



**HAL**  
open science

## Measurement of Hospital Efficiency, Using a Latent Class Stochastic Frontier Model

Carlos Pestana Barros, António Gomes Menezes, José António Cabral Vieira

► **To cite this version:**

Carlos Pestana Barros, António Gomes Menezes, José António Cabral Vieira. Measurement of Hospital Efficiency, Using a Latent Class Stochastic Frontier Model. *Applied Economics*, 2011, 45 (01), pp.47-54. <10.1080/00036846.2011.579061>. <hal-00732115>

**HAL Id: hal-00732115**

**<https://hal.science/hal-00732115v1>**

Submitted on 14 Sep 2012

HAL is a multi-disciplinary open access archive for the deposit and dissemination of scientific research documents, whether they are published or not. The documents may come from teaching and research institutions in France or abroad, or from public or private research centers.

L'archive ouverte pluridisciplinaire HAL, est destinée au dépôt et à la diffusion de documents scientifiques de niveau recherche, publiés ou non, émanant des établissements d'enseignement et de recherche français ou étrangers, des laboratoires publics ou privés.



HAL Authorization



## Measurement of Hospital Efficiency, Using a Latent Class Stochastic Frontier Model

Journal:	<i>Applied Economics</i>
Manuscript ID:	APE-08-0288.R1
Journal Selection:	Applied Economics
Date Submitted by the Author:	15-Aug-2010
Complete List of Authors:	Barros, Carlos; Technical University of Lisbon, Economics Menezes, António; University of the Azores, Economics Vieira, José António; University of the Azores, Economics
JEL Code:	I10 - General < I1 - Health < I - Health, Education, and Welfare, C29 - Other < C2 - Econometric Methods: Single Equation Models < C - Mathematical and Quantitative Methods
Keywords:	Hospitals, random frontier, Translog frontier model, Decision-making

SCHOLARONE™  
Manuscripts

## Measurement of Hospital Efficiency, Using a Latent Class Stochastic Frontier Model

Carlos Pestana Barros<sup>a</sup> António Gomes de Menezes<sup>b</sup> and José Cabral Vieira<sup>b</sup>

<sup>a</sup> Instituto Superior de Economia e Gestão (ISEG), Technical University of Lisbon, Portugal. E-mail: Cbarros@iseg.utl.pt

<sup>b</sup> University of Azores and CEEApIA

**Abstract:** This paper analyses the technical efficiency of Portuguese hospitals from 1997 to 2008 with the latent class frontier model, enabling the identification of different segments in the cost frontier. It is found that there are three statistically significant segments in the sample, leading to the conclusion that no common health policy can be applicable to all of the hospitals analysed, calling rather for policies conceived for each hospital segment identified. The health policy based in the identified segments enables a more accurate and cost-effective management of resources.

**Key words:** Hospitals, stochastic cost frontier, latent class model, technical efficiency, panel data.

**JEL-code:** I1, C29

### 1. Introduction

Efficiency in hospitals is a theme that has attracted much research in recent decades (Friesner; Roseman and McPherson, 2007; Barbeta, Turati and Zago, 2007; Staat, 2006; Steinmann and Zweifel, 2003; Prior, 1996; Maniadakis and Thanassoulis, 2000; Parkin and Hollingsworth, 1997). A review of the literature shows two main approaches: the DEA - data envelopment analysis (Ozcan, Luke and Haksever, 1987; Burgess and Wilson, 1993; Dalmau and Puig-Junoy, 1998; Siciliani, 2006); and the

1  
2  
3 stochastic frontier models (Barbeta, Turati and Zago, 2007; Siciliani, 2006; Blank and  
4  
5  
6 Eggink, 2004; Greene, 2004; Rosko, 2001).

7  
8 The aim of the present study goes beyond previous research by adopting the  
9  
10 latent frontier model, in line with Orea and Kumbhakar (2004). The work's objective is  
11  
12 to combine operational and financial variables in the evaluation of hospital efficiency  
13  
14 (Skinner, 1994). The distinctions between these groups of factors - operational and  
15  
16 financial - means that merging the two constitutes a technical problem that requires the  
17  
18 support of econometric techniques, such as frontier models. The motivation for the  
19  
20 present research is based on the fact that hospitals in Portugal can be identified as  
21  
22 having either public, private, or mixed status. The aim of this paper is to investigate the  
23  
24 statistical factors that characterise the hospitals, clustering the sample in segments  
25  
26 enabling us to define specific health policies for identified segments and to monitor  
27  
28 each group with adequate targets. This procedure permits a more focused, cost-effective  
29  
30 health policy, which can be generalised and applied to samples other than that for  
31  
32 Portugal.  
33  
34  
35  
36  
37

38 The contribution of this paper within hospital research is twofold. First, it adopts  
39  
40 an innovative stochastic frontier model, which endogenously identifies segments of  
41  
42 hospitals in a sample, overcoming the hypothesis of homogeneity of the variables  
43  
44 adopted by the frontier models mentioned earlier. Secondly, it applies the model to  
45  
46 Portuguese hospitals. Given that there is rigorous regulation of hospital services, this  
47  
48 paper uses an innovative model that may improve our understanding of the best way to  
49  
50 regulate the service as a whole (Hadley and Zuckerman, 1994).  
51  
52  
53

