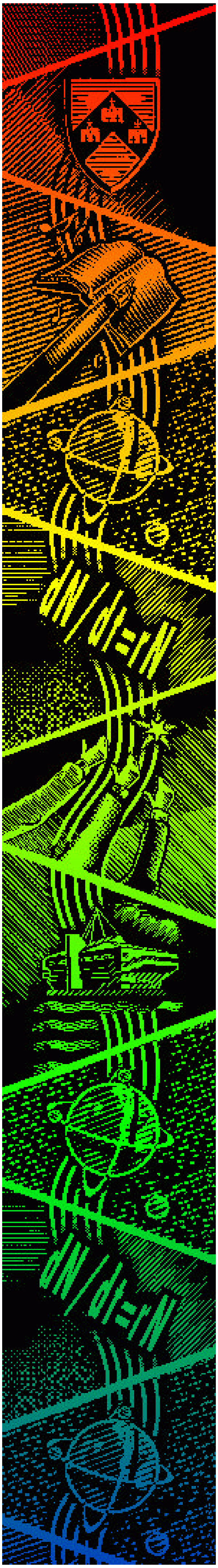

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Has DRG Payment Influenced the Technical Efficiency and Productivity of Diagnostic Technologies in Portuguese Public hospitals? An Empirical Analysis using Parametric and Non-Parametric Methods

by

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Running Title:
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ABSTRACT

The use of Diagnostic Related Groups (DRG) as a mechanism for hospital financing is a currently debated topic in Portugal. The DRG system was scheduled to be initiated by the Health Ministry of Portugal on January 1, 1990 as an instrument for the allocation of public hospital budgets funded by the National Health Service (NHS), and as a method of payment for other third party payers (ex. Public Employees (ADSE), private insurers, etc.). Based on experience from other countries such as the United States, it was expected that implementation of this system would result in more efficient hospital resource utilisation and a more equitable distribution of hospital budgets. However, in order to minimise the potentially adverse financial impact on hospitals, the Portuguese Health Ministry decided to gradually phase in the use of the DRG system for budget allocation by using blended hospital-specific and national DRG case-mix rates. Since implementation in 1990, the percentage of each hospital's budget based on hospital specific costs was to decrease, while the percentage based on DRG case-mix was to increase. This was scheduled to continue until 1995 when the plan called for allocating yearly budgets on a 50% national and 50% hospital-specific cost basis. While all other non- NHS third party payers are currently paying based on DRGs, the adoption of DRG case-mix as a National Health Service budget setting tool has been slower than anticipated. There is now some argument in both the political and academic communities as to the appropriateness of DRGs as a budget setting criterion as well as to their impact on hospital efficiency in Portugal. This paper uses a two-stage procedure to assess the impact of actual DRG payment on the productivity (through its components, i.e. technological change and technical efficiency change) of diagnostic technology in Portuguese hospitals during the years 1992-1994, using both parametric and non-parametric frontier models. We find evidence that the DRG payment system does appear to have had a positive impact on productivity and technical efficiency of some commonly employed diagnostic technologies in Portugal during this time span.

I. INTRODUCTION

The use of Diagnosis Related Groups (DRG) as a mechanism for hospital financing is a currently debated topic among both practitioners and academicians in many countries. The DRG patient classification system was first developed by Fetter as an instrument to group inpatients according to the diagnosis and resource use in order to facilitate utilisation review activities[1] [Fetter, 1991]. Afterwards, it was used by the US federal government to fix prices paid by Medicare for hospital inpatient care where the reimbursement rate per case was set prospectively for each DRG category according to the average cost for that DRG. The introduction of such reimbursement policy was justified on the basis that payment reductions would be matched by lower levels of spending through reduced lengths of stay, reduced intensity of care and therefore more efficient hospital production.

Based on the US experience, several western countries initiated the incorporation of the DRG system as a budget financing criterion into the national hospital financing system[2]. In Europe, Portugal was the first country to implement the DRG system at a national level in the context of a budgeting system for public inpatient hospital care [Bentes et al., 1996]. The DRG system was scheduled to be initiated by the Health Ministry of Portugal on January 1, 1990 as an instrument for the allocation of public hospital budgets funded by the National Health Service (NHS), and as a method of payment for other third party payers (ex. Public Employees (ADSE), private insurers, etc.). The adoption of the DRG system marked the transition from a system based on retrospective reimbursement to a new financing system centred on prospective payment where the reimbursement rate per case is set prospectively for each DRG category, according to the average cost for that DRG. It was expected that implementation of this system would result in more efficient resource utilisation and a more equitable distribution of hospital budgets. However, in

[1] According to Fetter, the first function of a hospital is to convert raw materials such as labour, supplies and equipment into intermediate products such as diagnostic procedures, surgeries, etc. The second and major function of the hospital is to receive human beings who have a problem and supply physicians and other health professions with the intermediate products deemed necessary for their evaluation and treatment. It is this bundle of goods and services that comprise the final output of the hospital which can then be classified into DRGs.

