHS over the last decade. The proposed framework is based on a detailed breakdown of the hospitals' operation taking into account their service/case mix and cost structure. The empirical part of the paper examines data from 87 public hospitals in Greece over the period 2005-2009, using multiple combinations of input and output variables, which provide insights on efficiency results in terms of the service/case mix of the hospitals and their cost structure.

Keywords: Hospital efficiency, Technical efficiency, Cost efficiency, Data Envelopment Analysis

1. INTRODUCTION

Throughout the world, healthcare systems have been under increasing pressure to improve performance by controlling healthcare costs without compromising the quality of the provided services and access to them. This has become particularly important after the outbreak of the

[*] Corresponding author: Constantin Zopounidis, e-mail: kostas@dpem.tuc.gr, Tel. +30-28210-37236, Fax: +30-28210-69410

recent economic crisis, which has led to tightening public budgets that have also affected healthcare.

In May 2010 “The Economic Adjustment Programme for Greece” [15] was established. The memorandum between Greece, the IMF and the EU puts emphasis on the implementation of extensive structural reforms and expenditure cuts in order to restore the competitiveness of the Greek economy and cut down the existing budget deficit. The healthcare sector is one of the main areas where particular emphasis has been put, taking into consideration the significant rise in public health expenditure in Greece over the past decade. The implementation of the programs policies is expected to have a major effect on the healthcare system in the country.

The success of this effort depends, among others, on the successful implementation of policies to improve the utilization of the available resources. Hospital managers play a central role in achieving this goal. From that perspective, achieving a high level of managerial efficiency is crucial. According to Chilingerian and Sherman [11, 12] can be equated with producing nursing care, diagnostic and therapeutic services, and treatment programs of satisfactory quality, using the least resources. In this context, hospital managers have to set up and implement policies for controlling labor, medical supplies, and all expenditures related to nursing, intensive care, emergency care and ancillary services, without sacrificing the quality of the services provided to the patients.

It is widely known that the efficiency of hospitals is complicated and multifaceted, as both clinically and managerial efficiency should be achieved. From a clinical perspective, it is the physician’s decision making (i.e., patient management) that matters in order to provide high quality medical services on the basis of the complexity and severity of each patient. Non-clinical managers, on the other hand, are responsible for use of all hospital assets by managing its overall operation [11, 12]. Efficiency measurements performed in such a context should be an integral part of a holistic system for evaluating, monitoring, and benchmarking the overall performance of a hospital in combination with additional factors such clinical processes quality and patient satisfaction [17, 20, 35].

Our research focuses on the evaluation of the overall managerial efficiency of the acute care hospitals in Greece using benchmark techniques, combining both operational efficiency and cost efficiency estimates. The Greek National Healthcare System (NHS) has undergone major transformations over the past decade (with three reforms introduced since 2001), but it still faces significant operational and financial challenges. This study is based on an up-todate data set consisting of 87 public hospitals over the period 2005-2009, which account for more than 80% of the total public hospitals operating in Greece.

The first objective of the study is to evaluate the efficiency of Greek public hospitals in the light of the reform efforts made to restructure the health system with the aim to improve the effectiveness and efficiency of hospitals in the country. The second objective is to provide insights that could be useful to the administrations (managers) of hospitals and policy makers, through the introduction and analysis of disaggregated evaluations of the hospitals' overall efficiency, in terms of their medical services, case mix, and cost dimensions. The third objective involves the evaluation between the health units of the sample in order to facilitate the exercise of control by the Regional Health Administrations in order to contribute to equitable distribution and utilization of financial and other resources (personnel and medical equipment) of the healthcare system. This could be achieved by increasing the mobility of healthcare staff (including doctors, nurses and other staff) within and across health facilities. Furthermore, the results of this research could be an important tool for revising the activity of small, medium and large hospitals towards specialization in areas such as pathological or surgical departments by optimizing and balancing the available resources.

The analysis is based on a non-parametric approach, namely data envelopment analysis, which enables efficiency assessments in a multidimensional input/output framework under which hospitals are considered as operational units seeking to use their available recourses (personnel, equipment, capital, etc.) as efficiently as possible for providing medical services to patients. In contrast to previous studies for Greek public hospitals [3, 4, 13, 16, 31], that have relied on static data (e.g., one or two years) prior to 2005, we use an updated data set that spans a five-year period from 2005 to 2009. We measure the overall efficiency of the hospitals in two main dimensions that cover their operational characteristics and cost structure, based on the consideration on multiple combinations of input/output specifications corresponding to different efficiency perspectives and measurements on specific aspects of the hospitals service and case mix as well as their cost structure. On the service and case mix side, these include the clinical activity in pathological and surgical departments (case mix), emergency visits and appointments in outpatient's department (service mix), surgeries operated based on their severity (low or high – complexity of case mix), and laboratory work divided into two areas, that of radiological and laboratory exams (service mix). On the cost side, labor cost and supply costs are considered. Thus, this research is a comprehensive attempt to capture and measure the Greek hospitals' efficiency, while controlling for the specific aspects of their production process. The disaggregated approach adopted in this framework with regard to the hospitals' operation and cost structure, enables not only to test the robustness of the obtained results but also to identify particular strengths and weaknesses of the hospitals, while controlling for each of the above main dimensions. In this respect, the obtained results could provide useful guidelines on the design and implementation of measures for improving the particular aspects of the hospitals' operations according to their specific characteristics, as well as to improve the weaknesses of the latest reforms imposed by the government.

The rest of the paper is organized in five sections as follows. In section 2 we outline the context of the study focusing on the structure of the Greek NHS and the existing literature on healthcare efficiency measurement in Greece and internationally. Section 3 introduces the theoretical framework of the study, as well as the input and output specifications used to assess the efficiency of health units. In section 4 we focus on the empirical results of the study, whereas section 5 concludes the paper and discusses some future research perspectives.

