Comparison of DEA Models Relating e-Health and Hospital Efficiency

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Abstract. An industry that is under pressure to radically improve its efficiency performance is healthcare. In this paper, we examine the impact of e-health systems upon hospital efficiency. According to our methodology and since e-health has a broad meaning, an e-health system is defined as a set of at least the following practices: (i) the use of a hospital information system, (ii) the use of electronic health records, (iii) the implementation of an e-procurement policy, and, (iv) a human resource development policy for e-health. The literature points out that one of the most appropriate methodologies for assessing the efficiency of healthcare providers is Data Envelopment Analysis (DEA). Implementing two different models, i.e., normal DEA and system differentiated DEA, the results indicate that in both cases the proportion of the efficient hospitals is more than double in favor of the hospitals that use e-health systems.

Keywords: e-health; healthcare, efficiency, performance, normal DEA, system differentiated DEA

1. Introduction

The pursuit of increased efficiency in the healthcare system is a major concern of most developed countries. Certain efficiency measures focus on: a) facilitating access to patients' medical records, b) improving quality of care and reducing poor treatment decisions, c) cost savings, and, d) promoting research. This concern becomes more urgent as the pressures of technological innovation, an aging population and increased public demands and expectations combine to drive up expenses on healthcare still further. Our major focus here is to identify fundamental e-health attributes, proceeding with an empirical analysis on certain efficiency hospital e-health characteristics, applying Data Envelopment Analysis (DEA).

2. Research proposition

Our research focus here is to identify, quantify and evaluate certain e-health efficiency attributes that pertain to hospital organization and healthcare management. We support the view and proceed in its investigation that e-health does provide certain quantifiable efficiency evidence pertaining to hospital healthcare provision. We propose that e-health induces measurable increases in efficiency in certain measurable attributes. We also question whether e-health requires processes of a large initial investment, such that e-health efficiency relates to large scale hospital care. It is a fact that many studies concerning various sectors investigate the relationship between efficiency and business size. Therefore, we ask whether e-health specialized hospital services require a certain hospital size.

3. Methodology

The approaches which have been mostly used to measure healthcare efficiency are DEA and Stochastic Frontier Analysis (SFA). Their main common strength is suitability for multiple inputs and outputs. In contrast with DEA, SFA is a parametric technique that defines the efficient behavior by specifying a stochastic model of output. We selected DEA here, for the following reasons: DEA applies fewer assumptions than SFA concerning outputs' relationship to inputs. DEA also produces relative efficiency measures by comparing the efficiency of an entity to that of its peers, which fits to the purpose of our study.

The appropriate model to evaluate the efficiency of healthcare providers is the VRS model, accounting for Variable Returns to Scale (a proportional increase in all inputs results in an increase of the output, but not at the same proportion). Constant Returns to Scale (CRS) is not a valid assumption in healthcare studies. Doubling, for instance, the number of medical staff and the number of beds, i.e., two of the most significant inputs of a healthcare delivery system, will not certainly result in doubling the satisfaction of the patient.

In our case, two different DEA models have been applied, the normal and the system differentiated model. The second one has been chosen since the DEA results might have been affected by the fact that half of the hospitals examined use e-health systems and the other half do not, meaning that all DMUs considered may not be exactly peers. System differentiated DEA is appropriate when DMUs under examination exhibit systematic differences [1]. Additionally, the adoption of two different models enables comparison of the results and quite possibly provides a stronger support of the conclusions. All DEA computations have been carried out with DEA-Solver v.6.0 [2].

This work focuses on healthcare providers and more specifically public hospitals. The efficiency is defined as the ratio of outputs (services and outcomes of the healthcare system) produced over the inputs (resources) used, assuming constant service quality. It is certain that there is no agreed method of determining whether or not a specific variable should be included (or not) in the model. We followed the general criteria of exclusivity and exhaustiveness for the choice of inputs and outputs in our DEA model, given that official data availability on these e-health issues is most limited. Consequently, we have chosen, among the officially available data, these inputs that capture the most of the accounted resources and, those outputs that capture the most of the accounted outcomes deemed relevant for the particular e-health efficiency analysis, subject to the rule of exclusivity and exhaustiveness [3]. In our case, the numerator of the efficiency ratio is defined by the weighted sum of two variables, which are: (i) the average hospitalization time and (ii) the hospital's revenue from medical expenses and examinations. The average hospitalization time is a key output related to the quality of health services delivered to patients, while the revenue from medical expenses and examinations is a financial outcome which reflects the economic performance of the healthcare system. Correspondingly, the denominator of the efficiency ratio is defined by the weighted sum of three variables, namely: (i) the number of medical staff, (ii) the number of beds and (iii) the operating expenses excluding payroll. The three components of input represent the labor, physical capital and financial resources, respectively. We excluded payroll from the operating expenses, to avoid correlated inputs in our analysis.

A sample of 36 Greek public hospitals, controlled by the government and operating under the National Health System, was used. Each hospital belongs to one of the 16 Regional Medical Administrations [4]. The sample comprises general hospitals only, ensuring in that way the comparability of DMUs. The sample size is satisfactory since the total number of the Greek public hospitals is 132 (that is a percentage of 27.3%). It should also be noted that the small number of DMUs is not a constraint, since DEA produces reliable results using small samples.

The selection procedure of the sample was as follows: three hospitals were randomly selected from each Regional Medical Administration. After taking off the hospitals, for which there were not complete data, an attempt was made to produce a sample equally divided into two groups, the first one consisting of hospitals that use e-health systems for three years at least, and the second of those which do not.