[2] These include Australia, France, Italy, Norway and so on. For a survey of each country experience, see the conference proceedings of the Eight Conference-Casemix and Change; international Perspectives, 16-18 September 1996, Sidney, Australia.

order to minimise the potentially adverse financial impact on hospitals, the Portuguese Health Ministry decided to gradually phase in the use of the DRG system for budget allocation by using blended hospital-specific and DRG case-mix national rates. Since implementation in 1990, the percentage of each hospital's budget based on hospital specific costs was to decrease, while the percentage based on DRG case-mix was to increase. While all other non-NHS third party payers are currently paying based on DRGs, the adoption of DRG case-mix as a National Health Service budget setting tool has been slower than anticipated. There has also been some arguments in both the political and academic communities as to the appropriateness of DRGs as a budget setting criterion as well as to their impact on hospital resource allocation in Portugal [Costa 1994].

This latter issue has been the object of recent investigation. Dismuke [1995] has found evidence that unadjusted length of stay in Portuguese hospitals declined for some of the most frequently occurring DRGs since the system was implemented. Further, Dismuke [1996] has shown that Portuguese hospitals have started to change the intensity of care devoted to each admission. These works appear to provide evidence that Portuguese hospital administrators are reacting to the new financing system. However, whether such reallocation of resources has meant an improved efficiency in producing hospital services is still an open issue. Therefore, in this paper we assess to what extent the introduction of actual DRG payment has had a positive impact on the productivity growth (and its components, i.e. technological change and technical efficiency change) of three diagnostic technologies commonly used in Portuguese public hospitals: Computerised Axial Tomography Scanner (CAT), Electrocardiogram (EEG) and the Echocardiogram (ECO) in the two principal groups of hospitals, district and central hospitals. We limit our study to these three technologies since they are the most commonly used in diagnosing the patients which comprise the two DRGs of interest[3]. More specifically, we measure to what extent the changes in the utilisation of these diagnostic technologies can be attributed to an increase in efficiency and productivity[4] in the use of these diagnostic tools and

[3] However, we do not have data which allow us to quantify how much money is spent on these three interventions.

[4] In this paper, productivity and total factor productivity will be used interchangeably.

whether these changes in efficiency and productivity can be attributed to the new reimbursement system.

To measure the change in technical efficiency and productivity, we employ frontier analysis where technical efficiency is measured as the deviation of the productive unit from a idealised frontier isoquant computed for the whole industry [Farrell, 1957]. The frontier literature is usually divided into two groups according to the methodology used to construct the reference technology [Lovell et al., 1993]. It is customary to distinguish between parametric methods (including the deterministic approach of Aigner and Chu [1968] and the stochastic one of Aigner, Lovell and Schmidt [1977]) and the non-parametric methods such as Data Envelopment Analysis (DEA, henceforth) described in Charnes, Cooper and Rhodes [1978]. The merits of the alternative approaches are often listed as being that the stochastic parametric approach can account for noise and allow conventional hypothesis tests to be conducted, while the non-parametric approach has the advantage of not requiring the arbitrary selection of a functional form for the production structure and distributional forms for the error terms. However, the absence of a stochastic specification has always been regarded as one of the major shortcomings of the technique. Both methodologies are usefully employed to measure and explain the determinants of both technical efficiency and total factor productivity growth in several industries[5] and in health care it is now a fashionable tool to measure the performance of health care institutions[6].

In this paper, the empirical analysis is undertaken using a two-stage procedure, as in Lovell [1993]. In the first stage, measures of the Total Factor Productivity Growth (TFPG) and its components (technological change and technical efficiency change) are derived using both parametric and non-parametric methods. Specifically, in the former case, technical efficiency change and technological change are derived by estimating the input requirement frontiers for the three technologies with stochastic methods, as suggested by Fecher and Pestieu [1993].[7] Subsequently, measures of

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[5]Among others, see Bauer et al. (1993) for an application to the US banking industry; Forsund (1993) for an analysis of total factor productivity in Norwegian Ferries; Price and Weyman-Jones (1996) for a study of productivity in UK gas industry (before and after privatisation) using the Malmquist indices.

[6] See Zukerman et al 1994; Vitaliano and Toren 1994; Kooreman; 1994; Magnussen 1996; Luoma *et al* 1996; Chattopadhyay and Ray 1996, Sena 1998.

[7] Parametric stochastic methods to the measurement of productivity growth have been employed by Fecher and Pestieu (1993) to measure productivity growth within the OECD financial services.

TFPG are derived by summing the technical efficiency change and technological change. In the latter case, Total Factor Productivity Growth and its components are measured by computing a Malmquist index, following the work by Fare, et al. [1992]. Both parametric and non-parametric techniques are used to test the robustness of the derived performance indicators and to get a better insight into the individual hospital's performance. The relationship between TFPG and DRG payment is analysed in the second stage. After controlling for variables which may effect technology usage (e.g. hospital characteristics), the TFPG indices are regressed on an index designed to capture the effects of DRG payment on hospital production.