2. STUDY CONTEXT

2.1 The Greek National Healthcare System

The main characteristic of the Greek NHS since its foundation has been its decentralized structure. The significance and importance of this feature has increased particularly after 2000. The establishing law of the Greek NHS in 1983 anticipated the creation of strong regional health authorities and the transfer to them of a wide range of administrative tasks. The founding act of the Greek NHS introduced a regional structure, allowing local administrations to play an important role in determining responsibilities and to formulate proposals to better address local needs. However, the reform failed to be implemented fully leaving the health system fully dependent on the central government.

The reform interventions of 2001 and 2003 launched an explicit, institutionally regulated process of structuring the regional health systems and welfare, assigning regional administration with responsibilities for strategic and operational decisions. The Ministry of Health had the role of policy planning at the national level. Overall 17 local administrative units were established, but the reform became inactive during 2004 and new legislation was passed in 2005. Ultimately, a new administrative structure was introduced in 2007 based on seven district regional health administrations (RHAs).

The Greek NHS combines models based on private and public healthcare services, with the public sector being the dominant one. The private sector is mostly focused on providing primary care services. On the other hand, public hospitals cover about 70% of the total number of beds. Public financing also covers the majority of the total health expenditure (about 60%). Public financing is given either directly by central government or through public social insurance funds. According to data from the World Health Organization, the health expenditure per capita in Greece has increased from 920$ in 2000 to more than 3,000$ in 2008, with a decrease to 2,730$ in 2010. The total health spending in Greece accounted for 10.2 % of GDP in 2010, above the average of 9.5% in OECD countries [33]. A significant part (about 25%) of the total spending involves pharmaceuticals. In fact Greece has become one of the highest spending countries on pharmaceuticals in OECD.

The Greek healthcare system has consistently faced serious problems concerning its organization, financing, and quality of the provided services. Among other problems, Economou [14] emphasizes: (a) the absence of cost-containment measures and well-defined funding policies, (b) the lack of incentives to improve performance in the public health sector, (c) the unequal regional distribution of health resources, (d) the lack of planning and coordination, (e) the oversupply of physicians, (f) irrational pricing and reimbursement policies. Naturally, these persistent and unresolved problems have not only led to financial and operational difficulties, but also resulted to low satisfaction as perceived by the citizens.

2.2 Literature review

The continuous increase in public health spending and hospital's deficits led governments to legislate new forms of hospital operations in order to reallocate resources. Efficiency measurement has proven to be an effective and versatile tool for healthcare management, supporting decision and policy making with regard to the rational distribution and utilization of human, economic, and technical resources.

In an input/output context, the evaluation of efficiency refers to the evaluation of the way that scarce input resources (e.g., staff, beds, costs, supplies) are converted into outputs (number of patients, laboratory tests, surgeries, etc.). Several parametric statistical/econometric and non-parametric (mathematical programming-based) methods have been used for efficiency evaluation (see [21, 22, 32, 40] for reviews). Among these approaches, data envelopment analysis (DEA [9, 10]) has become particularly popular. Worthington [40] notes that the non-parametric nature of DEA (which is based on linear programming models), provides increased flexibility on the selection of the inputs and outputs in multidimensional context (in contrast to parametric techniques that often rely on a single output [32]). This is particularly appealing feature for applications in the public sector where the axioms of profit maximization are not applicable. Furthermore, the implementation of DEA models does not require the explicit specification of the functional relationship between inputs and outputs, and facilitate the identification of the sources for inefficiency for each separate hospital (instead of describing the efficiency conditions that prevail in a sample of healthcare units). As O'Neill et al. [32] note DEA is better suited for managerial decision-making, whereas parametric techniques are more useful for policy analysis.

The above mentioned features of DEA have made it a very popular methodology for estimating the relative efficiency of hospitals, with many applications in Greece [1, 3-5, 13, 16, 19, 26, 27, 31, 41] as well as in Europe and the rest of the world [7, 8, 11, 18, 21-25, 34, 36, 38, 39]. Hollingsworth [22] provides a review of 317 published papers on frontier efficiency measurement in healthcare, concluding that even though there is an increasing use of parametric techniques, such as stochastic frontier analysis, around 75% of the papers use DEA.

Most of the studies for the assessment of Greek public hospitals used DEA in order to examine the operational efficiency of healthcare units. Athanassopoulos et al. [4] measured the technical efficiency and the efficiency of distribution, with data relating to 1992, in 98 Greek hospitals, under constant and variable returns to scale. The study showed a higher efficiency of suburban and rural hospitals than in large cities due to over-concentration of human and financial resources in large cities. The technical efficiency was found to be higher in hospitals with small and medium amount of bends sized up to 86 and 335 beds, respectively.

A study by Zavras et al. [41], evaluated the relative efficiency of the primary services of the Social Insurance Institute (IKA), through DEA, based on data for 133 primary healthcare centers across the country using data for 1998-1999. The authors used as input variables, the number of personnel (divided into several categories), and the population covered by each center, whereas the outputs involved the number of patient visits. According to the results, primary healthcare centers with the technological infrastructure to perform laboratory or radiological examinations showed the highest efficiency. Moreover, the medium-sized units, covering population areas of 10,000 to 50,000, were the most efficient.

The study of Kontodimopoulos et al. [26] used DEA to assess the technical efficiency of a group of 17 small-scale hospitals (hospital-health centers) for 2003. These hospitals are located in rural areas (covering a population of at most 20,000 people) providing primary, secondary healthcare, and preventive services. An input-oriented DEA model was applied under the assumption of constant returns to scale using as input variables, the number of doctors, nurses and beds. On the other hand, the outputs involved visits to outpatients and medical services provided. The results showed that the efficiency of the hospitals ranged at about 75%.

