A multilevel model to estimate unavoidable costs and to disentangle allocative inefficiencies of hospital care

Monica Oliveira[1]
Operational Research Department and LSE Health and Social Care, London School of Economics and Political Science, U.K.

Gwyn Bevan[2]
Commission for Health Improvement and Operational Research Department, London School of Economics and Political Science, U.K.

Abstract

Unavoidable costs of hospital care are defined as those costs that lie outside the control of hospital management. Estimates of these costs of hospital care are crucial to inform policies designed to promote equity and efficiency. The objective of this study was to build a model to estimate unavoidable costs of Portuguese hospitals, which is generalisable to other countries. We have developed a multilevel model that estimates total costs per unit of measurable output and identifies causes of variations in hospital costs. This model makes use of random intercepts and random slopes to decompose the different causes of allocative inefficiency; and follows an integrated approach to estimate unavoidable costs. Application of the model to Portugal shows: the ratio beds to doctors is a key component of allocative inefficiency; larger hospitals have diseconomies of scale and are most affected by allocative inefficiencies; and lack of flexibility and the existence of perverse incentives in the system are accountable for a significant level of avoidable costs.

1 Objectives

Unavoidable costs (UCs) of hospital care are defined as those costs that lie outside the control of hospital management. Modelling UCs provides crucial information for equity and efficiency analysis (McGuire and Hughes 2002).

The ultimate objective of this study is to build a measure of the relative levels of UCs for the Portuguese district level. UCs are dealt at the hospital level, which can be aggregated to district level. This study develops a different approach to that of previous studies in estimating UCs. The approach in use recognises that variations in hospital costs can be explained by compositional effects of individual hospitals, by contextual effects of hospitals in different levels of an administrative hierarchy, and hospital location in different geographic areas. The model is also used to decompose for sources of allocative inefficiency. The model was developed in the context of the Portuguese health care system, but can be adapted to other countries, where there is some central control over planning and management of the hospital network, no competition between hospitals and little flexibility in hospital management tools.

This paper consists of five further sections which: structure the problem of building adjustments for UCs; build hierarchical models to estimate UCs; describe the application of the models to Portugal; discuss results and further research; and make concluding remarks.

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[2] Author currently on secondment to the Commission for Health Improvement, U.K.. The views of this paper are those of the authors and do not reflect policies of the Commission for Health Improvement.

2 Problem structuring

This section briefly: reviews previous studies that derived estimates of UCs; describes problems of related literature, such as on economies of scale and scope; and reviews the literature on the Portuguese hospital system relevant to model UCs.

2.1 Unavoidable cost adjustments

A review of the approaches used in estimating UCs in resource allocation in different countries shows that: several approaches have been used; modelling is complex; and the approach taken is highly influenced by the country and by systems of hospital finance. Most of adjustments for UCs begin by defining 'legitimate' differentials in provider costs, defined as components of costs that hospital managers cannot reduce. 'Legitimate' differential costs are mostly explained by (Hutchison et al. 1999): variations in the external environment of hospitals and variations in internal factors (in some cases). Examples include:

1. *Costs implied by economies of scale and scope of hospital care.* Scotland is one of the few countries that adjust for the impact of economies of scale and scope on hospital costs, using estimates produced by a behavioural cost function model (Scottish Office 1999)[3].
2. *Costs implied by variations in input prices.* The Netherlands applies regional factors, depending on levels of urbanisation (favouring urban areas) (Rice and Smith 1999); and England adjusts for differential staff costs and costs of capital, which again favours urban areas (mainly London) (Resource Allocation and Funding Team 2000);
3. *Costs implied by different mixes on health care provision*, such as the public/private and the primary/secondary care mixes in provision. Australia has considered private provision as a substitute for public expenditure and deducted from the public budget a component for the private provision of services evaluated at DRG prices (Rice and Smith 1999).
4. *Costs of delivering health care services in rural areas.* Northern Ireland, Finland, New South Wales, New Zealand, Scotland and Wales (Rice and Smith 1999) and England (for emergency ambulance service) (Townsend 2001) have been adjusting for these costs.
5. *Costs of delivering care to specific disadvantaged groups.* Australia weights costs of delivering to Aboriginal islanders by 2.5 and England is adjusting for ethnicity (Townsend 2001)[4].

For the hospital sector, the most important components of the UCs are the first, second and third of these adjustments. Although these elements might interact (for example, analysis of economies of scale cannot disregard input prices), most of the adjustments in use have focused on some dimensions of UCs to the exclusion of others. This paper describes an integrated approach for estimating UCs that considers the literature on cost functions, efficiency, economies of scale and scope, input prices, etc and aim to account simultaneously for the effects of these elements. The next sub-section briefly reviews literature on economies of scale, scope and efficiency and describes the implications of that literature in the estimation of UCs.