The empirical analysis produces two key results. First, after the introduction of the DRG system, all Portuguese hospitals experience an increase in technical efficiency for the CAT while technical efficiency decreases for the ECO in district hospitals and it increases in central hospitals. Finally technical efficiency is decreasing for the EEG in district hospitals while it is stable in central hospitals. These findings about CAT and ECO are plausible as Portuguese central hospitals were probably using these technologies inefficiently before the introduction of the DRG system and therefore, after the short in available financial resources, large volumes of slack were used up (that is, unproductive resources reallocated, unnecessary ancillaries and days eliminated and so on) [Dismuke 1996]. Second, we find evidence that DRG payment has had a positive impact on the total factor productivity growth of the three technologies. Of course, these results must be taken with due caution as the empirical analysis has involved only three diagnostic technologies and not the whole hospital. However, they provide some initial evidence that the reform of the hospital financing system is producing the desired results in terms of improved efficiency and productivity of hospital services.

The structure of the paper is as follows. Section 2 consists of a theoretical consideration of the implications of DRG payment for hospital resource usage with an emphasis on the peculiarity of the Portuguese public hospital system. Section 3 contains a description of the methodology and data employed in the estimation. Section 4 highlights the empirical results while some conclusions are provided in Section 5.

2. BACKGROUND

The main objectives of the introduction of the DRG system as a hospital budget setting tool are two: to reduce the rate of increase in inpatient payments and to decrease overall hospital cost inflation. The expectation is that in order to attain these two results, hospital administrators will reduce unnecessary prolonged lengths of stay and economise utilisation of procedures and therefore practice more cost effectively.

The implications of the DRG prospective payment system for U.S. hospital resource utilisation are well documented in the literature [Coulam and Gaumer 1991; Gilman 1997]. A recent study suggests that there are two separate effects: selection and moral hazard [Ellis and McGuire 1996]. The selection effect stems from hospitals altering the average severity of admissions in response to changes in payment structure. The moral hazard effect results from hospitals reacting to payment structure alterations by changing the level of services per discharge for a given admission severity. This latter effect can be separated into two types of incentives: marginal payment and average reimbursement. Hospitals may lower the intensity of services per patient in order to either avoid covering a larger share of costs (marginal payment incentive) or to discourage the admission of unprofitable patients (average reimbursement incentive) [Hodgkin and McGuire 1994]. Evidence of all three effects have been found for US hospitals. Several authors claim that the severity-adjusted average length of stay fell (moral hazard effect) for US hospitals after introduction of prospective payment. Concurrently, the average admission severity at higher paid hospitals rose while the average admission severity at lower paid hospitals fell (selection effect). Furthermore, it was also discovered that the decline in resource utilisation for more severely ill patients was greater than that for those who were less severely ill (moral hazard average reimbursement effect) [Guterman and Dobson 1986; Rosko and Broyles 1987; Sloan et al. 1988; Ellis and McGuire 1996]. Through these various effects, Medicare appears to have been able to control the growth of inpatient hospital costs without increasing costs to beneficiaries as well as to increase the productivity of hospital services [Coulam and Gaumer 1991].

The type of behavioural response to the new financing incentives which could be expected of Portuguese hospitals administrators is not very clear. The selection effect is highly improbable for the Portuguese case since this type of response, while possible for U.S. hospitals, would be difficult for Portuguese public hospitals whose catchment area is defined by the Health Ministry. Portuguese public hospitals are obligated to accept all patients from their catchment area for which they are capable and equipped to treat. Consequently, admission severity is exogenously determined for the Portuguese public hospital. Similarly, the moral hazard average payment effect is unlikely for the Portuguese case. Portuguese citizens are required to seek care at the public hospital whose catchment area covers their residence. The only exceptions are individuals who are insured by other forms of social insurance or private insurance who may seek care in private clinics for certain planned procedures or obstetrics. However, this would be exactly the type of individual that the public hospital would wish to attract in order to acquire extra revenue. Hence, the type of individual the hospital may wish to discourage as a result of the moral hazard average reimbursement effect is obligated by law to seek care in that same hospital. Portuguese public hospitals could however respond to the marginal payment effect by altering resource utilisation intensity. As mentioned in the introduction to the paper, Dismuke [1995, 1996] finds that Portuguese hospitals are starting to react to the new financing system by altering the intensity of care. However, no previous analysis has been conducted to test whether such changes have meant an increase in efficiency of Portuguese hospital production. We attempt in this study to assess to what extent the utilisation intensity of some commonly used diagnostic technologies in Portuguese public hospitals has been affected by the DRG system and whether the changes are desirable. More specifically, has DRG payment had a positive impact on the efficiency and productivity of these diagnostic tools?

3. DATA, VARIABLES AND THE EMPIRICAL METHODOLOGY

The initial data used in this analysis consist of all adult public hospital discharge abstracts for the two most frequent DRGs during the years 1992-1994: DRG 14-Specific Cerebrovascular Disorders Except Transient Ischemic Attack and DRG 127- Heart Failure and Shock. They amount to 48122 discharges for DRG 14 and to

29021 for DRG 127 during the 1992-1994 time period. The data were provided by the Instituto de Gestão Informática e Financeira da Saúde, the institute responsible for collecting and managing health care financing information in the Portuguese Health Ministry. The hospital inpatient discharge abstracts contain a wealth of information regarding patient age and sex, primary and secondary diagnostic codes (ICD-CM-9), primary and secondary procedure codes, discharge status, intensive care utilisation and length of stay. A coded hospital identifier is used to match hospital characteristics with discharge records.