Another study by Aletras et al. [3], measured the technical efficiency and scale efficiency in 51 general hospitals in the Greek NHS for the years 2000 and 2003. The purpose of this study was to compare the efficiencies of the hospital before and after the implementation of the reform act 2889/2001, which provided administrative and financial independence of inputs chosen by hospitals. The inputs used in the study included the total number of doctors, other staff and the number of beds. The outputs involved the total number of inpatients, the number of surgeries, the visits to outpatient clinics, as well as laboratory tests and the inpatients' severity index/complexity Roemer index. The study concluded that the implementation of the reform act has affected negatively the hospitals' efficiency.

Finally, two recent studies were presented recently by Mitropoulos et al. [31] and Dimas et al. [13]. Mitropoulos et al. [31] evaluated the efficiency of public hospitals with two alternative conceptual models. First they considered a model involving resource usage (production efficiency), while the second model focused on financial results (economic efficiency). They employed a sample of 96 general hospitals in the Greek national health system for one year (2005). The results indicated that, although the average efficiency scores in both models have remained relatively stable compared to past assessments, internal changes in hospital performances do exist. On the other hand, Dimas et al. [13] evaluated the productive performance, efficiency, and technology changes of 22 Greek public general hospitals for the period 2003–2005. The results suggest that productivity changes were dominated by the technical change component while hospital's inefficiency was attributed to an excessive increase of their expenditures.

3. METHODOLOGICAL FRAMEWORK

This study focuses on the assessment of public hospitals in Greece from the perspective of managerial efficiency, seeking to assess the ability of the hospitals to utilize the available human, technical, and economic resources to produce services in the most efficient and effective manner. Chilingerian and Sherman [11, 12] discuss the differences between this approach and the alternative perspective of focusing on clinical efficiency, which is oriented towards patient management, i.e., the utilization of minimum clinical resources to provide high quality treatment to patients taking into consideration complexity of each case.

In Greece data associated with qualitative information involving the evaluation of treatment provided in patients are not yet available. A new initiative towards this direction (Diagnostic Related Groups of patients), has started to be implemented at the end of 2011 and is still in its very early stages to provide useful data. Therefore, in this study we focus on decisions taken by the managers of the hospital and/or health administration regions in relation to the quantity and distribution of inputs within a hospital or health district. In this framework, the analysis is organized around eight different scenarios/models for measuring the operational and financial efficiency under different views. In this section we first provide a brief outline of data envelopment analysis and then discuss the proposed model specification framework.

3.1 Data envelopment analysis

DEA, first introduced by Charnes et al. [10], is a very useful methodology in the context of benchmarking the operation of healthcare units, as it enables the assessment of productivity and efficiency of organizational units, like hospitals, which use multiple resources to produce multiple products.

The main objective of DEA is to find an efficiency frontier formed by those combinations of resources which optimize the amount of outputs produced, while minimizing the input resources. DEA extends simple input/output ratios, through the consideration of multiple inputs and outputs, to provide estimates of technical efficiency. As noted by Magnussen [28] a hospital is said to be technically efficient if an increase (decrease) in an output (input) requires a decrease (increase) in at least one other output (input). The multidimensional efficiency frontier introduced by DEA provides a reference for benchmarking the efficiency of all operational decision making units.

Under constant returns to scale (CRS) and with an input orientation for a data set involving N hospitals, described over K inputs and M outputs, the maximum efficiency of a hospital i can be estimated through a linear programming model, which is expressed in dual form as follows (CCR model [9]):

$$
\begin{aligned}
\min \quad & F = \theta_i^C - \varepsilon(\mathbf{1s}_i^I + \mathbf{1s}_i^O) \\
\text{Subject to:} \quad & \mathbf{X\lambda} - \theta_i^C \mathbf{x}_i + \mathbf{s}_i^I = \mathbf{0} \\
& \mathbf{Y\lambda} - \mathbf{s}_i^O = \mathbf{y}_i \\
& \boldsymbol{\lambda},\ \mathbf{s}_i^I,\ \mathbf{s}_i^O \geq \mathbf{0},\ \theta_i^C \in \mathbb{R}
\end{aligned}
\tag{1}
$$

where $\mathbf{X}$ is a $K \times N$ matrix with the hospitals' inputs, Y is a $M \times N$ matrix with the outputs, $\mathbf{s}_i^I$ and $\mathbf{s}_i^O$ are the vectors of slack variables for the inputs and outputs, respectively, indicating the improvements that an inefficient hospital should achieve in order to become efficient, $\mathbf{1}$ denotes a vector of ones, and $\varepsilon \approx 0$ is a small positive constant that allows the solution procedure to give first priority on the optimization of θ_i^c (in a lexicographic sense), which represents a weighted output/input efficiency ratio for hospital i. Denoting by F^* the value of the objective function of problem (1) at its optimal solution, hospital i is classified as efficient if and only if $F^* = 1$ (i.e., if the efficiency score is $\theta_i^C = 1$ and the slacks are zero). Variable returns to scale (VRS) can be introduced by simply adding the convexity constraint $\lambda_1 + \cdots + \lambda_N = 1$ to the above model. This constraint ensures that a hospital is benchmarked only against other units of similar size. The resulting model is known as the BCC model [6].

In this study the input-oriented DEA model has been used to assess the technical and scale efficiency of Greek hospitals under eight different scenarios with respect to their inputs and outputs. This approach enables the analysis of the results under different model-data settings, thus facilitating the formulation of robust conclusions. The following section describes the model specifications used in the analysis.