2.2 Related literature

There is a diverse literature on hospital cost functions. Many studies recognise the impact of hospital characteristics (including size and scope) on hospital costs, after controlling for variations on location, external factors, etc. However, there is no consensus in the existence and degree of importance of economies of scale and scope: in 1972, Berki (Berki 1972) postulated that economies of scale 'ought to exist'; Vitaliano (Vitaliano 1987) has shown that there is a lack of consensus on the existence of an optimal size; the review by Aletras et al. (Aletras, Jones, and Sheldon 1997) reported that the extent of existence of economies of scale is unknown; and McGuire and Hughes (McGuire and Hughes 2002) have summarised the conflicting conclusions on the existence of economies of scale and how those

[3] The problems involved in modelling economies of scale and scope are discussed in the next sub-section and partly justify why most countries have not used this type of adjustment.

[4] This adjustment can be seen either as an extra-needs adjustment factor above demographic factors, or as an extra-cost to deliver care by hospital units.

conclusions related with the techniques of estimation. This lack of consensus relates to many problems, such as: the complexity of adequately measuring hospital output; a multiplicity of variables and aspects that influence the behaviour of hospital agents and thus on costs (Vitaliano 1987); the use of different methods, functional forms and methodological choices (Folland and Hofler 2001)[5]; it has proved difficult to disentangle different sources of variation in costs, such as variations in efficiency (Newhouse 1994); most of the studies have made the often unjustifiable assumption that hospitals behave as cost minimisers (Cremieux and Ouellette 2001). In modelling cost functions, many studies have controlled for geographic variations that have been statistically significant (Lave and Lave 1970) (Grannemann and Brown 1986) (Vitaliano 1987) (Zuckerman, Hadley, and Iezonni 1994). However, there has not been a common framework for treating the influence of geographic and other external variables such as prices and environment, and it is not known whether these variables are important *per se*, or capture the effects of other confounding, which have not been considered.

The two main approaches for estimating hospital cost functions to take account of inefficiency have been the two frontier methods of data envelopment analysis (DEA) and stochastic frontier methods (SFM). DEA computes the frontier practice isoquant (Folland, Goodman, and Stano 1997) and computes distances between the hospital cost and/or output and the frontier, as a measure of technical inefficiency. The DEA method is, however, insensitive to random/unobserved shocks (Folland, Goodman, and Stano 1997) and makes critical assumptions on returns to scale. SFMs overcome DEA's weaknesses of not considering random variation, estimate the stochastic frontier using econometric modelling, and are based on the theory of the firm to link hospital inputs and outputs to costs. Given the objective of estimating UCs and of not imposing constraints on making assumptions on returns to scale, the SFM approach is to be preferred to DEA.

There are two main types of SFMs: *ad hoc* models and flexible cost functions (such as translog models). Translog models suffer from various disadvantages[6]. *Ad hoc* models seem to perform better for dealing with technical and allocative efficiency, for producing estimates for hospitals in the whole range of the network and for forecasting costs, although they face other problems in imposing constraints to the technological function they assume (i.e., the link between inputs, outputs and prices).

Recent studies on SFMs indicated a preference for using fixed and random effects, which allow for adjusting the intercepts so that the cost frontier shifts to the appropriate level between groups of hospitals (Linna, Hakkinen, and Linnakko 1998). Nevertheless, there has been little theoretical guidance on the distributional assumptions used in random effects models (Linna, Hakkinen, and Linnakko 1998). Some authors point out that some of the techniques require strong assumptions that cannot be tested (Newhouse 1994) (such as in the technological production function used in some studies). SFMs also have been criticised as they neglect systematic inefficiency (Zuckerman, Hadley, and Iezonni 1994)[7].

Consequently, there are many difficulties in modelling hospital cost functions. Some additional difficulties arise in the use of this type of literature for resource allocation:

- The use of utilisation data without adequate control for factors such as quality and inefficiency might create perverse incentives in using the resulting estimates in a funding formula.
- It is not clear if some of the adjustments being carried out are significant (such as the staff market forces factor for Scotland (Townsend 2001)) or meaningful as their precise purpose has not always been clear (Rice and Smith 1999).

[5] For example, it has not always been clear whether it is more appropriate to use short or long run estimations and on which design options to choose (ex: pooled vs. partitioned data).