In constructing the data set used in the empirical analysis, we have first omitted observations for six hospitals which had fewer than 10 discharges as well as those for which information was missing on relevant variables such as patient age. Patients younger than 18 years have also been omitted since children are believed to have different utilisation patterns than adults. Finally, in order to eliminate the effects of extreme outliers, discharges for which length of stay were higher than 65 days were omitted.

The remaining discharges were then aggregated per hospital type. Hospitals in Portugal are classified as central, district and level one depending on the number of specialities which the hospital is equipped to treat. Since level one hospitals, those with the fewest number of specialities, are rarely equipped with technology such as the Computerised Axial Tomography Scanner (CAT), we only consider discharges from central and district hospitals where such technology is available. Of these, 36 hospitals are considered to be district and 16 central of which 6 are teaching hospitals. The final sample thus consists of 37,232 discharges in DRG 14 and 24, 904 discharges in DRG 127 during the 1992-1994 time period. These restrictions resulted in the deletion of approximately 30% of discharges from the original data set.

The proper measures of hospital inputs and outputs are not uniformly agreed upon. The output of the hospital productive process is difficult to define. Output is often measured by the number of patient days or the number of patients, weighted by DRG weights, as well as the number of external visits [Magnussen 1996]. This measure of output has been often criticised as it does not allow the distinction between inefficiency of output use and higher quality production [Newhouse 1994]. Indeed, an increase in the quality of care would require more inputs for a given volume of output produced, which might be considered as inefficient if differences in quality are not considered when hospital output is measured. We attempt to address these concerns about differences in quality by dividing output into two different types: desirable as measured by the number of alive discharges and undesirable as the number of dead discharges[8]. Indeed, diagnostic technologies are used to encounter a more accurate diagnosis, aiding in the establishment of a more effective treatment which will hopefully result in a positive outcome for the patient. However, deaths do occur due to circumstances beyond the control of the physician as well as failures in diagnoses and treatments. Improvements in utilisation of diagnostic technologies should reduce the undesirable output and these differences in the ability of using technologies should be taken into account when measuring technical efficiency and productivity growth. The distinction between alive and dead discharges permits the analysis of whether the variation in efficiency and productivity can be attributed to an effort of hospitals' administrators to shift the output mix in favour of the desirable output. In this sense, an increase in desirable output is regarded positively even if it has implied an increase in input usage, for a given total number of discharges[9,10].

As for input measures, in this study we concentrate on diagnostic technology utilisation and in particular on three specific technological inputs: the Computerised Axial Tomography Scanner (CAT), the Electrocardiogram (EEG) and the Echocardiogram (ECO) in the production of discharges from two of the most frequent non-obstetric DRGs in Portuguese public hospitals: DRG 14 (Cerebrovascular Disorders Except Transient Ischemic Attack) and DRG 127 (Heart Failure and Shock). Therefore we measure inputs as the number of CAT scans for DRG 14, the number of Electrocardiagrams and the number of Echocardiagrams (considered separately) for DRG 127, used in producing alive and dead discharges.

To estimate the impact of the DRG payment on TFPG of each diagnostic technology, we use the two-stage approach suggested by Lovell et al. [1993]. In the first stage, we derive measures of productivity for the three technologies using both parametric and non-parametric methods. Therefore, employing parametric methods,

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8 Patients who were transferred are excluded from the analysis as we consider them to be incomplete outputs whose outcome is uncertain.

9 Notice that we do not consider in this case the impact of clinical appropriateness of the use of diagnostic technologies on the output mix.

10 There are strong arguments that mortality may not be the best measure of quality but it is certainly one of the most commonly used and an important indicator for Portuguese hospitals [Dismuke and Guimarães, 1997; Tomal, 1998].

we first estimate separate input requirement frontiers for the three technologies and, using the procedure suggested by Battese and Coelli [1992], we derive the time-varying technical efficiency scores which are then used to measure technical efficiency change over time. Also we include a time trend in the three frontiers to check whether technological change has occured shifting the three frontiers over time. In this way, it is possible to distinguish between variation in technical change from changes in technical efficiency. The TFPG is then measured as the sum of the technical efficiency change index (given by the change of the technical efficiency scores) and the estimate of the technological change. Notice that technical change is measured at the frontier level; that is, it measures the technical change that the best operating productive units experience over time and it is assumed that it is common to all the decision making units. Therefore, this measure of technical change does not give insights of whether a productive unit (not on the frontier) has actually experienced technical change. The same is true for TFPG. Indeed the TFPG obtained from parametric methods measures the change in productivity experienced by the productive units, assuming that the technical change is common to all of them; therefore it does not give information on the actual productivity growth experienced by the single productive unit. To get firm-specific measures of technical change and TFPG, we then apply non-parametric methods (namely the Data Envelopment Analysis, DEA) to measure TFPG and its components over time using the Malmquist index [Fare et al., 1992].