Since, the term "e-health" has a broad meaning, we defined an e-health system of a hospital as a set of at least the following items: (i) the use of a hospital information system, (ii) the use of electronic health records, (iii) the implementation of an e-procurement policy, and, (iv) a human resource development policy for e-health. Only the hospitals that fulfil all the above prerequisites were classified in the first group. The hospitals which have none or fewer than all the above practices were classified in the second group.

We used data from three different sources: (i) Web sites of the sampled hospitals, (ii) annual financial reports published by these hospitals (base year of 2008), and (iii) official reports published by the Greek Ministry of Health and Social Solidarity (base year of 2008). Contacts with the administrative staff of certain hospitals were needed in order to verify the application of the aforementioned specific e-health practices.

4. Results

A summary of normal DEA results is given in Table 1. Fifteen out of 36 hospitals are efficient DMUs. Efficient DMU is the one which has an efficiency score equal to unity (this is referred to as "technical efficiency"), without input excesses and output shortages (in fact, these inefficiencies are referred to as "mix inefficiencies"). Both conditions must be satisfied, so that efficiency of a DMU is attained. The percentage of efficient DMUs (41.7%) seems to be high. Nevertheless, we mention that the DEA method provides only relative measures. The average efficiency score is 0.8523 and the standard deviation 0.1852.

Table 2 presents a summary of system differentiated DEA results, which exhibit slight differences compared to normal DEA results. Now the number of efficient DMUs is 17, increased by 2, in comparison to normal DEA model. The average efficiency score is slightly higher (0.8644), while the standard deviation is almost identical (0.1825). Analyzing the results by group, the number of efficient e-health users has increased by 1 (12), as exactly the number of efficient non-users (5); the proportion of efficient users to efficient non-users remains over doubled. The average efficiency score is 0.9109 for the users, and 0.818 for the non-users; both slightly higher compared to normal DEA results.

5. Comparison of the results of the two DEA models

Two different DEA models were used to evaluate the impact of e-health practices on hospital efficiency, i.e., normal DEA assuming VRS and system differentiated DEA. The latter model was used to consider possible systematic differences between the two discrete groups of hospitals, i.e., e-health users and non-users. Only few differences arise by comparing the results of the two models. The number of efficient DMUs is slightly higher in system differentiated DEA, as well as the average efficiency score. The proportion of efficient e-health users to efficient non-users is over doubled in both models (11:4 in normal DEA and 12:5 in system differentiated DEA); hence, the conclusion regarding the impact of e-health on hospital efficiency would be the same either using the one or the other model.

6. Relationship between efficiency and hospital size

In order to investigate whether efficiency is related to the hospital size, the Pearson correlation coefficient was calculated. In this study, the hospital size is determined by the number of medical staff and the number of beds. The results regarding the correlations of efficiency to (i) the number of medical staff and (ii) the number of beds are presented in Table 3. The results show a negative relationship between efficiency and the two hospital size-specific determinants at the 0.01 level of significance.

7. Discussion

The current case study of the Greek National Health System reveals significant e-health results, thus adding to the scarce relevant literature that supports e-health based hospital efficiency outcomes and investments. We provide empirical evidence that e-health contributes to public hospitals' efficiency increase. This evidence is in line with the literature findings, indicating that certain attributes of an e-health system could be enablers for increased efficiency. However, there is no precise definition of an e-health system, nor the components of an e-health system are strictly defined. In this study, we suggest the following items as fundamental attributes of a hospital's e-health system: (i) the use of a hospital information system, (ii) the use of electronic health records, (iii) the implementation of an e-procurement policy, and, (iv) a human resource development policy for e-health. On the basis of these available but certainly crucial e-health attributes, we provide findings that the proportion of the efficient hospitals is more than double, in favor of the hospitals that use these certain e-health systems. We also conclude that hospital size, in terms of medical staff and number of beds, relates negatively to efficiency scores. Despite its minimal significance level, the latter statistical result might be indicative of certain e-health attributes that require further specialized research.

References

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Appendix

	Number of medical staff	Number of beds	Operating expenses excluding payroll	Average hospitalisation time	Revenue from medical expenses and examinations
Max	385	1100	7972.51	11.8	42584.28
Min	57	120	719.16	3.6	2832.84
Average	147.11	450.22	2498.8	7.47	13258.26
SD	90.31	272.73	1854.55	2.2	10281.53
No. of DMUs in Data:	36				
No. of efficient DMUs:	15				
No. of inefficient DMUs:	21				
Average of scores:	0.8523				
Standard Deviation of scores:	0.1852				
Total number of simplex iterations:	702				

Table 1: Summary of normal DEA results

Total Statistics	
No. of DMUs in Data:	36
No. of efficient DMUs	17
No. of inefficient DMUs	19
Average of scores	0.8644
Standard Deviation of scores	0.1825
Total number of simplex iterations	440
Statistics by System or Group	
Group 1: e-health users	
No. of DMUs	18
No. of efficient DMUs	12
No. of inefficient DMUs	6
Average	0.9109
Standard Deviation	0.1539
Group 2: e-health non-users	
No. of DMUs	18
No. of efficient DMUs	5
No. of inefficient DMUs	13
Average	0.818
Standard Deviation	0.1965

Table 2: Summary of system differentiated DEA results

		No. of medical staff	No. of beds
Efficiency (normal DEA)	Pearson Correlation	-.506*	-.547*
	Sig. (2-tailed)	.002	.001
	N	36	36
Efficiency (system differentiated DEA)	Pearson Correlation	-.531*	-.581*
	Sig. (2-tailed)	.001	.000
	N	36	36

* Correlation is significant at the 0.01 level

Table 3: Correlation results