[6] Some of the disadvantages of translog models are: do not allow for distinguishing between allocative and technical efficiency (Folland and Hofler 2001) as their estimation produces small residuals and the estimates of costs are near deterministic; provide estimates of coefficients that should be interpreted only for average values of the sample (Vita 1990) (Linna, Hakkinen, and Linnakko 1998) and they are more useful when the focus of research is on the hospital production function (Li and Rosenman 2001).

[7] These criticisms apply to the model developed in this study.

- Determinants of costs reflect the system of incentives to key hospital actors and the characteristics of previous financing system, and it might be difficult or not possible to control for these effects. These elements have been shown to be critical for the Portuguese case, and often apply to other countries.

2.3 The Portuguese context

It is vital to take account of the characteristics of the Portuguese hospital system in designing cost models. This sub-section describes the country information setting that should inform modelling on UCs.

2.3.1 Related literature review

There have been several studies of costs and production functions of Portuguese hospitals: (Paiva 1993) (Lima 1998) (IGIF 1999) (Barros and Sena 1999) (Carreira 1999) (Lima 2000). The main criteria for analysing (and assessing) those studies were taken from Aletras et al. (Aletras, Jones, and Sheldon 1997). Analysis of these studies shows:

1. Variation in the objectives and sophistication of techniques used. Most studies aimed to understand the nature and the structure of hospital costs (making use of translog models). Not all the studies seem to have adequately controlled for confounding variables, such as for the use of several inputs.
2. Most studies support the idea that hospitals with an average size between 200-300 beds (mostly district hospitals) seem to be operating with economies of scale, while hospitals with average size between 600-800 beds (mostly central hospitals) seem to be operating with diseconomies of scale.
3. Some studies make use of the cost minimisation assumption for the behaviour of Portuguese hospitals; and several studies have pointed out high variations on efficiency scores. The assumption of cost minimisation does not reflect the system within which Portuguese hospitals operate.
4. Most studies have described the high variability of input ratios, output ratios and costs of Portuguese hospitals, even between hospitals of the same administrative group and with similar characteristics. This heterogeneity in hospital characteristics creates problems in estimating costs, inefficiencies and economies of scale and scope (as it requires multiple controls).

2.3.2 Country information-setting

Since 1979 Portugal has a NHS based on the principles of universal access to health care (nearly) free at the point of use, and on a financing system based on general taxation. This section focuses on three areas to characterise the hospital sector: the administrative hierarchy of the hospital system, payment systems and incentives, and efficiency-related patterns.

Administrative hierarchy. Portuguese hospitals are classified in an administrative hierarchy (from central to level I hospitals) that shows a decreasing order of technological complexity on the treatment of illnesses, and a decreasing size of catchment areas of hospital provision:

- *Central and general hospitals* provide highly specialised services with advanced technology and specialist human resources.
- *Central and specialised hospitals* focus on a range of specialised services. Both general and specialised hospitals tend to be located in the main urban centres.
- *District hospitals* provide a range of specialist services, and are located in the district capital. In general, there is at least one district hospital in each geographic district.
- *(District) Level I hospitals* are at the base of the hierarchy and provide internal medicine, surgery and one or two other basic specialties only. They tend to be located in small towns.

Hospitals at the bottom of the hierarchy send patients to hospitals at the top of the hierarchy, as they do not provide all specialties treatment. There is a referral system between GPs and hospitals, and between hospitals, but there are in practice admissions outside the referral system.

Payment systems and incentives. Portuguese hospitals are public, not for profit and expected to pursue social objectives. Hospital managers have weak incentives to operate within the hospital budget constraint: hospital budgets are determined mainly by historical reimbursement and partly by production levels. There are no penalties for systematic budget overruns. Hospital administrators operate within a highly centralised system of planning and have little autonomy in decisions on investment and human resources. There is no charging system for capital costs. Hospital administrators have little control over hospital doctors. Doctors are paid by salary, have a dual employment status, which gives them little incentive to be productive in public hospitals, as they generate income in the private and by working overtime hours in the public. There is little accountability and hence scope for inefficiencies and problems for cost containment. Although hospitals are expected to charge for their services to private insurers, this is not consistent in practice.

Efficiency-related patterns. Evidence suggests that for smaller hospitals, a lack of doctors has constrained the use of beds (the converse probably applies in large hospitals). The ratio of nurses to doctors is low and is expected to have an adverse impact on productivity levels and costs. Doctors located in urban areas tend to have a lower productivity, as they also work in the private sector. There is also evidence of various factors that impact on both allocative and technical efficiency:

- High variations in the mix of inputs of doctors/nurses/beds provide evidence of variations in allocative efficiency across hospitals;
- High levels of outsourcing for services with high levels of technology, and outsourcing is higher for urban hospitals;
- There is no central policy in the purchase of pharmaceuticals and of goods and services, which might explain variations on these costs.