The relationship between the TFPG and the DRG payment is analysed in the second stage. After controlling for variables which may affect technology usage (e.g. hospital characteristics), the measures of TFPG are regressed on an index designed to capture the effects of DRG payment on hospital production.

4. RESULTS

Utilisation rates for the three diagnostic technology inputs are shown in Table 1 for both district and central hospitals. It is evident that CAT utilisation has increased for both types of hospitals and though central hospitals have a much higher utilisation rate, the gap is diminishing over time. It is interesting that the EEG, a much less expensive technology is used similarly in both types of hospitals and at a much lower rate than the CAT. The use of ECO increases over time for the district hospitals, while it decreases steadily in central hospitals.

(Insert Table 1 here)

In the next sub-paragraphs, we present the measures of technical efficiency, technical change and productivity growth for the three technologies resulting from both parametric and non parametric methods.

4.1 *Parametric measures of Total Factor Productivity Growth*

The maximum likelihood estimates of the input requirement frontiers for the three technologies are shown in Tables 2-4 for both types of hospitals, with separate output measures for alive and dead discharges. We also include a time trend to capture the technological change over the three years. In addition to the parameter estimates, each table contains the total variance of the residuals (σ^2), the sum of the variance of the two components of the residual term, and the parameter (γ), which measures the weight of the variance of the technical efficiency term divided by the total variance of the residuals [Coelli 1996]. These statistics show that the inefficiency component is the most important one in the total residual term. Tables 2-4 also indicate that the parameters on the output and trend variables are significant for all three technologies.

(Insert Table 2 here)

The parameter estimates in Table 2 indicate that central hospitals have a greater utilisation of the Computerised Axial Tomography Scanner (CAT) in the production of desirable output than do district hospitals. Moreover, central hospitals use more CAT resources to produce desirable than undesirable output. This seems reasonable since hospitals would theoretically increase Computerised Axial Tomography Scan (CAT) utilisation in order to decrease undesirable output. However, the coefficient on the time trend variable indicates that district hospitals have had a more rapid increase in utilisation of this input over time than their central counterparts.

(Insert Table 3 here)

The coefficients contained in table 3 demonstrate another pattern for Electrocardiograms (EEG). This relatively inexpensive technology is employed more often in producing desirable output in district hospitals than in central. In fact, neither coefficient on the output measures is significant for the central hospitals and the time trend coefficient suggests that requirement of this input has declined over time for this group.

(Insert Table 4 here)

Echocardiogram (ECO) usage is also higher in producing desirable output in district hospitals as shown in table 4. It is interesting that the statistically significant coefficient on undesirable output is very low in district hospitals while the coefficient on desirable output is not significant in central hospitals, though the time trend is both positive and significant. These estimates appear to indicate that the ECO is being used much more to produce desirable output than undesirable, a favourable result from the hospitals viewpoint.

(Insert Table 5 here)

The mean efficiency level and TFPG estimates for combined desirable and undesirable outputs are shown in table 5 for the three technologies. The TFPG estimate is given by the sum of changes in technical efficiency scores and technological change as measured by the time trend. According to these estimates, there has been an increase in the mean efficiency level of CAT usage in district hospitals accompanied by a decrease in the mean efficiency level of both the ECO and the EEG. However, the increase in efficiency in the use of the CAT has been accompanied by a worsening of the quality of the production, while the opposite is true for the ECO and the EEG. From these results, it appears that in district hospitals, the staff has definitely changed intensity of care to increase efficiency (or decrease efficiency in the case of ECO and EEG), but this has implied a decline in the quality (or improvement for the ECO and the EEG) of the output produced with the CAT. Therefore, these findings cast some doubts on the staff capabilities in using these diagnostic tools[11]. Except for a dip in 1994 for the EEG, central hospitals appear to have increased their mean efficiency level for all technologies. Further, these hospitals seem able to improve efficiency and, at the same time, the quality of their production; the only exception is for EEG where the balance between desirable/undesirable output is in favour of the latter.

Both groups of hospitals register a positive Total Factor Productivity Growth for all technologies. The only exception is the EEG in central hospitals whose productivity growth is stable. Notice that negative technical progress is offset by a good performance in terms of technical efficiency change in the case of the ECO. It is notable that the TFPG estimates are quite a bit higher for the district hospitals than for the central.

4.2 *Non-parametric input-oriented Malmquist indices*

Table 6 shows the Malmquist indices and their decomposition into technical efficiency change and technological change computed using Data Envelopment Analysis[12]. Three models have been solved for each of the three technologies; in each model, the measure of input was the number of procedures (i.e. number of CAT scans, number of Electrocardiagrams and number of Echocardiograms), while outputs were measured by the number of desirable and undesirable output receiving the specific procedure. The chosen DEA model is the input-oriented one, solved under the assumption of constant returns to scale. Therefore, we measure the increase in technical efficiency and productivity for a given level of produced output; consequently, we do not get information of how the mix between undesirable and desirable output has changed over time when technical efficiency and productivity has varied as well.

(Insert Table 6 here)

[11] A referee pointed out that it would be interesting to add some information on the seniority and qualifications of staff performing the procedures to better qualify this statement. Unfortunately, there is no available information on this point and therefore we cannot address the problem in a more specific way.

