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Does the adoption of new technology boost productive efficiency in the public sector? The case of ICUs system

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ABSTRACT

In the last decade, a significant amount of financial resources has been devoted by the Greek Government and the European Union to provide the intensive care units (ICU) of the Greek Public Health Care System with high-tech medical equipment in order to improve their productive efficiency. Using a unique data set, we employ the DEA bootstrap of Simar and Wilson (2007) approach to estimate the efficiency of each ICU and to explore the impact of these investments on their efficiency. Our results indicate that, although the technical efficiency is benefited from the embodiment of new medical technology, the scale efficiency remains unaffected. The role of the asymmetric information, of the ICUs' proximity to pools of knowledge and of the composition of the medical personnel, seems to be the crucial factors for the improvement of their productive efficiency.

1. Introduction

Intensive care medicine focuses on the diagnosis and treatment of patients whose life is at a critical stage. Intensive care units (ICUs) were therefore organized with the assumption that critically ill patients require constant attention and often quick responsive action, both of which depend on high technology life support systems and skilled personnel. In order to achieve this, the best option was to keep all critically ill patients together in one ward, close to the most sophisticated equipment and the best qualified staff rather than disperse them in the various wards of the hospital. According to the Universal Medical Device Nomenclature System (UMDNS), the most frequently used equipment in an ICU are infusion pumps, physiologic monitoring systems, ventilators, pumps, eternal feeding, oximeters, pulse defibrillators, sphygmomanometers, electronic electrocardiographs and aspirators blood gas/pH analysers.

In the last few years the care of critically ill patients in Greece and intensive care units in particular have become the focus of public health economics, which attribute a large proportion of the increase in health expenditure on their operation and maintenance (ECRI, 2000). As a consequence, the Greek Government exerts pressure on these units to increase their efficiency (Greek Ministry of Health, 2000). A thorough literature review concerning alternative approaches for ICU performance measurement is presented by Dey et al. (2006) and Dervaux et al. (2009).

Over the last two decades an excessive demand for ICU services has become noticeable in the Greek Healthcare System, accompanied by public investment aiming to supply ICUs with modern medical equipment. Financial resources were drawn from the second and third European Union Support Frameworks. More specifically, in the context of measure 1.2. "*Operational modernization of Hospitals*", of the third European Support Framework, efforts were made for the replacement and upgrading of medical equipment and especially upgrading with high-tech equipment for special health units, like the intensive care and increased care units (Greek Ministry of Health, 2000). The total funds spent under the abovementioned measure were 103.08 M Euros, from which 44.23 M Euros came from the European Social Fund, 25.95 M Euros from the European Regional Development Fund and 33.62 M Euros from the Greek National Resources, and more specifically from the Greek Government's Public Investment Budget. One of the benefits that were expected from these investments was to reduce the excess demand for ICU services, through the improvement of the ICUs' productive efficiency (Greek Ministry of Health, 2000).

Researchers (Sissouras et al., 1994; Athanassopoulos et al., 1999; Athanassopoulos and Gounaris, 2001) have argued that the cause of the demand–supply deficit should be explored in the direction of the spatial distribution of ICUs in Greece. More specifically, they argue that (i) the spatial distribution of ICUs does not correspond to the spatial distribution of the demand for ICU services (the abovementioned researchers claim that for consumers not residents of the large Greek cities

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(Athens, Thessaloniki and Patras), the opportunity cost which is associated to the consumer's decision to "buy" medical care from a peripheral ICU exceeds the corresponding transportation cost) and (ii) that there exist significant differences in the marginal utilities that the consumers attain from the services of a centrally located ICU in comparison to an ICU that is located peripherally. However, the Greek Administration has explicitly adopted and carried out mainly through policy priorities and interventions, the productive efficiency approach, and a significant amount of financial resources has been allocated to the technological modernization of the ICU system.

In light of the above, the main objective of the present paper is to determine the impact of new medical technology on the production efficiency of intensive care units (ICUs) in Greece, and as a consequence, on the reduction of the excess demand for the ICUs' produced services. Furthermore, we investigate the ICUs' spatial distribution, age, institutional and organizational (human capital, internal structure) characteristics that may be associated with inefficiency in the use of resources. In doing so, we are able to provide an efficiency ranking, as well as the set of determinants that affect both technical and scale efficiency of the ICU system in Greece, focusing on the role of medical technology. The above information may prove to be valuable for healthcare systems' policy makers.

The paper is organized as follows: In the second section, we present the basic methodological approach used in this study; that is bootstrapped data envelopment analysis (DEA). In the third section, we briefly present the data used as well as the survey procedure we have undertaken. Fourth section includes the estimation results, further empirical elaboration and the discussion of the study's findings. Finally, the fifth section concludes the paper.