There is a lack of information on: the impact of quality on costs; on the levels of private activity in public hospitals; and on the effect of deficiencies in long-term and home care on hospital costs. Accessibility of populations to hospitals highly varies within Portugal.

The foregoing suggests that in the Portuguese context, a method for adjusting for UCs should:

1. Avoid assumptions of cost minimisation;
2. Aim to capture how payment systems and hospital organisation are influencing the hospital cost structure;
3. Focus on how different input mixes result in allocative inefficiencies at the hospital or at the hospital group level; and
4. Deal with structural differences between:

- Hospitals at different levels of the administrative hierarchy (that relate with size and scope);
- Input prices;
- Geographic variations.

3 Stochastic hierarchical models

This section presents a summary of the methodological approach, the cost and hierarchical model, and then describes the development of that model into two models, referred as: HFEM for the Hierarchical Fixed Effects Model and MLM for the multilevel model with random intercepts and slopes.

3.1 Methodological approach

The methods developed in this paper are normative[8] and follow an integrated approach[9]. The choice for an integrated approach to model UCs implies a simultaneous treatment of input prices, inefficiencies, economies of scale and scope and other factors on the model. The objective is to build a measure of hospital UCs at the hospital level, which accounts for individual hospital characteristics, for structural differences by hospital type, and for variations in geographic location; and that deals with well-specified sources of allocative inefficiency. The proposed stochastic model is based on hierarchical and multilevel techniques. The proposed model:

a. Uses **the total cost per unit of output as the dependent variable**, so as to create a standardised indicator that is compatible across areas.
b. Focuses on **structural differences between hospitals and between hospital groups** at different levels of the administrative hierarchy.

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[8] E.g. it is used an explicit framework to justify the choice of methodological options. This is required in the context of high variability of model results due to different methods and techniques.

[9] It is not clear for Portugal which specific factors matter for the highest component of UCs.

c. Presents **two different models: the hierarchical fixed effects model and the multilevel model**. The hierarchical fixed effects model is a simpler model that uses dummies to control for the administrative classification of the hospital; is used as a benchmark for comparing with the MLM model. The multilevel model uses random intercepts and slopes across different levels of the network, and the purpose of these random intercepts and slopes at the hospital group is to identify the different sources of allocative inefficiency.
d. **Controls for a wide range of variables** that impact on costs: geographic area variations, hospital size, input prices, input mixes and indicators of the hospital cost structure.
e. Makes use of an ***ad-hoc* approach to disentangle between allocative inefficiency** effects and to estimate the level of costs (Vita 1990). An *ad hoc* approach is more compatible with the choice of not imposing cost minimisation assumptions, and it does so by **controlling for the influence of past hospital decisions and the historical level of funding** on hospital costs.

Table 1 contains the notation in use. Given that any hospital i belongs to a hospital group j and to a geographic area k, the indexes j and k are omitted in some of the variables. The index i is taken as the key identifier. The index l represents an alternative hospital group classification for which information on unit costs is available.

Table 1: Notation of the study

Notation	*Interpretation*
i , i'	Hospital identifier ($i = 1,...,n$) ($i \neq i'$)
j	Types of hospital in the administrative (and hierarchical) classification ($j = 1,...,m$) (for Portugal: $j =$ general and central, specialised and central, district, level I)
k	Geographic place of location ($k = 1,...,r$)
l	Type of hospital in the costs' statistics classification ($l = 1,...,s$) (for Portugal: $l =$ central, district, level I)
$COutput_i$	Total cost standardised by an index of hospital production. This indicator is referred to as standardised cost
$TotCost_i$	Total cost
$OutputIndex_i$	Equivalent patients index
$Disch_{il}$	Number of hospital inpatient discharges of hospital i (hospital i that belongs to hospital group l)
$Outpat_{il}$	Number of outpatients attendances of hospital i (hospital i that belongs to hospital group l)
$Emerg_{il}$	Number of emergency and accident admissions of hospital i (hospital i that belongs to hospital group l)
a_l , b_l , c_l	Total unit costs from hospitals of type l , for inpatient discharges, outpatients attendances and emergency and accident admissions, respectively
d_i	Numbers of doctors
n_i	Number of nurses
b_i	Number of beds
C , C'	Function linking the standardised cost with the covariates; and linear function linking the natural logarithm of standardised cost with the covariates
α , β , θ	Parameters from the general hierarchical model
$x_i^{'}$, $x_i^{''}$, x_i	Explanatory variables vector for standardised costs (x_i). $x_i^{'}$ is the sub-set of variables that have a log-linear function relationship with the dependent variable ($x_i^{'} \subset x_i$); and $x_i^{''}$ is the sub-set of variables with a semi-log function relationship with the dependent variable ($x_i^{''} \subset x_i$).
e_i	Random error for the general hierarchical model
α_0 , α_1	Coefficients of the fixed part of the HFEM (excluding the geographic and hospital group related coefficients)
g_{ik}	Dummy variables for the geographic location of hospital i in place k (HFEM and MLM)
α_{2k}	Fixed coefficients for dummies of the geographic area k (geographic related coefficients) (HFEM)
t_{ij}	Dummy variables for the hospital i in the administrative hierarchy j (HFEM)
α_{3j}	Fixed coefficients for dummies of the administrative group j (HFEM)