54 The paper is organised as follows: Section 2, explains the method; Section 3  
55  
56 presents the data; Section 4 presents the results; Section 5 discusses the results and  
57  
58 makes the concluding remarks.  
59  
60

## 2. Latent Class Frontier Models

In this paper, we adopt the stochastic cost econometric frontier approach (Kumbhakar and Lovell, 2000). The general frontier cost function proposed by Aigner et al. (1977) and Meeusen and van den Broeck (1977) is the following:

$$C_{it} = C(X_{it}) \cdot e^{v_{it} + u_{it}} ; \quad i = 1, 2, \dots, N, t = 1, 2, \dots, T \quad (1)$$

Where  $C_{it}$  represents a scalar cost of the decision-unit  $i$  under analysis in the  $t$ -th period;  $X_{it}$  is a vector of variables including the input prices and the output descriptors present in the cost function; and  $\varepsilon_{it} = u_{it} + v_{it}$  is the error term. This term may be decomposed into two components:

- (i) the error term  $v_{it}$  is the one that is traditional of the econometric models, assumed to be independently and identically distributed, that represents the effect of random shocks (noise  $v_{it} \sim N(0, \sigma_v^2)$ ) and is independent of  $u_{it}$ ;
- (ii) the inefficient term  $u_{it}$  represents technical inefficiencies and is assumed to be positive and normally distributed with a zero mean and variance  $\sigma_u^2$ . The positive disturbance  $u_{it}$  is reflected in a half-normal independent distribution truncated at zero, signifying that each hospital's cost must lie on or above its cost frontier. This implies that any deviation from the frontier is caused by management factors controlled by the hospitals.

The total variance is defined as  $\sigma^2 = \sigma_v^2 + \sigma_u^2$ . The contribution of the error term to the total variation is as follows:  $\sigma_v^2 = \sigma^2 / (1 + \lambda^2)$ . The contribution of the inefficient term is:  $\sigma_u^2 = \sigma^2 \cdot \lambda^2 / (1 + \lambda^2)$ , where  $\lambda$  is defined as  $\lambda = \frac{\sigma_u}{\sigma_v}$ , providing an indication of the relative contribution of  $u$  and  $v$  to  $\varepsilon = u + v$ .

Given that the estimation procedures of equation (1) yield merely the residual  $\varepsilon$ , rather than the inefficiency term  $u$ , this term in the model must be calculated indirectly (Greene, 2000). In the case of panel data, such as that used in this paper, Battese and Coelli (1988) use the conditional expectation of  $u_{it}$ , conditioned on the realised value of the error term  $\varepsilon_{it} = (v_{it} + u_{it})$ , as an estimator of  $u_{it}$ . In other words,  $E[u_{it} / \varepsilon_{it}]$  is the mean productive inefficiency for the  $i$ -th hospital at any time “ $t$ ”. Following Orea and Kumbhakar (2004), we can write equation (1) as a latent class frontier model:

$$C_{it} | j = C(X_{it}) | j . e^{v_{it} | j + u_{it} | j} ; \quad i=1,2,\dots,N, t=1,2,\dots,T \quad (2)$$

Where subscript “ $i$ ” denotes the hospital, “ $t$ ” indicates time and “ $j$ ” represents the different classes or groups. The vertical bar signifies that there is a different model for each class “ $j$ ” and, therefore, each hospital belongs to the same group in all the periods. Assuming that  $v$  is normally distributed and  $u$  follows a half-normal distribution, the likelihood function ( $LF$ ) for each hospital company “ $i$ ” at time “ $t$ ” for group “ $j$ ” is (Cf. Greene, 2004):

$$LF_{ij} = C(x_{it}, \beta_j, \sigma_j, \lambda_j) = \frac{\Phi(\lambda_j \cdot \varepsilon_{it} | j / \sigma_j)}{\Phi(0)} \cdot \frac{1}{\sigma_j} \cdot \phi\left(\frac{\varepsilon_{it} | j}{\sigma_j}\right) \quad (3)$$

Where  $\varepsilon_{it} | j = \ln C_{it} | j - \beta_j' x_{it}$ ,  $\sigma_j = [\sigma_{uj}^2 + \sigma_{vj}^2]^{1/2}$ ,  $\lambda_j = \sigma_{uj} / \sigma_{vj}$ , while  $\phi$  denotes the standard normal density and  $\Phi$  the cumulative distribution function. The likelihood function for hospital “ $i$ ” in group “ $j$ ” is obtained as the product of the likelihood functions in each period. See Orea and Kumbhakar (2004) for details.

### 3. Data

The dataset was compiled from the Portuguese Ministry of Health records and from the financial accounts of the hospitals. Our dataset covers the years from 1997 to 2008 and 51 hospitals, i.e., the vast majority of hospitals in Portugal. In order to have hospitals with similar natures and technology, this sample includes all the district hospitals.

Table 1 presents the characteristics of the variables used in the analysis. We transformed the variables according to the description column. We adopted the traditional log-log specification (Translog) to allow for the possible non-linearity of the frontier. We specify a translog variable cost frontier model with capital as a quasi-fixed factor (Caves and Christensen, 1980; Kaparakis et al., 1994).