2. Theoretical underpinnings and modelling issues

2.1. The notion of ICU efficiency

The operation of hospitals is currently determined by continuous investments on new technology, by increased expenditure on medical supplies and by an increased demand for quality services. This gives rise to debates concerning the inevitable tradeoffs between objectives of efficiency and equity. Equity may be affected indirectly by the way resources are allocated in the Public Health sector and in particular through the increase of the ICUs' system capacity. Thus, the achievement of the desired goal, behind the adoption of new technologies by ICUs, becomes an empirical issue. The present study examines whether the adoption of new technology has indeed resulted in improvement of the productive efficiency in Greek Hospitals and their ICUs. The advances in the theory and applications of economics and management science, mainly in the last two decades, enable us to address this question.

The initial objective of this is to determine the relative efficiency of each of the ICUs examined. Efficiency is a multifaceted phenomenon. From an output point of view, an ICU may be characterised efficient, if it produces the optimal quantities of output in a certain technological environment and at given input quantities. From an input point of view, an ICU may be characterised efficient, if it produces a given level of output in a certain technological environment using an optimal quantity of inputs. Efficiency is measured by the ratio of outputs to inputs. In the case of a single output—multiple inputs, which is the case in this study, the appropriate efficiency index is that of the weighted outputs divided by summed weighted inputs (Färe et al., 1994). In a theoretical framework, measuring efficiency presupposes the existence of a production hyperplane (envelope or frontier) that reflects the maximum possible output quantities that may be produced by several input quantities. This boundary actually correlates aggregate input quantities to aggregate output quantities in technological terms (Seiford and Thrall, 1990). The facets of the hyperplane define the efficiency frontier and the degree of inefficiency is quantified and partitioned by a series of metrics that measure various distances from the hyperplane and its facets (Leibstein and Maital, 1992).

The formulation of such a theoretical framework allows us to consider efficiency in two perspectives: technical and scale efficiency. Technical efficiency (*TE*) is the distance from the point of the ICUs' current input–output combination to the boundary. In practice, an ICU's technical efficiency score shows the deviation of this ICU's productive performance from the best performers in the sample. This deviation is usually assigned to either differential firm management capabilities or to the external environment in which firms operate. On the other hand, an ICU's scale efficiency(*SE*), given its technical efficiency level, depicts the extent to which an ICU exploits scale economies, i.e. it shows the distance between the ICU's current position and the constant returns to scale area or the so-called ICU's minimum efficient size by Tsekouras et al. (2009).

In the relevant literature, there are two distinct approaches in estimating technical and scale efficiency. In fact, there are additional approaches including the conventional growth accounting approach and the index number approach. These are not considered because they implicitly assume productive efficiency for each time period and hence provide no insight into the issue of interest (Färe et al., 1985). Going back in our approaches, the first is widely known as the stochastic frontier (SF) and the second as the data envelopment analysis (DEA). The main difference between these two methodological approaches is that the SF, since parametric, allows the coexistence of inefficiencies and random errors, while the DEA, since non-parametric attributes the total deviation from the frontier to inefficiency. The main advantages and disadvantages of the stochastic frontier and DEA approaches are discussed analytically by Coelli et al. (2005). In our case, the main reason leading to the adoption of DEA in estimating the Greek ICUs' production frontier is the number of observations at our disposal. A stochastic frontier approach, as an econometric method, is data demanding, while DEA, as a linear programming methodology, does not require those prerequisites. Of course, DEA application requires the precondition that the white noise involved in the estimation of the stochastic frontier is small, i.e. that the ratio of inefficiency to the total deviation from the frontier is adequately high. However, in order to account for such DEA limitations, among others, we used the corresponding bootstrapping version introduced and further developed by Simar and Wilson (1998, 1999, 2000, 2007). More specifically, the bootstrapped DEA enables us to retrieve statistical properties of efficiency estimates, while producing standard errors and confidence intervals for them. In addition, it is worth mentioning that regarding the case examined in this paper at hand, results of an estimated stochastic production frontier a la Battese and Coelli (1992) yielded a ratio of the variance of inefficiency to the sum of the variances of inefficiency and white noise equal to 0.819 and statistically different from zero.

2.2. The efficiency of ICUs: a bootstrapped DEA approach

DEA follows a linear programming methodology to construct a non-parametric frontier over the data, and this frontier can then be used as basis to calculate the efficiency measure of the different ICUs. Let us consider a sample of i ICUs which uses N