e_{ijk}^{HFEM}	Random error for the HFEM
$\beta_0, \beta_1, \beta_2, \beta_3$	Coefficients of the fixed part of the cost model (excluding geographic-related and hospital group related coefficients) (MLM)
β_{4k}	Fixed coefficients for dummies of the geographic area k (geographic related coefficients) (MLM)
β_{0j}	Random coefficient of the random intercept of the MLM, defined at the hospital administrative group level
β_{1j}, β_{2j}	Random coefficients of the random slopes of the MLM, defined at the hospital administrative group level; β_{1j} and β_{2j} are the random coefficients of the nurses to doctors and beds to doctors ratios, respectively
μ_{0j}	Random component of the random coefficient of the MLM, defined at the hospital administrative group level
μ_{1j}, μ_{2j}	Random component of the random slopes of the MLM, defined at the hospital administrative group level
e_{ijk}^{MLM}	Random error at the hospital level (MLM)
$\sigma_{\mu 0}^2$, $\sigma_{\mu 1}^2$, $\sigma_{\mu 2}^2$	Variances of the random components of the model at the group level. $\sigma_{\mu 0}^2$ is the variance of the random component of the intercept, while $\sigma_{\mu 1}^2$ and $\sigma_{\mu 1}^2$ is the variance of the random component of the slopes (MLM)
σ_{e0}^2	Variances of the error term at the hospital level (MLM)
σ_{01}, σ_{02}, σ_{12}	Set of covariance between the random components, defined at the group level (MLM)

3.2 Hierarchical cost model

This subsection is divided in a description of the underlying cost model and in a decomposition of this model into the hierarchical cost model.

3.2.1 Cost model

Given that the objective is to compare UCs between hospitals, the dependent variable is the total cost per level of measurable output (afterwards referred as standardised cost). Measurable output is defined as inpatient discharges, outpatient attendances and emergency and accident admissions. As hospital output is multidimensional by nature, these outputs are aggregated in an equivalent patients index as presented in equation 1. This index weights inpatient discharges, outpatient attendances and accident and emergency admissions by the coefficients of total unit costs per hospital type (l) for each of these outputs. The standardised cost is computed by the ratio presented in equation 2.

$$OutputIndex_i = \sum_l \left[\frac{Disch_{il} * a_l + Outpat_{il} * b_l + Emerg_{il} * c_l}{a_l + b_l + c_l} \right] \quad (1)$$

$$COutput_i = \frac{TotCost_i}{OuputIndex_i} \quad (2)$$

In the context of a public system operating inside a NHS, the variables that affect the standardised cost are[10]: price of inputs and price of intermediate inputs; relative mix of raw inputs and relative mix of intermediate inputs; hospital size, type of hospital (administrative group) and potential economies of scale and scope; complexity of the output; quality; hospital cost structure; hospital location; inefficiency and previous levels of funding. It is not assumed that hospitals are cost minimisers: some covariates capture inefficiencies or other avoidable costs components. This *ad hoc* model is not derived from a specific assumption of hospital behaviour.

[10] This list accounts indirectly for the multidimensional nature of output and for the unobserved price of hospital output and the fact that market mechanisms are very weak and there are no explicit prices.

The model developed in this study differs from the SFM approach. Mainstream SFMs have assumed a positive distribution of the error term structure (error at the hospital level) that imply: covariates capture the frontier/envelope of costs; the errors represent positive deviations to that absolute frontier/envelope and are interpreted as indicators of technical inefficiency. The methods used in this study do not assume a positive distribution of the error, but a normal distribution. This is due to constraints imposed by the software available to estimate multilevel models. Given the lack of data on quality, technical efficiency and other variables, the error term should not be interpreted as a full component of technical inefficiency. The model imposes a log-linear or a semi-log relationship between the standardised cost and the covariates (functional relationships as defined in (Gujarati 1995)) as shown in equation 3.

$$COutput_i = \alpha * x_i^{''\beta} * e^{\theta * x_i^{'}} * e^{e_i} \quad (3)$$

This cost model is developed to integrate the hierarchical structures of geographic location and of administrative types of hospitals in the following sub-sections.