**Table 1: Descriptive Statistics of the Data 1997-2008**

Variable	Description	Minimum	Maximum	Mean	Standard deviation
logVCT	Log of variable cost at constant price 2002	15.714	19.342	18.132	0.712
Trend	Trend variable	1	12	6.5	3.293
LogY1	Output measured by number of discharged patients	7.745	10.538	9.342	0.574
LogY2	Intermediate input measured by the length of stay in hospital	1.410	2.895	2.152	0.195
LogY3	Output variable measured by the log of external consultations	9.507	12.557	11.052	0.639
logY4	Output variable measured by log of emergency visits	-2.302	12.290	11.052	1.840
Log Mix	Intermediate input measured by the mix of specialist services	-0.289	0.335	0.006	0.090
Log K	Capital proxied by the number of beds	-0.157	0.059	-0.052	0.072
Log W1	Price of labour measured by the ratio of wages by the number of employees	8.579	10.410	10.017	0.188
Log W2	Price of other factors proxied by the regional price index	4.189	6.493	5.537	0.568
RAA	Dummy variable equal to one for	0	1	0.125	0.33112

	hospitals located on Azores islands and zero otherwise				
SA	Dummy variable equal to one for hospitals with private enterprise status and zero otherwise	0	1	0.421	0.231
DivK	Dummy equal to one for hospitals serving more than one county and zero otherwise	0	1	0.2745	0.4468
Quality	Dummy equal to one for hospitals with management system credited by the King's Fund and zero otherwise	0	1	0.632	0.271

#### 4. Results

The empirical specification of the cost function is the translog. We have chosen a flexible functional form in order to avoid imposing unnecessary *a priori* restrictions on the technologies to be estimated. Each explanatory variable is divided by its geometric mean. In this way, the translog can be considered as an approximation to an unknown function and the first-order coefficients can be interpreted as the production elasticities evaluated at the sample geometric mean. We also include both a time trend and a squared time trend in order to obtain some temporal changes (Breyer, 1987). The equation to be estimated is:

$$\log VCT_{it} = \beta_0|_j + \beta_y|_j \log Y_{it} + \sum_l \beta_{wl}|_j \log W_{ilt} + \frac{1}{2} \beta_{yy}|_j \log(Y_{it})^2 + \frac{1}{2} \sum_l \beta_{wwl}|_j \log W_{ilt}^2 + \sum_l \beta_{wly}|_j \log W_{ilt} \log Y_{it} + \delta_t|_j \cdot t + \delta_{tt}|_j \cdot t^2 + v_{it}|_j + u_i|_j \quad (4)$$

where VCT is the variable cost of the hospital,  $Y$  is the output,  $W$  denotes input price,  $t$  is a time trend,  $v$  is a random error which reflects the statistical noise and is assumed to follow a normal distribution centered at zero, while  $u$  reflects inefficiency and is assumed to follow a half-normal distribution. In order to test the number of groups, we used the testing-down procedure proposed by Greene (2005), in which beginning from a  $J^*$  known to be at least as large as the true  $J$ , one can test down, given that the  $J-1$  class model is nested with the  $J$  class model imposing  $\theta_j = \theta_{j-1}$ , based on likelihood ratio tests, as well as the SBIC and AIC. The model with four groups does not converge, likewise

the model with two groups is rejected against the model with three groups according and therefore, we estimate the model with three groups<sup>1</sup>. Moreover, since none of the variables used as separate variables was significant, we decided to adopt the model in which none of the separate variables was included. Following this, the latent class model uses the goodness of fit to create the groups. For comparative purposes, a non-random frontier model is estimated, together with a traditional production function.

**Table 2: Latent Translog Panel Production Frontier (dependent variable: log VCT)**

Variables	Standard SF. Coefficients (t-ratio)	Latent class 1 Coefficients (t-ratio)	Latent class 2 Coefficients (t-ratio)	Latent class 2 Coefficients (t-ratio)
Constant	-2.123 (-1.321)*	-2.132 (-2.999)***	-1.321 (3.219)***	-1.129 (-2.932)***
Trend	0.901 (3.212)*	0.115 (3.138)***	0.109 (3.893)***	0.112 (3.892)***
LogY1	0.731 (2.423)**	1.544 (2.324)**	0.125 (3.512)***	0.217 (4.124)***
LogY2	0.128* (1.027)	1.718 (2.453)**	0.727 (4.329)***	0.529 (3.128)***
LogY3	0.425 (3.123)***	0.812 (3.318)***	0.216 (3.124)***	0.135 (3.137)***
logY4	0.065 (0.043)	0.071 (3.219)***	0.231 (3.018)***	0.531 (3.218)***
Log Mix	-0.038 (-0.071)	-1.802 (-2.045)**	-0.128 (-3.162)***	-0.381 (-4.117)***
Log K	0.171 (0.183)	1.075 (2.173)**	1.012 (3.421)***	0.923 (3.219)***
logW1	0.042 (0.152)	0.827 (3.189)***	0.129 (4.129)***	0.327 (4.215)***
Log W2	0.045 (0.071)	0.319 (3.132)***	0.271 (4.219)***	0.283 (3.419)***
Trend <sup>2</sup>	-0.181 (-0.038)	-0.563 (-2.532)**	-0.215 (-4.219)***	-0.215 (-3.128)***
1/2Log(Y1) <sup>2</sup>	0.017 (3.002)***	1.272 (2.201)**	0.579 (2.626)**	0.832 (2.835)**
1/2Log(Y2) <sup>2</sup>	0.731 (2.590)**	0.153 (0.945)	1.076 (3.229)***	0.534 (1.674)*
1/2Log(Y3) <sup>2</sup>	0.131 (4.218)***	0.082 (0.820)	0.021 (4.126)***	0.032 (2.784)**
1/2Log(Y4) <sup>2</sup>	0.189 (4.324)***	0.185 (3.568)***	0.257 (3.783)***	0.217 (3.219)***

<sup>1</sup> The program used to estimate the model was Limdep 9.0.

