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

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**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

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

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8 The aim of the present study goes beyond previous research by adopting the  
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10 latent frontier model, in line with Orea and Kumbhakar (2004). The work's objective is  
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12 to combine operational and financial variables in the evaluation of hospital efficiency  
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14 (Skinner, 1994). The distinctions between these groups of factors - operational and  
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16 financial - means that merging the two constitutes a technical problem that requires the  
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18 support of econometric techniques, such as frontier models. The motivation for the  
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20 present research is based on the fact that hospitals in Portugal can be identified as  
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22 having either public, private, or mixed status. The aim of this paper is to investigate the  
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24 statistical factors that characterise the hospitals, clustering the sample in segments  
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26 enabling us to define specific health policies for identified segments and to monitor  
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28 each group with adequate targets. This procedure permits a more focused, cost-effective  
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30 health policy, which can be generalised and applied to samples other than that for  
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32 Portugal.  
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38 The contribution of this paper within hospital research is twofold. First, it adopts  
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40 an innovative stochastic frontier model, which endogenously identifies segments of  
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42 hospitals in a sample, overcoming the hypothesis of homogeneity of the variables  
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44 adopted by the frontier models mentioned earlier. Secondly, it applies the model to  
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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  
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50 regulate the service as a whole (Hadley and Zuckerman, 1994).  
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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
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3 The hospitals with the lowest cost efficiencies are CH Vila Real Peso da Regua and H  
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5 Senhora da Oliveira – Guimarães. It should be emphasised that these two hospitals are  
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7 located in small towns in the north of mainland Portugal. The highest cost-efficiency  
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9 scores are achieved by CH Baxo Alentejo, CH Torres Vedras, H Divino Espirito Santo  
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11 and H Mirandela.  
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16 Concerning the comparison between the standard stochastic frontier and the latent  
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18 class model efficiencies, it is worth indicating that the rankings are preserved and the  
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20 latent frontier displays greater cost efficiency for all hospitals. The average difference is  
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22 0.036, which is rather significant. Likewise, the differences are not consistent for all  
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24 hospitals, implying that the latent class model efficiencies are not merely a constant  
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26 added to the standard stochastic frontier model.  
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## 32 **5. Discussion and Conclusion**

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35 The interpretation of the obtained results is as follows. First, they allow us to  
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37 conclude that latent frontier models describe the Portuguese hospitals well, when  
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39 allowing for heterogeneity and defining segments in the sample. This is possibly the  
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41 most significant finding of the present paper. The implication of this result is that a  
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43 common government policy would be inappropriate for all hospitals, since the three  
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45 segments identified point to the existence of heterogeneity. Therefore, any health policy  
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47 which involves some of these heterogeneous variables should be tailored according to  
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49 the segments. Second, our analysis has led us to identify three segments. However, this  
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51 does not mean that there are only three segments to be found in the Portuguese hospital  
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53 network (Dismuke and Sena, 2004). Rather, it signifies that given the small number of  
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55 observations available, the model cannot distinguish more segments. The third finding  
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57 is that hospitals in the first segment are defined as generic Portuguese hospitals, a  
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3 picture that emerges with traditional homogenous frontier models (Barros et al. 2008).  
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5 These hospitals are characterised by the outputs and inputs increasing the costs, which  
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7 have a positive relationship with *RAA* and a negative relationship with *SA*, *DivK* and  
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9 *quality*, signifying that these variables decrease costs. However, *DivK* is not statistically  
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11 significant. The results for the first segment are intuitive and in accordance with the  
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13 economic theory (Cf. Varian, 1987).  
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17 In the second segment, the hospitals' costs have the same relationship with outputs,  
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19 inputs and input prices. Moreover, the dummy variables have the same relationship with  
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21 costs that was observed in the first segment, with the exception of quality, which is now  
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23 positive. These are hospitals that have adopted the quality standards, but do not  
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25 maintain them. The third segment is distinct from the other two, based on the negative  
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27 sign of *DivK*, i.e., hospitals serving more than one county, which is now positive and  
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29 statistically significant.  
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33 What is the overall rationale for these results? They are in fact quite intuitive, since  
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35 hospitals are not homogenous. For instance, there are small and large hospitals in the  
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37 sample. These tangible characteristics result in different performance levels, dissimilar  
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39 flux and discrepancies in their financial debts, which account for the different segments  
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41 in the sample. In the case of the Portuguese hospitals, there are three different segments  
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43 that can be distinguished on the grounds of the values and signs of the exogenous  
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45 variables.  
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49 With regard to the implications of the results, first, there is evidence that private  
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51 hospitals (*SA*) are more efficient than public hospitals, since *SA* characteristics decrease  
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53 costs. This outcome is based on the negative sign of the attributes of private hospitals.  
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55 This result is also supported in previous research in this field, with alternative models.  
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58 This result serves as a cross-validation of previous results in this field.  
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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).  
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7 However, those hospitals that do not maintain the quality procedures resort to using  
8 them as a device to conceal bad managerial practices.  
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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).  
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23 Finally, given the sign of the variable *RAA* in all segments, the mainland hospitals  
24 seeking profits perform efficiently (Barney, 1991; Rumelt, 1991).  
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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.  
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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  
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3 derived from a clear allocative contract that minimises transaction costs and property  
4 rights (Klein, Crawford and Alchian, 1978; Williamson, 1979, 1985).  
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