3.2 Input-output specifications

The selection of input and output variables that describe the multifaceted operation of health care units is clearly an important factor for evaluating their efficiency status. The review of O'Neill et al. [32] provides a comprehensive categorization of multiple input and output variables used in DEA-based efficiency analysis studies in the health care sector. As far as the inputs are concerned they identify six major categories, involving beds, clinical staff, non-clinical staff, working hours, services offered, and costs. On the output side, the review indicates that most studies focus on two main categories of variables, namely: (a) medical visits, cases, patients, and surgeries, and (b) inpatient days.

The variables used in this study follow a similar categorization. In particular, we use output variables to take into account the service mix, case mix, outpatient and inpatient cases of Greek public hospitals, based on the nature of services that they provide, as follows:

- External patient care (outpatient and emergency visits).
- Inpatient care (total number of patients in surgical and pathological departments).
- Surgical operations (minor or major operations).
- Laboratory services (quantity of laboratory and diagnostic tests).

The hospitals' inputs, on the other hand, are categorized into three broad categories, related to clinical capacity (number of beds), labor (clinical and non-clinical), and operating costs (staff salaries and medical supplies).

Following McKillop et al. [30] who emphasized the importance of taking into consideration the sensitivity of the results to changes in the input-output specifications, we test different modeling scenarios each reflecting different aspects of the services provided by public hospitals, as shown in Table 1. The considered scenarios cover two major dimensions of the overall efficiency of the hospitals, including their operational and cost efficiency. This modeling framework facilitates not only the examination of the sensitivity of the results, but also the identification of particular effects due to the service/case mix and the cost structure of the hospitals.

Insert Table 1 here

The first five settings are all related to operational efficiency. The first scenario (DEA 1) is the basic model. It measures the overall operational/production efficiency of the hospitals using as inputs the annual data for clinical staff, nurses, administrative and other staff, as well as the number of beds in use. On the output side, the variables used are the annual number of inpatients, surgeries, outpatient and emergency visits, and laboratory examinations. Except for the basic model, four additional scenarios (DEA models 2-5) are also considered to evaluate the performance of the hospitals according to their service and case mix. Model DEA 2 is used to evaluate the case mix efficiency using as outputs the minor and major operations concerning the mix of surgeries. On the other hand, model DEA 3 introduces a patient mix disaggregation, distinguishing between the patients in two treatment categories, namely pathological and surgical patients. Accordingly, in order to measure the production efficiency in terms of service mix, we evaluate the hospitals' outputs in terms of laboratory examinations and the mix of outpatient treatment (models 4 and 5).

Except for operational efficiency, cost efficiency models are also employed in the analysis. The first scenario (DEA 6) measures the total cost efficiency using as input variables the total operating expenses of hospitals and as outputs the annual number of inpatient visits, the number of surgeries, the number of outpatient visits and the number of laboratory examinations. On the other hand, settings 7 and 8 examine cost efficiency through a disaggregation of the operating costs into labor and supplies costs. The outputs of the three cost models involve four variables related to the service and case mix, including the number of surgeries, outpatient and emergency visits, laboratory examinations, as well as the Roemer case-mix index, which provides an adjusted estimated for the average length of stay taking into account the occupancy rates of the hospitals [3, 37].

4 EMPIRICAL ANALYSIS

4.1 Sample data

The sample of the study consists of 87 public general hospitals operating in the Greek health system during the period 2005 to 2009. Our initial data included 128 hospitals, but the final choice was made after the adoption of certain criteria related to the health services provided by the hospitals and other main characteristics of their case and service mix. In particular, the final set of hospital was specified on the basis of a mix of criteria related to the character (special purpose) of the hospitals (profit - non-profit, public or private), the mix of treatment they provide (general or special hospitals, university or non-university), the mix of cases encountered (pathological or surgical cases), and the size of the hospitals (as measured by the number of beds). Thus, the final sample consists of hospitals satisfying the following four criteria:

- Type of hospitals: Non-profit hospitals that are public entities.
- Type of hospitalization: The sample involves only general hospitals, that provide a full range of secondary health care medical services, excluding special hospitals (psychiatric, pediatric, oncology etc.), as well as university hospitals.
- Case mix of services: The hospitals in the sample have services such as: fully operational pathological and surgery departments, laboratory departments, outpatient's services, emergency department and operating rooms to perform surgeries.

- The size of the hospitals: The sample consists of hospitals with more than 60 beds. Thus, we have excluded very small hospitals which operate with low-level technical facilities and do not employ all specialties of staff.

The 87 hospitals in the final sample are geographically distributed over the country, they are organized into seven regional health administrations, and they are of different size, as shown in Table 2. The sample hospitals account for more than 80% of the total number of Greek public hospitals and have a capacity in excess of 21,000 beds (about 83% of the total bed capacity of all Greek public hospitals), employ more than 16,000 doctors and 25,500 nursing staff (about 90% of the corresponding totals). Table 3 summarizes the sample descriptive statistics for all input and output variables. It is worth noting the significant increase in total operating costs (supplies and labor costs) during the time period of the analysis. However, this increase in expenses is not accordance with the changes in the average number of inpatients and outpatient visits, the number of surgeries and laboratory exams served and produced respectively by hospitals. By contrast, no significant change is observed in intermediate outputs (e.g., number of patients, exams and surgeries) of the sample hospitals.

Insert Tables 2 & 3 here

4.2 Operational efficiency

Table 4 summarizes the efficiency results under the five models that focus on the operational efficiency of the hospitals on the basis of their service and case mix. It is evident that the efficiency scores according to model DEA 1, which provides an overall estimate, are higher than the rest of the models. However, this should not be a surprise as this model takes into consideration a larger set of variables (the efficiency scores of DEA generally increase with the number of inputs and outputs). This overall model indicates a minor decrease in efficiency up to 2008 (from 86.9% down to 82.6% under the CRS approach and from 92.6% down to 88.2% under the VRS assumption), with an improvement in 2009. For the rest of the models (which all use the same number of inputs and outputs), the hospitals' efficiency is higher when evaluated under model DEA 3, which focuses on inpatient treatment, whereas the worst results are obtained from the point of view of laboratory examinations (model DEA 4). Efficiency scores obtained with models DEA 2 and 5 are also found to be generally low.