3.2.2 Hierarchical model

The hierarchical model differs from the cost model presented in equation 3 as it makes explicit the hierarchical structures. A multilevel structure[11] is available in (Snijders and Bosker 1999). Taking into account the composition and the context of each hospital in the network, and making use of that multilevel structure classification, a hierarchical model for the hospital sector considers that:

a. Hospitals are level-1 units (i level in the hierarchy). The covariates at this level relate to the composition and characteristics of individual hospitals.
b. Hospitals belong to one group from the administrative hierarchy (j level in the hierarchy), which corresponds to a level-2 unit. The covariates at this level relate to the context of hospital care, as captured by structural differences between administrative groups of hospitals.
c. Hospitals belong to one geographic area (k level in the hierarchy) that corresponds to another alternative level-2 unit. The covariates at this level relate to the context of hospital care, as captured by location.

Equations 4 and 5 give the generic hierarchical structure of the cost model and the logarithmic structure of the model to be estimated, respectively. That logarithmic structure is used given the assumptions of the model and the ‘expected’ skewed distribution of the distribution of standardised costs. The logarithm structure suits the objectives of normalising the cost distribution.

$$COutput_{ijk} = C_{ijk}(x_{ijk}) * e^{e_{ijk}} \quad (4)$$

$$\ln(COutput_{ijk}) = C_{ijk}^{'}(x_{ijk}) + e_{ijk} \quad (5)$$

The model assumes that there are systematic variations between hospitals from different groups (both hospital hierarchy and location) and that hospitals within the same group might share a set of characteristics. Hierarchical models can be estimated using two types of models that make use of different assumptions both on the structure of the error (e_{ijk}) and on the association between hospital characteristics and standardised costs[12]. These two models are developed in detail in the next sub-sections:

- **Hierarchical fixed effects model (HFEM).** The HEFM captures variations between areas and across the hierarchy of hospitals under the use of a set of fixed effects for hospital type and for geographic area. This model assumes that the residuals (e_{ijk}) behave as in the assumptions of the classic model, and estimation can be done using the traditional OLS estimation technique[13].

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[11] At this level of analysis, multilevel and hierarchical models are used interchangeably. Nevertheless, in the next sections, these two names will be differentiated.
[12] These two models are not exhaustive of all the meaningful models. The HEFM is built only to compare performance with the MLM.
[13] As explained below, GLM estimation with an identity function is used in the context of this study.

- **Multilevel model with random intercepts and random slopes (MLM)**. In comparison with previous models that have used random effects (i.e., random intercepts) to capture allocative inefficiency, the proposed MLM aims to capture and identify different types of allocative inefficiency. The model uses random intercepts and random slopes to identify sources of allocative efficiency; and it controls for spatial variations under the use of dummies for the geographic area. The MLM makes use of assumptions on the error term (e_{ijk}) that differ from the classical assumptions used in OLS regression, as they account for intra and between-group correlation in the error term structure.

3.3 Hierarchical fixed effects model (HFEM)

Besides the set of covariates that explains variations in costs (defined above and captured by the vector of covariates x_{ij}), the HFEM makes use of dummies to control for hospital administrative hierarchy (captured by the t_{ij}'s) and for geographic variations (captured by g_{ik}'s). The structure of the HFEM is presented in equation 6. This corresponds to a conventional model to be estimated by OLS and with controls for geographic and hierarchical variations made by the use of fixed effects. For the Portuguese context, hospital hierarchy variations are captured in the four level classification described in section 2.3.2: central and general, central and specialised, district and level I hospitals. The spatial classification used is presented in Table 6 (appendix).

$$\ln(COutput_{ijk}) = \alpha_0 + \alpha_1 * x_{ij} + \sum_k (\alpha_{2k} * g_{ik}) + \sum_j (\alpha_{3j} * t_{ij}) + e_{ijk}^{HFEM} \qquad (6)$$