1/2Log Mix <sup>2</sup>	0.328 (1.832)*	0.210 (2.674)**	0.315 (3.067)***	0.878 (2.197)**
1/2Log K <sup>2</sup>	0.319 (4.027)***	0.128 (3.534)***	0.128 (3.710)***	0.068 (3.419)***
1/2Log(W1) <sup>2</sup>	0.021 (1.074)	0.278 (1.452)	0.629 (3.058)***	0.420 (3.129)***
1/2Log (W2) <sup>2</sup>	0.031 (0.308)	0.216 (1.145)*	0.814 (3.457)***	0.791 (2.967)***
LogY1* LogY2	1.217 (3.015)***	1.278 (2.378)**	0.279 (3.073)***	0.126 (4.219)***
LogY1* LogY3	0.113 (3.427)***	1.012 (2.342)**	0.167 (0.110)	0.719 (1.210)
LogY1* LogY4	0.821 (4.295)***	0.218 (0.452)	0.290 (2.278)**	0.781 (3.189)***
LogY1* Log Mix	0.318 (3.045)***	0.829 (1.002)	0.428 (3.531)***	0.523 (2.054)*
LogY1* Log K	0.329 (3.145)***	-0.016 (-0.119)	-0.135 (-3.228)***	-0.153 (1.078)
LogY1* log W1	-0.348 (-3.319)***	-0.568 (-1.945)*	-0.174 (-3.219)***	-0.114 (2.978)***
LogY1* Log W2	-0.078 (-3.045)***	-0.057 (-0.726)	-0.109 (-3.805)***	-0.120 (-2.317)
LogY2* LogY3	-0.135 (-3.110)***	-0.129 (-0.341)	-0.251 (-3.672)***	-0.239 (-2.534)**
LogY2* LogY4	0.267 (3.729)***	0.254 (0.371)	0.332 (4.512)***	0.612 (1.674)***
LogY2* Log Mix	0.137 (3.218)***	0.818 (2.224)**	0.151 (2.321)***	0.528 (3.017)***
LogY2 *Log K	0.042 (5212)***	0.351 (1.432)	0.185 (3.162)***	0.312 (3.072)***
LogY2 * log W1	0.038 (4.345)***	0.167 (0.032)	0.282 (2.412)***	0.305 (3.127)***
LogY2 * log W2	-0.067 (-2.623)	-0.621 (0.778)	-0.296 (-4.029)***	-0.104 (-1.029)***
LogY3* LogY4	-0.363 (-3.195)***	-1.578 (-1.710)**	0.271 (3.619)***	0.219 (3.395)***
LogY3* Log Mix	-0.073 (-3.174)***	-0.191 (-1.029)	-0.471 (-1.712)**	-0.325 (-1.106)*
LogY3* Log K	0.845 (1.219)	0.110 (0.135)	0.151 (3.128)***	0.517 (3.029)***
LogY3* log W1	-0.347 (-2.753)**	-0.289 (-1.232)**	-0.715 (-1.218)*	-0.612 (-1.292)*
LogY3* log W2	0.583 (3.819)***	-0.779 (-1.682)**	-0.821 (-0.321)	-0.419 (-1.157)
LogY4* Log Mix	0.371 (3.045)***	0.141 (1.305)*	0.579 (2.626)**	0.525 (2.012)*
LogY4* Log K	0.256 (3.356)***	0.135 (1.674)*	1.076 (2.229)**	0.725 (3.126)***
LogY4* log W1	-0.178 (-3.162)***	-0.187 (-0.359)	-0.021 (-0.126)	-0.115 (-1.123)

LogY4* logW2	0.801 (3.132)***	1.89 (2.128)**	0.810 (2.925)**	0.612 (2.729)**
Log Mix* Log K	0.127 (4.129)***	0.321 (0.712)	0.282 (3.031)***	0.229 (3.110)***
Log Mix*log W1	-0.187 (-4.028)***	-1.032 (-1.256)	-0.620 (-3.721)***	-0.819 (-3.524)***
Log Mix*Log W2	0.219 (1.828)**	0.253 (2.023)**	0.307 (3.291)***	0.810 (3.190)***
Log K* log W1	0.178 (4.032)***	0.823 (4.219)***	0.871 (3.510)***	0.226 (3.131)***
Log K* log W2	0.017 (1.292)*	0.045 (3.129)***	0.028 (3.731)***	0.126 (3.056)
Log W1* log W2	0.018 (0.219)	0.032 (0.178)	0.051 (0.029)	0.118 (1.319)
RAA	0.527 (2.318)**	0.719 (2.521)**	0.538 (1.819)*	0.228 (1.418)*
SA	-1.062 (-2.128)**	-0.631 (-2.219)**	-0.243 (-3.184)***	-0.220 (-3.719)***
DivK	-0.031 (-0.052)	-0.045 (-0.372)	-0.027 (-1.290)	0.156 (1.219)*
Quality	0.232 (3.073)***	-0.175 (2.210)**	0.517 (4.289)***	0.475 (3.087)***
$\sigma = (\sigma_v^2 + \sigma_u^2)^{1/2}$	0.412	0.271**	0.317*	0.325*
$\lambda = \sigma_u / \sigma_v$	140.316	240.98	175.31	234.02
Log Likelihood Function	111	115		
NOBS	612	612	612	612

(t-statistics) in parentheses are below the parameters. \* = significance at 10%, \*\* = 5%, and \*\*\* = 1%.