Insert Table 4 here

Our results are in accordance with those reported in past studies on Greek hospitals [3, 13, 16, 19, 26, 31], which have employed data prior to 2005 and also found efficiency scores between 80% and 85%. However, the decomposition and more refined analysis introduced in this study through the examination of models that cover different aspects of the hospitals' medical services, highlights that inpatient treatment is the main strength of Greek hospitals operations, whereas improvements can be sought areas such as laboratory examinations, surgeries, and outpatients' treatment.

It should also be noted that the reforms introduced in 2001, 2003 and 2007 have set as their main objective to improve and modernize the Greek NHS in order to increase productive efficiency as well as to introduce new management structures and prospective reimbursement for public hospitals. However, the results of our study indicate that the expected benefits from these reforms have not in general been materialized.

The ratio between the CRS to the VRS efficiency results provides indications on scale efficiency. An examination of the results shown in Table 4 reveals that the scale effect is stronger for models DEA 2, 4 and 5, where the average scale efficiency ranges between 82-85%, whereas under DEA 3 the average scale efficiency exceeds 89% and under DEA 1 it is higher than 94%. Thus, the scale of the hospitals' operation is particularly relevant for their efficiency as far as it concerns specific aspects of their service and case mix, namely surgeries, laboratory examinations, and outpatients. In that regard, the low CRS and VRS efficiency scores observed earlier in these dimension can be mostly attributed to the scale size effect.

To analyze this issue further, Table 5 provides a detailed breakdown of the efficiency results by the size of the hospitals. The results indicate that the overall CRS efficiency is higher for medium size hospitals, followed by small and large hospitals. However, in terms of their pure VRS technical efficiency, smaller hospitals consistently outperform medium and large-sized ones under all models. Thus, even though medium-sized hospitals operate in the best scale size when evaluated under their global operational efficiency (model DEA 1), a more refined analysis indicates that the scale factor differs when a breakdown is introduced on the service and case mix of the hospitals. In particular, models DEA 2-5 show that the scale effect for the smaller hospitals is stronger as far as it concerns models DEA 2 (case mix-surgeries) and DEA 4 (service mix-laboratory examinations), whereas their efficiency results in terms of outpatients treatment (DEA 5) are much better. On the other hand, larger hospitals perform poorly in terms of outpatients' treatment (model DEA 5) and at the same time the scale effect appears to be strong in this dimension. These results are in accordance with the fact that surgeries and laboratory examinations are more efficiently handled by larger hospitals, which have the necessary technical facilities and staff, whereas inpatients and outpatients are more efficiently handled by medium-sized hospitals. This finding is consistent with results from the existing literature, which indicate that medium hospitals (e.g., 200-300 beds) are generally more efficient than large hospitals [1, 2, 3, 29]. However, our results indicate that this conclusion does depend on specific dimensions of the service and case mix of the hospitals.

The additional results shown in Table 6 reveal that decreasing returns to scale prevail for the majority of large hospitals (except for model DEA 2), whereas increasing returns to scale prevail in the vast majority of small hospitals, under all models. The same applies to medium-sized hospitals, particularly for models DEA 2-4. Given that the inputs used in models DEA 1-5 are involved with the personnel of the hospitals and the available beds, the above results indicate that a different balance in the distribution of these resources could improve the efficiency of the hospitals, if the characteristics of the service and case mix of the hospitals are carefully taken into consideration along the lines of the results discussed above.

Furthermore, examining the time trend of the ratio between hospitals operating in increasing returns to scale and the hospitals operating in decreasing returns to scale, under the overall operational efficiency model DEA 1, indicates that the ratio has decreased from 1.25 in 2005 to about one in 2006 and 2007, but it increased to 1.3 in 2008 with an additional increase in 2009 when it reached 1.5. Thus, it seems that the latest reform of the Greek NHS has failed to address successfully the scale imbalances that affect the operational efficiency of the Greek hospitals.

Table 7 summarizes the efficiency scores of the hospitals, averaged according to the seven regional health administrations (RHAs) in Greece. The hospitals under the control of the 3rd RHA of Macedonia performed almost consistently better than the rest, followed by the 4th district (Thessaly). However, it would be difficult to attribute the differences between the RHAs solely to the policies implemented at the regional level. Indeed, as shown earlier in Table 2, there are significant differences in the size of the hospitals in each region. For instance, the first RHA in Attica mostly comprises of large hospitals, whereas the RHAs in Macedonia (3rd), Thessaly (5th) and Peloponnese (6th) control medium and small-sized hospitals. In that regard, there is no clear evidence on the effects that the policies implemented at the regional level and the characteristics of each region have on the efficiency of the hospitals. This finding confirms the results reported in the recent study of Kounetas and Papathanassopoulos [27] who applied a two-stage bootstrap DEA approach to a sample of 114 Greek public hospitals and found that the location of the hospitals was not a significant factor for explaining the technical and scale efficiency of Greek hospitals. However, a deeper examination at the RHA or prefecture level considering additional data on the socio-economic conditions in each area (see for instance [19]) could possibly lead to a more detailed analysis on how regional differences affect hospital performance.

Insert Table 7 here

4.3 Cost efficiency

As described in section 3.2 three models are used to analyze the cost efficiency of the hospitals. Model DEA 6 considers the total cost (i.e., cost of supplies and payroll), whereas models DEA 7 and 8 provide a decomposition focusing on labor and supplies costs respectively. The results shown in Table 8 show that the overall (CRS) cost efficiency of the hospitals under model DEA 6 ranged between 76% and 78% over the examined time period, whereas the corresponding pure (VRS) cost efficiency ranged between 84% and 86%. The results obtained with the cost efficiency models DEA 6 and 7 are similar with those reported by Mitropoulos et al. [31], who found that the cost efficiency of Greek hospitals in 2005 ranged between 74% and 80% under the CRS and VRS models respectively.