3.4 Multilevel random intercepts and slopes model (MLM)

Multilevel models, random coefficient models and hierarchical linear models have been used interchangeably and stand for types of statistical models that handle simultaneously (within the same model) the micro-scale of observation units and the macro-scale of contexts (Duncan, Jones, and Moon 1998). The multilevel framework has been used to analyse data that fall naturally into hierarchical structures (Carey 2000), have been used in several health and health care areas (Rice and Jones 1997), in particular to address geographic variations (Subramanian, Kawachi, and Kennedy 2001) and to analyse health care provider costs and efficiency (Carey 2000). Several studies have shown the advantages of the multilevel approach over OLS estimation (Rice and Jones 1997). SFMs have used multilevel techniques to decompose the error term into two components of allocative and technical inefficiency[14]. The multilevel approach is useful for analysing hospital systems when the following conditions apply. First, hospitals are organised into administrative hospital groups (as in an organisational hierarchy). Second, effects of hospital organisation and structure (known as 'compositional' effects) affect hospital costs and relate with internal factors including local area characteristics. Third, contextual effects influence hospital activity and costs. As hospitals within the same hospital administrative group, or with geographic location have similar characteristics, the covariance structure of hospital costs should consider the similarities of hospitals within the same administrative group.

Given the objectives of this study and the characteristics just described, it is suggested the use of a multilevel model with random intercepts and with random slopes (afterwards referred by MLM). The MLM deals specifically with the relationship between costs and the mix of inputs that are (expected to) generating allocative inefficiencies. These allocative inefficiencies are defined in the Portuguese context: the input mix of doctors, nurses and beds was identified as a cause for allocative inefficiency. The proposed model is defined in equations 7 and 8. Equation 7 gives the groups of determinants of the MLM. Equation 8 gives the same model, making the split between deterministic and random components explicit.

[14] The weaknesses of this approach were described in section 2.2.

Equation 7: the impact of some of the covariates on standardised costs depends not only on the hospital values but also on the characteristics of the administrative group to which the hospital belongs. This model uses random slopes for two covariates –the ratios of nurses/doctors (β_{1j}) and beds/doctors (β_{2j})-, and for a random intercept (β_{0j}) as components of allocative inefficiencies. The remaining covariates (x_{ij} and g_{ik}) follow the same interpretation of the HFEM.

Equation 8: besides the random effects at the hospital level (e_{ijk}^{MLM}), there are three types of random effects that operate for the hospital group level: one random intercept and two random slopes. Equations 8a-c decompose the random coefficients into a deterministic and a random component. The random intercept (β_{0j}) captures systematic variations in costs between different hospital types. Previous studies have used this component to capture allocative efficiency variations. The use of random slopes in the MLM allows for decomposing the random elements at the group level that relate with the identified allocative inefficiencies on input mix.

$$\ln(COutput_{ijk}) = \beta_{0j} + \beta_{1j} * \left(\frac{n}{d}\right)_{ij} + \beta_{2j} * \left(\frac{b}{d}\right)_{ij} + \beta_3 * x_{ij} + \sum_k (\beta_{4k} * g_k) + e_{ijk}^{MLM} \quad (7)$$

$$\ln(COutput_{ijk}) = \left[\beta_0 + \beta_1 * \left(\frac{n}{d}\right)_{ij} + \beta_2 * \left(\frac{b}{d}\right)_{ij} + \beta_3 * x_{ij} + \sum_k (\beta_{4k} * g_k)\right] + \left[\mu_{0j} + \mu_{1j} * \left(\frac{n}{d}\right)_{ij} + \mu_{2j} * \left(\frac{b}{d}\right)_{ij} + e_{ijk}^{MLM}\right] \quad (8)$$

With:

$$\beta_{0j} = \beta_0 + \mu_{0j} \quad (8a)$$
$$\beta_{1j} = \beta_1 + \mu_{1j} \quad (8b)$$
$$\beta_{2j} = \beta_2 + \mu_{2j} \quad (8c)$$

The proposed model uses a set of assumptions. First, on the distribution of the random elements that follow normal distributions (equations 9a-d).

$$\mu_{0j} \approx N(0, \sigma_{\mu 0}^2) \quad (9a)$$
$$\mu_{1j} \approx N(0, \sigma_{\mu 1}^2) \quad (9b)$$
$$\mu_{2j} \approx N(0, \sigma_{\mu 2}^2) \quad (9c)$$
$$e_{ij} \approx N(0, \sigma_e^2) \quad (9d)$$

Second, on the covariance structure (equations 10a-f): covariances between the level 2 random components and level 1 error are null (10a); and covariances between random components and covariates without random slopes are null (10e-f). Covariances between level 2 random components are estimated within the model (10b-d).