For illustrative purposes in Table 6, one indicates no change, a number greater than one indicates an improvement in productivity and a number less than one indicates a decline in productivity as generally interpreted in the literature. These indices seem to imply that there is a decline in efficiency in district hospitals in the utilisation of the CAT between 1992 and 1993 while the opposite is true from 1993 to 1994. The same is true for the ECO; however, notice that the increase in efficiency from 1993 to 1994 is very small (as the figure is very close to 1). For the EEG, there is a continuous decline in efficiency over all three years. Notice that these results are generally consistent with the ones obtained from parametric methods, as it can be seen from Table 7.

(Insert Table 7 here)

The only notably exception is the direction of the efficiency change for the CAT from 1992 to 1993 and the ECO from 1993 to 1994. Such a difference can be however attributed to the different stochastic representation of technology between parametric and non-parametric frontiers. In spite of the fact that the frontier has shifted due to positive technical change for the three technologies (as it is shown by parametric methods), the district hospitals on average have experienced technological progress between 1992 and 1993 followed by technological regress between 1993 and 1994 for the CAT and the EEG, while there is a continuous improvement in technological change over time for the ECO. The same is true for TFPG; while the parametric methods show a positive productivity growth, on average total factor productivity growth is decreasing for the CAT during the whole period while it is increasing for the ECO and first increasing then decreasing for the EEG.

The Malmquist indices for the central hospitals show a different pattern. Here efficiency is declining between 1992 and 1993 and improving between 1993 and 1994 for the CAT. Efficiency in ECO usage has increased over time while the pattern for the EEG has been first improvement and then declines. These results are again consistent with the parametric ones, except for the direction of the efficiency change from 1992 to 1993 for the CAT. The estimation of parametric frontiers shows technical progress for CAT and ECO, while the opposite is true for the EEG. At the hospital level, technical progress occurred for the CAT from 1992 to 1993 and then declined between 1993 and 1994. Technical regress appears to be evident for the ECO during the entire period while the EEG exhibits continuous technical progress. The same comments can be made for the TFPG. Indeed at the frontier level, productivity growth is positive for the three technologies. However, at hospital level, the composite TFPG measures show an initial growth and then decline for the CAT and the EEG while the opposite is true for the ECO where productivity growth is initially negative and then positive.

4.3 *The DRG reimbursement system and the TFPG indices*

The second part of our analysis consists of estimating the relationship between the TFPG indices for the three technologies and DRG payment. First, we transform the indices using the method suggested by Kalirajan and Shand [1988]. After controlling for variables that may affect technology usage, these productivity measures are regressed on an index developed in order to capture the effects of DRG payment on the hospital's production. Since the relationship between the productivity indices for the different technologies may not be independent, we estimate a system of seemingly unrelated regressions using the SURE estimator. [Greene 1997].

The control variables for technology usage are defined as the following: a dummy indicating whether the hospital is a district or central hospital (CENTRAL), a dummy indicating whether the hospital is a university teaching hospital (TEACH), the overall case-mix for the hospital (CASEMIX), the number of beds as a measure of size (BEDS), and our variable of interest, the percentage of overall discharges paid for by DRG in that hospital (PCDRG). The estimates are presented in tables 8 and 9. Both the parametric and non-parametric indices are used. It is of note that the results do not differ greatly and are interesting for several reasons.

(Insert Tables 8 and 9)

First, we find that central hospitals (CENTRAL) are less productive than district in utilisation of all three technologies though teaching hospitals (TEACH) which are a subset of central hospitals are more productive than all others. The medical staff of teaching hospitals may be more knowledgeable of the correct manner in which to employ these technologies than their non-teaching counterparts. Bed size (BEDS) has a negative impact on productivity which may be due to diseconomies of scale that can arise when hospitals become so large that they become difficult to manage. Case-mix (CASEMIX) has a positive impact on productivity which may also reflect that hospitals with experience at treating more complicated cases are better able to diagnosis and treat patients. Finally, we find evidence that our variable of interest, the percentage of discharges actually paid for by DRG (PCDRG) has a positive impact on productivity which seems to indicate that those hospitals with more discharges paid for by DRG are more productive at using these technologies. It may be that administrators in these hospitals are more aware of the utilisation patterns of their hospital and put pressure on physicians to use the technology when necessary but not excessively. They may also be in a better position for bargaining with the Health Ministry for investment in new technologies in addition to having extra revenue to spend on modernisation of older technologies.

5. CONCLUSIONS

The main objective pursued by Portuguese Health Ministry with the introduction of the DRG payment system was that of encouraging a more efficient utilisation of resources in public hospitals to gain productivity and curb the uncontrolled growth of public expenditure in the health sector. In this paper, we have assessed to what extent the introduction of the DRG financing system has had a positive impact on the growth of productivity and technical efficiency of the three diagnostic technologies most commonly associated with two of the most frequent diagnoses in Portuguese public hospitals. To measure the change in technical efficiency and productivity, we have used the frontier analysis where technical efficiency is measured as the deviation of the productive unit from an idealised frontier isoquant computed for the whole industry. Two methodologies can be used to construct the reference technology: the parametric methods, based on the econometric estimation of the technology used by the firm and the non-parametric methods, based on linear programming.