Insert Table 8 here

The results of model DEA 7, which focuses on labor costs, are very similar to ones of the more general model DEA 6. Nevertheless, it is worth noting that even though DEA 7 considers more variables than DEA 6, its efficiency estimates are almost consistently lower compared to DEA 6. This indicates that the distribution of medical and administrative personnel among Greek hospitals is indeed a factor that has affected negatively their cost efficiency. On the other hand, the efficiency estimates under DEA 8 (supplies cost efficiency) are much higher than the two other models, but one should bear in mind that this model uses a larger set of input variables, thus possibly leading to inflated efficiency scores compared to the two other cost models. Finally, the comparison of the CRS and VRS efficiency results indicates that the scales efficiency effect is weaker compared to the operational efficiency results, as in all cost models scale efficiency exceeds 85%.

On the basis of the results obtained on the total cost efficiency of the hospitals (DEA 6-CRS), the estimated average cost reductions (in total operating costs) that could have been achieved over the examined time period reach about 650 million euros annually (an annual reduction of more than 22%). This result also serves as an indicator of the differences in the operating costs of the hospitals due to the prices of the supplies and materials that they use, as well as the absence of clinical protocols in Greek health system that would facilitate the rationalization of costs. Overall, it is worth noting that given the stability of the obtained cost efficiency estimates over the five year period under consideration, one can conclude that there are no indications of effective cost management practices implemented to improve the cost structure of Greek hospitals.

Comparing the cost efficiency results with the efficiency estimates discussed in the previous section on the productive efficiency of the hospitals, reveals that there are noticeable differences. In particular, Table 9 reports the percentage of hospitals found to be cost efficient (under the CRS assumption) that are inefficient in terms of their service and case mix (models DEA 1-5). It is evident that the agreement between the overall operational efficiency model DEA 1 and models DEA 6 (total cost efficiency) and DEA 7 (labor costs) range to about 57%, whereas the similarities are lower (38.2%) among models DEA 1 and 7 (overall operational efficiency vs supplies costs). The comparison of the three cost models to the disaggregated operational models DEA 2-5 shows that the similarities are even lower. Overall, the models DEA 6 and 7 have significant similarities as more than 78% of the hospitals which are efficient in terms of their total costs (DEA 6, CRS) are also efficient in the dimension of labor cost (DEA 7). By comparison this figure drops to 55% when the results of DEA 6 are compared to the supplies cost efficiency classifications obtained through model DEA 8.

Insert Table 9 here

Table 10 presents further details on the cost efficiency estimates by the size of the hospitals. The results indicate that large hospitals achieve higher levels of cost efficiency compared to small and medium-sized hospitals, under the total cost model (DEA 6) and the labor cost model (DEA 7). However, under the supplies' cost model (DEA 8) small hospitals are the top performers, followed by medium-sized hospitals, while large hospitals have the lowest overall CRS efficiency score (on average). Similar conclusions are also drawn in terms of scale efficiency, as under the labor cost model scale efficiency increases with the size of the hospitals, whereas the relationship is reversed under the supplies cost model.

Insert Table 10 here

5. CONCLUSIONS

The present study is the first attempt to assess the overall efficiency of NHS health units in Greece after the implementation of major reforms of the last decade and especially from 2001 to 2007. The analysis was based on a comprehensive set of variables related to the volume and type of services provided by the hospitals, their size, personnel, and costs structure. The consideration of these data was done in a structured framework in which both operational and cost efficiency was analyzed under different input/output specifications.

The empirical results confirm the well-known problems of the Greek health system concerning the over-supply of health services, equipment and human resources, mostly by large hospitals which are located in urban areas. The significant regulatory reforms that have been introduced over the years (three reforms since 2001) have not achieved their goals, as the obtained results do not indicate noticeable efficiency improvements over the examined time period. Even though the aim of the reforms was to encourage hospital administration to manage and control the use of resources in a rational way, considerable inefficiencies still exist.

According to the memorandum signed with the EU and IMF, Greece should implement a number of policy measures related to the health care system, focusing among others on reinforcing and integrating the primary healthcare network, reorganizing the insurance system, and the supply chain system. The program's policies aim at achieving savings in the purchasing (accrual basis) of outpatient medicines of about 1 billion euros in 2012 (compared to 2011) and to reach a total spending of about 2.4 billion euros in 2013 (accrual basis). The plan, which is in force since March 2012, seeks to reduce the existing inefficiencies and improve the quality of health services. Increasing the mobility of staff and the revision of the activities of small hospitals to achieve a high level of specialization are among the main means to achieve the program's goals together with the optimization and balancing of the available resources, and the reduction of administrative and non-medical costs. These major structural reforms should be monitored with new data over the subsequent years to evaluate their effectiveness and their impact on the efficiency of the hospitals.

In implementing such major operational and organizational reforms, it is of outmost importance to have tools that will enable the monitoring and benchmarking of the efficiency of the hospitals under multiple perspectives. The methodology introduced in this study provides a basis for the identification of the input and output variables that should be considered and their aggregation into a multi-dimensional efficiency analysis context.

Future research could extent the results of this study towards a number of directions. Among others these include the optimization of the allocation of resources available to the health care system (materials, personnel, capital), the consideration of the quality of the provided services as perceived by the patients, as well as the analysis and evaluation of specific measures designed at the hospital level. Extending the analysis to cross-country comparisons [39] with other EU countries could also be interesting as many countries share similar difficulties with their NHSs and that would facilitate the design and implementation of best practice guidelines and policies at the EU level.