The variables have the expected signs, since all price elasticities are positive. Moreover, instead of imposing homogeneity on prices, we have tested for it and accept that all segments have homogeneity in prices. It can be seen that the group with the highest labour elasticity is the first. The costs increase with the trend, but at a decreasing rate for all groups. Another interesting outcome is that the estimated coefficients of the standard stochastic frontier are, in general, between the minimum and the maximum of the latent class model coefficients. This result suggests that to some extent, the standard stochastic frontier estimates an average of the latent class model technologies.

#### 4.1 Efficiency Groups

First we present the groups formed by the latent class model using the posterior probabilities of class membership in Table 3.

**Table 3: Group Composition**

	Group 1	Group 2	Group 3
1	CH Torres Vedras	H Santa Maria da Feira	H Infante D. Pedro – Aveiro
2	H Divino Espirito Santo	H Sao Bernardo - Setubal	H Dr. Francisco Zagalo – Ovar
3	H Mirandela	H Faro	CH Coimbra
4	CH Alto Minho	CH P. Varzim V. Conde	H Garcia de Orta - Almada
5	H Sousa Martins – Guarda	CH Vila Nova de Gaia	H Montijo
6	CH Caldas da Rainha	H Santa Luzia – Elvas	H Chaves
7	H Santo Tirso	H Espirito Santo - Evora	H Egas Moniz
8	CH Cascais	H Curry Cabral	H Santo Espirito de Angra do Heroismo
9	CH Barlavento Algarvio	H S. Francisco Xavier	H Pulido Valente
10	H Braga	CH Cova da Beira	H Horta
11	H Padre Americo - Vale do Sousa	H Lamego	H Sao Teotonio – Viseu
12	H Reinaldo dos Santos - Vila Franca de Xira	H Sao Joao da Madeira	H Santa Maria Maior de Barcelos
13	H Sao Miguel - Oliveira de Azemeis	H Jose Maria Grande - Portalegre	CH Medio Tejo
14	H Braganca	H Sao Joao de Deus - Famalicao	H Agueda
15	CH Baixo Alentejo	H Sao Goncalo - Amarante	H Santarem
16	H Figueira da Foz	H Amato Lusitano - Castelo Branco	H Senhora da Oliveira - Guimaraes
17	H Santo Andre – Leiria	H Nossa Senhora do Rosario - Barreiro	CH Vila Real Peso da Regua
Observations	204	204	204

We observe that the most efficient hospitals appear in the first group. The second group consists of hospitals with an average level of efficiency. Finally, the third group comprises hospitals with the lowest levels of efficiency.

Finally, Table 4 shows the average cost efficiency for each hospital in the period. The cost efficiency is defined as the ratio between the minimum cost and the actual cost and takes values between 0 and 1. According to this definition, the closer to 1 is the efficiency measure, the more efficient must the hospital be considered. Given that the dependent variable is expressed in logarithms, it was calculated as:

$$EC = \exp(-\hat{u}) \quad (4)$$

where the estimated value of the inefficiency ( $\hat{u}$ ) is separated from the random error term ( $\vartheta$ ) using the Jondrow et al. (1982) formula.

**Table 4: Average Cost Efficiency in the Period**

Nobs	Hospitals	Standard SF	Latent Class Model	Difference
1	CH Vila Real Peso da Regua	0.56	0.66	0.10
2	H Senhora da Oliveira - Guimaraes	0.55	0.67	0.12
3	H Santarem	0.62	0.68	0.06
4	H Agueda	0.58	0.69	0.11