We have used a two-stage procedure to estimate the impact of DRG payment on the technology productivity growth using frontier models. In the first stage, measures of TFPG and its components (efficiency change and technical change) have been derived using both parametric and non-parametric methods. We used both techniques to test the robustness of the derived performance indicators and to get a better insight into the individual hospital's performance. More precisely, we have first computed measures of efficiency change and technical change by the estimation of three separate input requirement frontiers for each technology. Then, using Data Envelopment Analysis, we have estimated Malmquist indices of productivity change over time and decomposed these composite measures into technical efficiency and technological change indices. In the second stage, the relationship between the TFPG indices and DRG payment has been analysed. After controlling for hospital characteristics which may affect technology usage, the indices have been regressed on an index developed in order to capture the effects of DRG payment on hospital production.

The empirical analysis produces two main results. First, both parametric and non-parametric methods indicate that technical efficiency increased both in district and central hospitals for the CAT. Both types of estimates also indicate increasing efficiency in CAT utilisation accompanied by decreasing efficiency in district hospitals. For the ECO, there is declining technical efficiency for district hospitals, while it is increasing for central hospitals. As for EEG, technical efficiency is declining for district hospitals while it stable for central hospitals. However, improvement of technical efficiency has not been accompanied by an equivalent improvement in the quality of output in District hospitals; clearly these findings cast some doubts on the capabilities of the staff operating in this group of hospitals.

Second, we find evidence that movements in productivity can be attributed to the DRG payment system at least for these three diagnostic technologies. Of course, these results should be considered with the obvious caution as the empirical analysis has involved only three diagnostic technologies. Our results provide indication that hospital administrators are responding in the expected manner to the new financing system and therefore it gives indication that the Health Ministry should continue with its effort to systematically introduce the DRG based financing system to increase efficiency in the health care system.

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Table 1. *Utilisation Rates of the Three Technological Inputs for each considered year and for each hospital category*

	District Hospitals			Central Hospitals		
Year	CAT	EEG	ECO	CAT	EEG	ECO
1992	26.6%	18.2%	12.4%	63.4%	19.4%	76.2%
1993	31.9%	16.6%	24.5%	65.3%	19.3%	68.9%
1994	44.0%	24.6%	23.5%	71.5%	22.1%	65.9%

Note: The figures give the percentages of discharges (both alive and dead) having the specified analysis.

Table 2. *MLE Estimates of the Stochastic Input Requirement Function*
Dependent Variable: Number of Cat Scans

District Hospitals			Central Hospitals		
Variable	Coefficient	t-ratio	Variable	Coefficient	t-ratio
ALIVE	0.10	(6.9)	ALIVE	0.67	(3.5)
DEAD	0.03	(7.2)	DEAD	0.13	(4.6)
TIME	0.50	(2.5)	TIME	0.15	(2.3)
σ^2 =	0.58		σ^2 =	3.6	
γ =	0.96		γ =	0.78	

Note: σ^2 is the total variance of the residuals; γ measures the weight of the variance of the technical efficiency term divided by the total variance of the residuals. ALIVE is the number of alive discharges; DEAD is the number of dead discharges; TIME is the time trend.

Table 3. *MLE Estimates of the Stochastic Input Requirement Function*
Dependent Variable: Number of Electrocardiograms

District Hospitals			Central Hospitals		
Variable	Coefficient	t-ratio	Variable	Coefficient	t-ratio
ALIVE	0.69	(2.07)	ALIVE	0.51	(0.02)
DEAD	0.19	(1.20)	DEAD	0.15	(1.44)
TIME	0.16	(2.63)	TIME	-0.30	(-2.07)
σ^2 =	5.88		σ^2 =	17.12	
γ =	0.83		γ =	0.94	

Note: σ^2 is the total variance of the residuals; γ measures the weight of the variance of the technical efficiency term divided by the total variance of the residuals. ALIVE is the number of alive discharges; DEAD is the number of dead discharges; TIME is the time trend.

Table 4. *MLE Estimates of the Stochastic Input Requirement Function*
Dependent Variable: Number of Echocardiograms

District Hospitals			Central Hospitals		
Variable	Coefficient	t-ratio	Variable	Coefficient	t-ratio
ALIVE	0.55	(2.23)	ALIVE	0.35	(1.98)
DEAD	0.01	(2.00)	DEAD	0.37	(1.00)
TIME	0.08	(3.3)	TIME	0.15	(2.01)
σ^2 =	2.79		σ^2 =	3.44	
γ =	0.86		γ =	0.77	

Note: σ^2 is the total variance of the residuals; γ measures the weight of the variance of the technical efficiency term divided by the total variance of the residuals. ALIVE is the number of alive discharges; DEAD is the number of dead discharges; TIME is the time trend.