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Table 1: Model specifications

	INPUTS	OUTPUTS
Operational Efficiency (by service mix / case mix)	*DEA 1: Total operational efficiency*	
	Clinical staff	Inpatients
	Nurses	Surgeries
	Adnimistrative and other staff	Outpatient and emergency visits
	Beds	Laboratory examinations
	DEA 2: Case mix - Surgeries	
	Clinical staff	Minor operations
	Nurses	Major operations
	Adnimistrative and other staff	
	Beds	
	DEA 3: Case mix - Inpatient treatment	
	Clinical staff	Patients in general medicine
	Nurses	Surgical patients
	Adnimistrative and other staff	
	Beds	
	DEA 4: Service mix - Laboratory exams	
	Clinical staff	Microbiological examinations
	Nurses	Radioscopy examinations
	Adnimistrative and other staff	
	Beds	
	DEA 5: Service mix - Outpatient treatment	
	Clinical staff	Outpatient visits
	Nurses	Emergency visits
	Adnimistrative and other staff	
	Beds	
Cost efficiency	*DEA 6: Total cost efficiency*	
	Total operating expenses	Roemer index
	Beds	Surgeries
		Outpatient and emergency visits
		Laboratory examinations
	DEA 7: Labor cost efficiency	
	Medical staff costs	Roemer index
	Other staff costs	Surgeries
	Beds	Outpatient and emergency visits
		Laboratory examinations
	DEA 8 - Supplies cost efficiency	
	Medical supplies costs	Roemer index
	Pharmaceutical costs	Surgeries
	Other medical supplies costs	Outpatient and emergency visits
	Beds	Laboratory examinations

Table 2: Number of hospitals in the sample (by regional health administration and size)

Regional health administrations	Small	Medium	Large	Total
1st of Attica	1	5	10	16
2nd of Piraeus	5	2	4	11
3rd of Macedonia	4	7	2	13
4th of Macedonia - Thrace	1	6	3	10
5th of Thessaly	3	6	0	9
6th of Peloponnese	12	9	1	22
7th of Crete	3	1	2	6
Total	29	36	22	87

Small hospitals: 60-109 beds, medium hospitals: 110-324 beds, large hospitals: at least 325 beds.

Table 3: Descriptive statistics of selected input and output variables

Indicators	2005	2006	2007	2008	2009
Beds					
Mean	249	248	249	250	250
Min.	63	63	63	63	63
Max.	929	949	949	949	952
Doctors					
Mean	171	178	181	185	191
Min.	35	32	37	41	38
Max.	837	831	786	813	823
Nurses					
Mean	294	292	296	294	289
Min.	42	40	52	30	36
Max.	1,023	1,016	995	989	1,003
Administrative and other staff					
Mean	230	226	224	221	221
Min.	30	37	45	43	47
Max.	859	772	763	772	747
Total cost of supplies					
Mean	12,954,385.34	14,150,343.22	16,175,525.11	17,873,645.14	18,559,878.78
Min.	1,321,888.00	1,526,474.00	1,768,618.00	1,973,978.00	1,871,516.00
Max.	78,873,161.00	84,319,540.00	104,363,067.00	118,972,967.00	135,739,661.00
Total operating expenses (labor costs and supplies)					
Mean	29,092,257.65	30,623,573.43	33,134,116.59	35,241,599.76	36,403,770.92
Min.	3,984,614.35	4,227,318.00	4,511,370.00	4,804,728.00	5,087,850.00
Max.	131,271,144.82	135,680,522.00	155,301,973.00	170,945,492.00	189,726,377.00
No. of emergency visits					
Mean	48,259	49,254	48,710	48,679	48,574
Min.	5,032	4,169	3,936	3,623	2,409
Max.	153,812	180,296	163,230	166,086	153,812
No. of outpatients visits					
Mean	57,747	58,698	58,119	57,916	56,496
Min.	188,169	181,976	184,949	181,898	177,398
Max.	12,051	12,853	12,633	14,079	13,015
No. of inpatients					
Mean	15,039	15,165	15,267	15,340	15,183
Min.	1,817	1,888	1,831	1,921	1,733
Max.	52,896	50,277	61,852	70,505	50,989
No. of laboratory examinations					
Mean	1,263,298	1,321,779	1,354,916	1,376,283	1,450,893
Min.	92,683	97,388	95,139	97,905	99,464
Max.	7,148,781	9,792,133	7,903,563	8,354,064	8,619,897
No. of surgeries					
Mean	3,748	3,751	3,906	3,836	3,822
Min.	411	395	412	361	320
Max.	15,983	18,399	28,798	20,470	19,529

Table 4: Operational efficiency statistics (average with coefficient of variation and number of efficient hospitals in parentheses)