1					
2					
3	5	CH Medio Tejo	0.59	0.70	0.11
4	6	H Santa Maria Maior de Barcelos	0.60	0.72	0.12
5	7	H Sao Teotonio - Viseu	0.62	0.73	0.11
6	8	H Horta	0.65	0.74	0.09
7	9	H Pulido Valente	0.67	0.75	0.08
8	10	H Santo Espirito de Angra do Heroismo	0.67	0.76	0.09
9	11	H Egas Moniz	0.68	0.77	0.09
10	12	H Chaves	0.69	0.78	0.09
11	13	H Montijo	0.70	0.79	0.09
12	14	H Garcia de Orta - Almada	0.70	0.80	0.10
13	15	CH Coimbra	0.70	0.82	0.12
14	16	H Dr. Francisco Zagalo - Ovar	0.71	0.83	0.12
15	17	H Infante D. Pedro - Aveiro	0.72	0.84	0.12
16	18	H Nossa Senhora do Rosario - Barreiro	0.73	0.84	0.11
17	19	H Amato Lusitano - Castelo Branco	0.74	0.85	0.11
18	20	H Sao Goncalo - Amarante	0.75	0.85	0.10
19	21	H Sao Joao de Deus - Famalicao	0.76	0.86	0.10
20	22	H Jose Maria Grande - Portalegre	0.77	0.86	0.09
21	23	H Sao Joao da Madeira	0.78	0.86	0.08
22	24	H Lamego	0.79	0.87	0.08
23	25	CH Cova da Beira	0.79	0.87	0.08
24	26	H S. Francisco Xavier	0.80	0.88	0.08
25	27	H Santo Andre - Leiria	0.81	0.89	0.08
26	28	H Curry Cabral	0.83	0.90	0.07
27	29	H Espirito Santo - Evora	0.84	0.90	0.06
28	30	H Santa Luzia - Elvas	0.85	0.91	0.06
29	31	CH Vila Nova de Gaia	0.86	0.92	0.06
30	32	CH P. Varzim V. Conde	0.87	0.92	0.05
31	33	H Faro	0.88	0.93	0.05
32	34	H Sao Bernardo - Setubal	0.89	0.94	0.05
33	35	H Santa Maria da Feira	0.89	0.94	0.05
34	36	H Braganca	0.90	0.95	0.05
35	37	H Sao Miguel - Oliveira de Azemeis	0.90	0.95	0.05
36	38	H Reinaldo dos Santos - Vila Franca de Xira	0.91	0.95	0.04
37	39	H Padre Americo - Vale do Sousa	0.91	0.96	0.05
38	40	H Braga	0.91	0.96	0.05
39	41	CH Barlavento Algarvio	0.92	0.96	0.04
40	42	H Figueira da Foz	0.93	0.97	0.04
41	43	CH Cascais	0.94	0.98	0.04
42	44	H Santo Tirso	0.95	0.98	0.03
43	45	CH Caldas da Rainha	0.96	0.98	0.02
44	46	H Sousa Martins - Guarda	0.97	0.98	0.01
45	47	CH Alto Minho	0.98	0.99	0.01
46	48	H Mirandela	0.99	0.99	0.00
47	49	H Divino Espirito Santo	0.99	0.99	0.00
48	50	CH Torres Vedras	0.99	0.99	0.00
49	51	CH Baixo Alentejo	1.00	1.00	0.00
50		Mean	0.799	0.868	0.068
51		Median	0.800	0.880	0.080
52		Std. Dev	0.131	0.100	0.036
53					
54					
55					
56					
57					
58					
59					
60					

1  
2  
3 The hospitals with the lowest cost efficiencies are CH Vila Real Peso da Regua and H  
4  
5 Senhora da Oliveira – Guimarães. It should be emphasised that these two hospitals are  
6  
7 located in small towns in the north of mainland Portugal. The highest cost-efficiency  
8  
9 scores are achieved by CH Baxo Alentejo, CH Torres Vedras, H Divino Espirito Santo  
10  
11 and H Mirandela.  
12  
13

14  
15  
16 Concerning the comparison between the standard stochastic frontier and the latent  
17  
18 class model efficiencies, it is worth indicating that the rankings are preserved and the  
19  
20 latent frontier displays greater cost efficiency for all hospitals. The average difference is  
21  
22 0.036, which is rather significant. Likewise, the differences are not consistent for all  
23  
24 hospitals, implying that the latent class model efficiencies are not merely a constant  
25  
26 added to the standard stochastic frontier model.  
27  
28  
29  
30  
31

## 32 **5. Discussion and Conclusion**

33  
34  
35 The interpretation of the obtained results is as follows. First, they allow us to  
36  
37 conclude that latent frontier models describe the Portuguese hospitals well, when  
38  
39 allowing for heterogeneity and defining segments in the sample. This is possibly the  
40  
41 most significant finding of the present paper. The implication of this result is that a  
42  
43 common government policy would be inappropriate for all hospitals, since the three  
44  
45 segments identified point to the existence of heterogeneity. Therefore, any health policy  
46  
47 which involves some of these heterogeneous variables should be tailored according to  
48  
49 the segments. Second, our analysis has led us to identify three segments. However, this  
50  
51 does not mean that there are only three segments to be found in the Portuguese hospital  
52  
53 network (Dismuke and Sena, 2004). Rather, it signifies that given the small number of  
54  
55 observations available, the model cannot distinguish more segments. The third finding  
56  
57 is that hospitals in the first segment are defined as generic Portuguese hospitals, a  
58  
59  
60

1  
2  
3 picture that emerges with traditional homogenous frontier models (Barros et al. 2008).  
4  
5 These hospitals are characterised by the outputs and inputs increasing the costs, which  
6  
7 have a positive relationship with *RAA* and a negative relationship with *SA*, *DivK* and  
8  
9 *quality*, signifying that these variables decrease costs. However, *DivK* is not statistically  
10  
11 significant. The results for the first segment are intuitive and in accordance with the  
12  
13 economic theory (Cf. Varian, 1987).  
14  
15

16  
17 In the second segment, the hospitals' costs have the same relationship with outputs,  
18  
19 inputs and input prices. Moreover, the dummy variables have the same relationship with  
20  
21 costs that was observed in the first segment, with the exception of quality, which is now  
22  
23 positive. These are hospitals that have adopted the quality standards, but do not  
24  
25 maintain them. The third segment is distinct from the other two, based on the negative  
26  
27 sign of *DivK*, i.e., hospitals serving more than one county, which is now positive and  
28  
29 statistically significant.  
30  
31