Table 5. *Mean Efficiency Level and Mean TFPG For Alive and Dead Discharges for each year and for each group of hospitals*

		District Hospitals		Central Hospitals	
		Mean Efficiency level	TFPG	Mean Efficiency level	TFPG
CAT	1992	0.38	-	0.45	-
	1993	0.40	1.044	0.49	0.62
	1994	0.42	1.050	0.52	0.65
ECO	1992	0.097	-	0.24	-
	1993	0.090	1.260	0.26	1.01
	1994	0.084	1.280	0.28	1.02
EEG	1992	0.136	-	0.37	-
	1993	0.133	1.233	0.38	0.92
	1994	0.130	1.234	0.37	0.92

Note: CAT indicates Computerised Tomography Scanner. ECO indicates Echocardiagrams. EEG indicates Electrocardiograms. TFPG indicates Total Factor Productivity Growth.

Table 6. *Malmquist Index Summary for Alive and Dead Discharges for each year and for each group of hospital*

	District Hospitals			Central Hospitals		
	EC	TC	TFPG	EC	TC	TFPG
CAT 1992	-	-	-	-	-	-
1993	0.713	1.074	0.766	0.276	3.793	1.047
1994	1.544	0.421	0.649	1.859	0.499	0.928
ECO 1992	-	-	-	-	-	-
1993	0.887	1.170	1.038	1.061	0.858	0.910
1994	1.013	1.034	1.048	1.253	0.800	1.011
EEG 1992	-	-	-	-	-	-
1993	0.879	1.298	1.140	1.012	1.112	1.125
1994	0.830	0.840	0.697	0.576	1.653	0.953

Note: CAT indicates Computerised Tomography Scanner. ECO indicates Echocardiagrams. EEG indicates Electrocardiograms. TFPG stands for Total Factor Productivity Growth. EC is Efficiency change; TC is technical change. TFPG (or Malmquist index) is the geometric mean between EC and TC.

Table 7. *Summary of movements of technical efficiency, technical change and TFPG for the three technologies over the three years time period and for both District and Central Hospitals*

Parametric Methods						
	District Hospitals			Central Hospitals		
	EC	TC	TFPG	EC	TC	TFPG
CAT 1992	NC	NC	NC	NC	NC	NC
1993	+	+	+	+	+	+
1994	+	+	+	+	+	+
ECO 1992	NC	NC	NC	NC	NC	NC
1993	-	+	+	+	-	+
1994	-	+	+	+	-	+
EEG 1992	NC	NC	NC	NC	NC	NC
1993	-	+	+	+	+	ST
1994	-	+	+	+	+	ST
Non - parametric Methods						
	District Hospitals			Central Hospitals		
	EC	TC	TFPG	EC	TC	TFPG
CAT 1992	NC	NC	NC	NC	NC	NC
1993	-	+	-	-	+	+
1994	+	-	-	+	-	-
ECO 1992	NC	NC	NC	NC	NC	NC
1993	-	+	+	+	-	-
1994	+	+	+	+	-	+
EEG 1992	NC	NC	NC	NC	NC	NC
1993	-	+	+	+	+	+
1994	-	-	-	-	+	+

Note: CAT indicates Computerised Tomography Scanner. ECO is Echocardiagrams. EEG indicates Electrocardiograms. TFPG stands for Total Factor Productivity Growth. EC is Efficiency change; TC is technical change. The sign + indicates a positive change, while the sign – indicates a negative sign. ST stands for "stable" and it indicates when there is no change in the relevant variable over the time period. NC stands for "not computed" and refers to 1992, which is the base year used to compute the changes in variables.

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Table 8. *SURE Estimates for the Three Technological Inputs Parametric TFPG Indices For Alive and Dead Discharges*

CAT Scans		
Variable	Coefficient	T-Ratio
PCDRG	0.653	1.894
CENTRAL	-0.013	- 2.923
CASE-MIX	0.469	4.853
TEACH	0.864	14.689
BEDS	-0.94	-7.946

Electrocardiograms		
Variable	Coefficient	T-Ratio
PCDRG	0.687	2.018
CENTRAL	-0.067	- 0.583
CASE-MIX	0.569	5.837
TEACH	0.486	15.789
BEDS	-0.285	-7.858

Echocardiograms		
Variable	Coefficient	T-ratio
PCDRG	0.394	1.987
CENTRAL	-0.198	-1.896
CASE-MIX	0.478	4.786
TEACH	0.895	13.68
BEDS	-0.708	-8.869

Table 9. *SURE Estimates for the Three Technological Inputs Malmquist Indices for Alive and Dead Discharges*

CAT Scan

Variable	Coefficient	T-Ratio
PCDRG	0.786	1.962
CENTRAL	-0.100	-2.765
CASE-MIX	0.419	4.769
TEACH	0.786	14.589
BEDS	-0.792	-7.694

Electrocardiograms

Variable	Coefficient	T-Ratio
PCDRG	0.789	2.008
CENTRAL	-0.101	-0.679
CASE-MIX	0.389	6.789
TEACH	0.590	14.698
BEDS	-0.397	-5.897

Echocardiograms

Variable	Coefficient	T-Ratio
PCDRG	0.239	1.598
CENTRAL	-0.342	-1.795
CASE-MIX	0.674	3.587
TEACH	0.894	11.68
BEDS	-0.892	-8.769