	2005		2006		2007		2008		2009	
	CRS	VRS	CRS	VRS	CRS	VRS	CRS	VRS	CRS	VRS
DEA 1: Total operational efficiency	86.9	92.6	86.2	91.8	84.8	90.0	82.6	88.2	87.0	91.4
	(0.14)	(0.11)	(0.15)	(0.12)	(0.16)	(0.13)	(0.17)	(0.14)	(0.16)	(0.12)
	(23)	(42)	(19)	(39)	(20)	(35)	(18)	(32)	(28)	(42)
DEA 2: Surgeries	59.1	75.1	68.8	78.7	52.6	70.2	63.2	74.6	63.5	76.3
	(0.34)	(0.26)	(0.30)	(0.24)	(0.38)	(0.28)	(0.34)	(0.24)	(0.33)	(0.25)
	(6)	(17)	(11)	(22)	(3)	(14)	(7)	(16)	(9)	(17)
DEA 3: Inpatient treatment	76.4	84.0	74.7	83.4	74.6	83.8	72.2	81.1	73.8	85.0
	(0.24)	(0.19)	(0.23)	(0.19)	(0.25)	(0.19)	(0.27)	(0.20)	(0.24)	(0.18)
	(12)	(26)	(14)	(26)	(15)	(27)	(13)	(23)	(8)	(26)
DEA 4: Laboratory exams	61.9	73.4	56.9	69.9	59.4	72.9	59.7	70.5	59.0	70.4
	(0.36)	(0.29)	(0.38)	(0.29)	(0.34)	(0.26)	(0.36)	(0.29)	(0.36)	(0.28)
	(9)	(19)	(7)	(12)	(5)	(14)	(9)	(14)	(7)	(11)
DEA 5: Outpatient treatment	60.5	74.3	64.8	75.4	65.5	76.5	66.3	77.2	65.3	75.4
	(0.36)	(0.32)	(0.34)	(0.31)	(0.33)	(0.29)	(0.33)	(0.27)	(0.34)	(0.29)
	(7)	(19)	(6)	(20)	(7)	(23)	(13)	(26)	(11)	(22)

Table 5: Operational efficiency results by the size of the hospitals (averages over all years)

	CRS efficiency			VRS efficiency			Scale efficiency		
	Small	Medium	Large	Small	Medium	Large	Small	Medium	Large
DEA 1	85.88	86.61	83.13	93.22	89.06	90.51	91.84	97.17	92.05
DEA 2	56.28	64.18	63.86	86.24	70.56	67.36	64.17	90.53	94.53
DEA 3	69.99	78.48	73.22	89.62	81.12	79.11	77.74	96.40	93.02
DEA 4	61.19	56.01	62.51	86.15	62.48	66.71	70.30	88.59	94.25
DEA 5	72.92	67.88	47.80	88.59	73.68	62.26	81.80	91.96	79.40

Table 6: Percentage of hospitals with increasing and decreasing returns to scale (overall average of all years)

Returns to scale	Size	DEA 1	DEA 2	DEA 3	DEA 4	DEA 5
Decreasing	Small	8.3	0.7	0.7	3.4	2.8
	Medium	42.2	15.0	18.9	21.1	41.7
	Large	73.6	41.8	80.9	60.0	83.6
Increasing	Small	76.6	93.8	93.8	91.7	87.6
	Medium	43.3	81.7	71.1	77.8	52.8
	Large	14.5	48.2	12.7	31.8	16.4

Table 7: Operational efficiency results by regional health administration (averages of all years)

	CRS					VRS				
	DEA 1	DEA 2	DEA 3	DEA 4	DEA 5	DEA 1	DEA 2	DEA 3	DEA 4	DEA 5
1st of Attica	80.35	62.65	67.93	58.68	44.73	86.05	67.31	73.17	65.63	55.65
2nd of Piraeus	77.88	53.54	61.98	55.46	65.84	85.79	72.83	76.08	73.68	79.11
3rd of Macedonia	92.00	69.44	88.34	63.97	75.47	95.04	81.70	92.14	74.86	83.88
4th of Macedonia - Thrace	90.65	68.67	82.63	50.95	72.43	95.01	74.05	88.29	62.31	81.90
5th of Thessaly	86.63	62.13	74.48	54.47	63.01	92.47	72.07	84.58	68.40	78.48
6th of Peloponnese	87.91	59.24	76.47	62.71	69.50	91.80	80.09	87.40	74.60	79.98
7th of Crete	79.82	50.71	61.66	67.69	61.46	90.52	71.96	81.22	83.58	75.88

Table 8: Cost efficiency results (annual averages)

	2005		2006		2007		2008		2009	
	CRS	VRS	CRS	VRS	CRS	VRS	CRS	VRS	CRS	VRS
DEA 6: Total Cost Efficiency	76.1	84.5	79.1	86.2	77.5	84.8	78.3	85.1	78.2	85.3
	(0.20)	(0.18)	(0.20)	(0.18)	(0.19)	(0.17)	(0.21)	(0.18)	(0.20)	(0.18)
	(12)	(28)	(15)	(33)	(13)	(28)	(16)	(34)	(14)	(29)
DEA 7: Labor Cost Efficiency	75.6	84.6	78.0	85.4	75.3	83.3	75.5	82.5	76.4	83.1
	(0.21)	(0.18)	(0.22)	(0.18)	(0.21)	(0.18)	(0.23)	(0.19)	(0.22)	(0.18)
	(12)	(27)	(17)	(33)	(15)	(27)	(16)	(22)	(15)	(26)
DEA 8: Supplies Cost efficiency	87.7	93.8	88.6	93.2	89.5	95.1	89.5	93.9	87.7	92.7
	(0.15)	(0.12)	(0.15)	(0.12)	(0.13)	(0.10)	(0.14)	(0.12)	(0.16)	(0.13)
	(34)	(54)	(32)	(53)	(34)	(58)	(37)	(57)	(33)	(54)

Table 9: Percentage of cost efficient hospitals which are operationally efficient (all years)

	DEA 1	DEA 2	DEA 3	DEA 4	DEA 5
DEA 6	57.1	24.3	25.7	21.4	21.4
DEA 7	57.3	22.7	24.0	24.0	20.0
DEA 8	38.2	11.8	18.2	13.5	19.4

Table 10: Cost efficiency results by the size of the hospitals (averages over all years)

	CRS efficiency			VRS efficiency			Scale efficiency		
	Small	Medium	Large	Small	Medium	Large	Small	Medium	Large
DEA 6	77.71	76.79	79.74	86.09	81.70	89.62	89.83	94.27	89.45
DEA 7	74.99	74.67	80.11	85.95	80.61	86.12	86.73	92.80	93.45
DEA 8	93.36	87.65	83.88	96.57	91.04	94.43	96.50	96.36	89.05