32  
33 What is the overall rationale for these results? They are in fact quite intuitive, since  
34  
35 hospitals are not homogenous. For instance, there are small and large hospitals in the  
36  
37 sample. These tangible characteristics result in different performance levels, dissimilar  
38  
39 flux and discrepancies in their financial debts, which account for the different segments  
40  
41 in the sample. In the case of the Portuguese hospitals, there are three different segments  
42  
43 that can be distinguished on the grounds of the values and signs of the exogenous  
44  
45 variables.  
46  
47

48  
49 With regard to the implications of the results, first, there is evidence that private  
50  
51 hospitals (*SA*) are more efficient than public hospitals, since *SA* characteristics decrease  
52  
53 costs. This outcome is based on the negative sign of the attributes of private hospitals.  
54  
55 This result is also supported in previous research in this field, with alternative models.  
56  
57  
58 This result serves as a cross-validation of previous results in this field.  
59  
60

1  
2  
3 Second, the sign of credit hospitals in all segments (quality) is negative in the first  
4 segment, but positive in the other two. Therefore, we conclude that credit hospitals,  
5 motivated by the quest for quality, perform efficiently (Williamson, 1979, 1985).  
6  
7 However, those hospitals that do not maintain the quality procedures resort to using  
8 them as a device to conceal bad managerial practices.  
9  
10

11  
12  
13  
14  
15 Third, based on the sign of the variable *DivK* in all segments, hospitals serving more  
16 than one county perform efficiently, while seeking enhanced performance (Caves and  
17 Porter, 1977).  
18  
19  
20  
21

22  
23 Finally, given the sign of the variable *RAA* in all segments, the mainland hospitals  
24 seeking profits perform efficiently (Barney, 1991; Rumelt, 1991).  
25  
26  
27  
28

29 Hence, it can be concluded that, in this context, private hospitals are more efficient than  
30 public hospitals. This is supported by the theory of transaction costs and property rights  
31 (Klein, Crawford and Alchian, 1978; Williamson, 1979, 1985), signifying that  
32 Portuguese hospitals allocate dedicated asset-specificity (Williamson, 1985) according  
33 to the population density.  
34  
35  
36  
37  
38  
39

40  
41 Therefore, assuming the asset-specificity strategy, hospitals managed by whichever  
42 contracts are assumed to be efficient, displaying unique specific management assets, are  
43 seen as exhibiting inherently differentiated levels of efficiency and sustainable  
44 production, which are ultimately a return on the unique assets owned and controlled by  
45 the hospitals (Teece et al., 1997). The property resource is the main factor segmenting  
46 the sample. In addition, the strategic-groups theory (Caves and Porter, 1977), which  
47 justifies different efficiency scores on the grounds of differences in the structural  
48 characteristics of units within an industry or sector, could partially explain the  
49 differences observed in the efficiency of Portuguese hospitals. All these dynamics are  
50  
51  
52  
53  
54  
55  
56  
57  
58  
59  
60

1  
2  
3 derived from a clear allocative contract that minimises transaction costs and property  
4 rights (Klein, Crawford and Alchian, 1978; Williamson, 1979, 1985).  
5  
6  
7

## 8 9 **References**

10  
11 Aigner, D.J., Lovell, C.A.K. and Schmidt, P. (1977). Formulation and estimation of  
12 stochastic frontier production function models, *Journal of Econometrics*, 6, 21-37.  
13

14  
15 Barbeta, G.P.; Turati, G. and Zago, A.M. (2007). Behavioural Differences between  
16 Public and Private Non-Profit Hospitals in the Italian Health Service. *Health*  
17 *Economics*, 16,1,75-96  
18

19  
20  
21 Barney, J. (1991). Firm resources and sustained competitive advantage, *Journal of*  
22 *Management*, 17, 99-120.  
23

24  
25  
26 Barros, C.P.; Menezes, A.G.; Peypoch, N.; Solonandrasana, B. and Vieira, J.C. (2008)  
27 Na analysis of hospital efficiency and productivity growth using the Luenberger  
28 indicator. *Health Care Management Science*, 11,4,373-381  
29

30  
31  
32 Battese, G.E. and Coelli, T.J. (1988). Prediction of Firm-level technical efficiencies  
33 with a generalised frontier production function and panel data. *Journal of Econometrics*,  
34 38, 387-399.  
35  
36

37  
38  
39 Blank, J.L.T. and Eggink, E. 2004. The Decomposition of Cost Efficiency: An  
40 Empirical Application of the Shadow Cost Function Model to Dutch General Hospitals.  
41 *Health Care Management Science*, 7,2, 79-88.  
42  
43

44  
45  
46 Breyer, F. (1987) The specification of a hospital cost function. *The Review of*  
47 *Economics and Statistics*, 79, 3, 443-453.  
48

49  
50 Burgess, J.F. and Wilson, D.W. 1983. Technical Efficiency in Veterans Administration  
51 Hospitals. In Fried, H.O.; Lovell, C.A.K. and Schmidt, S.S. (eds) *The Measurement of*  
52 *Productivity Efficiency: Techniques and Applications*. Oxford, Oxford University Press,  
53 335-351.  
54  
55  
56  
57  
58  
59  
60

1  
2  
3 Caves R. and Porter M.E. (1977). From entry barriers to mobility barriers: Conjectural  
4 decisions and contrived deterrence to new competition. *Quarterly Journal of Economics*  
5 91, 241-261.  
6  
7

8  
9  
10 Caves, D.W. and Christensen, L.R. (1980). The Relative Efficiency of Public and  
11 Private Firms in a Competitive Environment: The Case of Canadian Railroads". *The*  
12 *Journal of Political Economy*, 88,5, 958-976.  
13  
14

15 Dalmau, E. and Puig-Junoy 1998. Market Structure and Hospital Efficiency: Evaluating  
16 Potential Effects of Deregulation in National Health Service. *Review of Industrial*  
17 *Organization*, 13, 447-466.  
18  
19

20  
21  
22 Dismuke, C.E. and Sena, V. 2004. Has DRG payment influenced the technical  
23 Efficiency and Productivity of Diagnostic Technologies in Portugal Public Hospitals: An  
24 Empirical Analysis using parametric and non-parametric methods. *Health Care*  
25  
26  
27

28  
29  
30  
31 Friesner, D.; Rosemanand, R. and McPherson, M.Q. (2007) Are\_hospitals seasonally  
32 inefficient? Evidence from Washington State. *Applied Economics*, 40, 6,, Pages 699 –  
33 723  
34  
35  
36

37  
38  
39  
40 Greene W. (2000). *Econometric Analysis (4<sup>th</sup> ed.)*; London, Prentice Hall  
41

42  
43 Greene, W. (2005). Fixed and random effects in stochastic frontier models, *Journal of*  
44 *Productivity Analysis*, Vol. 23, pp. 7-32.  
45  
46

47  
48 Greene, W. (2004). Distinguishing between heterogeneity and efficiency: stochastic  
49 frontier analysis of the World Health Organisation's panel data on national health care  
50 systems. *Health Economics*, 13, 959-980.  
51  
52

53  
54 Hadley, J. and Zuckerman, S. (1994) The role of efficiency measurement in hospital  
55 rate setting. *Journal of Health Economics*, 13, 335-340.  
56  
57  
58  
59  
60

1  
2  
3 Klein, B.; Crawford, R.C. and Alchian, A. (1978) Vertical Integration, Appropriate  
4 Rents, and the Competitive Contracting Process. *Journal of Law and Economics*, 22,  
5 297-326.  
6  
7

8  
9 Maniadakis, N. and Thanassoulis, E. (2000). Assessing productivity changes in  
10 UK hospital reflecting technology and input price. *Applied Economics*, 32,12, 1575 –  
11 1589  
12  
13

14  
15 Meeusen, W. and van den Broeck, J. (1977). Efficiency estimation from a Cobb-  
16 Douglas production function with composed error. *International Economic Review*, 18,  
17 435-444.  
18  
19

20  
21 Orea, L., and Kumbhakar, S. (2004). Efficiency measurement using a latent class  
22 stochastic frontier model. *Empirical Economics*, 29, 169-183.  
23  
24

25  
26 Ozcan, Y.A. and Luke, R.D. 1993. A national study of the efficiency of hospitals in  
27 urban markets. *Health Services Research*, February, 719-739.  
28  
29

30  
31 Parkin, D. and Hollingsworth, B. (1997) Measuring production efficiency of  
32 acute hospitals in Scotland, 1991-94: validity issues in data envelopment analysis.  
33 *Applied Economics*, 29,11,1425 – 1433  
34  
35

36  
37  
38 Prior, D. (1996) Technical efficiency and scope economies in hospitals. *Applied*  
39 *Economics*, 28, 10, 1295 – 1301.  
40  
41

42  
43 Rosko, M.D. 2001. Cost efficiency of US hospitals: a stochastic frontier approach.  
44 *Health Economics*,10, 6: 539-551.  
45  
46

47  
48 Rumelt, R. (1991). How much does industry matter? *Strategic Management Journal*,  
49 12, 2, 167-185.  
50  
51

52  
53 Siciliani, L. 2006. Estimating technical Efficiency in the Hospital Sector with Panel  
54 Data: A Comparison of Parametric and Non-Parametric Techniques. *Applied Health*  
55 *Economics & Health Policy*, 5,2, 99-116.  
56  
57

58  
59 Skinner, J. (1994) What do stochastic frontier cost functions tell us about inefficiencies?  
60 *Journal of Health Economics*, 13, 323-328.

1  
2  
3 Staat, M. (2006) Efficiency of hospital\_in Germany: a DEA-bootstrap approach.  
4 Applied Economics, 38, Issue 19, 2255 – 2263  
5  
6

7  
8 Steinmann, L. and Zweifel, P. (2003) On the (in)efficiency of Swiss hospitals. Applied  
9 Economics, 35, Issue 3, 361 – 370  
10  
11

12 Teece D.; Pisano G. and Shuen A. (1997). Dynamic capabilities and strategic  
13 management. *Strategic Management Journal*, 18, 7, 509-533.  
14  
15

16  
17 Varian, H.R. (1987). *Intermediate Microeconomics: A Modern Approach*. New York,  
18 W.W. Norton & Co.  
19  
20

21  
22 Williamson, O. (1981) The economics of organization: The transaction costs approach.  
23 American Journal of Sociology, 87, 548-577.  
24  
25

26  
27 Williamson, O. (1985) *The Economic Institutions of Capitalism: Firms, Markets and*  
28 *Vertical Contracting*. Free Press, N.Y.  
29  
30  
31  
32  
33  
34  
35  
36  
37  
38  
39  
40  
41  
42  
43  
44  
45  
46  
47  
48  
49  
50  
51  
52  
53  
54  
55  
56  
57  
58  
59  
60