$$\mathrm{cov}(\mu_{0j}, e_{ijk}^{MLM}) = \mathrm{cov}(\mu_{1j}, e_{ijk}^{MLM}) = \mathrm{cov}(\mu_{2j}, e_{ijk}^{MLM}) = 0 \quad (10a)$$
$$\mathrm{cov}(\mu_{0j}, \mu_{1j}) = \sigma_{01} \quad (10b)$$
$$\mathrm{cov}(\mu_{0j}, \mu_{2j}) = \sigma_{02} \quad (10c)$$
$$\mathrm{cov}(\mu_{1j}, \mu_{2j}) = \sigma_{12} \quad (10d)$$
$$\mathrm{cov}(e_{ijk}^{MLM}, x_{ij}) = \mathrm{cov}(\mu_{oj}, x_{ij}) = \mathrm{cov}(\mu_{1j}, x_{ij}) = \mathrm{cov}(\mu_{2j}, x_{ij}) = 0 \quad (10e)$$

$$\mathrm{cov}(e_{ijk}^{MLM}, g_{ik}) = \mathrm{cov}(\mu_{oj}, g_{ik}) = \mathrm{cov}(\mu_{1j}, g_{ik}) = \mathrm{cov}(\mu_{2j}, g_{ik}) = 0 \qquad \text{(10f)}$$

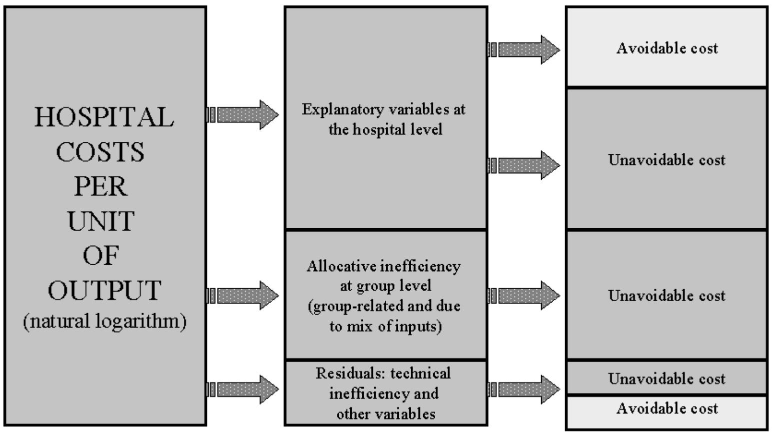
The use of this model implies that the estimated standardised cost for any hospital is not solely based upon its own data, but also by taking account of the value for other hospitals within the same group[15]. This feature is captured by the structure of variance and covariance of the model. The derived structure of variance and covariance (between two hospitals in the same group) of the MLM is shown in equations 11 and 12. These equations show how the variance and the covariance depend on the individual and group values (as remarked, this is a deviation of the classic assumptions of an econometric model).

$$\mathrm{var}\left[\ln(COutput_{ijk})\right] = \sigma_{\mu 0}^2 + \left(\frac{n}{d}\right)_{ij}^2 * \sigma_{\mu 1}^2 + \left(\frac{b}{d}\right)_{ij}^2 * \sigma_{\mu 2}^2 + 2*\left(\frac{n}{d}\right)_{ij} * \sigma_{01} + $$
$$+ 2*\left(\frac{b}{d}\right)_{ij} * \sigma_{02} + 2*\left(\frac{n}{d}\right)_{ij} * \left(\frac{b}{d}\right)_{ij} * \sigma_{12} + \sigma_{e0}^2 \qquad (11)$$

$$\mathrm{cov}\,ar\left[\ln(COutput_{ijk}), \ln(COutput_{i'jk})\right] = \sigma_{\mu 0}^2 + \left(\frac{n}{d}\right)_{ij}\left(\frac{n}{d}\right)_{i'j} \sigma_{\mu 1}^2 +$$
$$+ \left(\frac{b}{d}\right)_{ij} * \left(\frac{b}{d}\right)_{i'j} * \sigma_{\mu 2}^2 + \left[\left(\frac{n}{d}\right)_{ij} + \left(\frac{n}{d}\right)_{i'j}\right] * \sigma_{10} + \qquad (12)$$
$$+ \left[\left(\frac{b}{d}\right)_{ij} + \left(\frac{b}{d}\right)_{i'j}\right] * \sigma_{20} + \left[\left(\frac{n}{d}\right)_{ij} * \left(\frac{b}{d}\right)_{i'j} + \left(\frac{b}{d}\right)_{ij} * \left(\frac{n}{d}\right)_{i'j}\right] * \sigma_{12}$$

The levels of standardised costs are to be adjusted in a set of avoidable and unavoidable costs, as represented in Figure 1. UCs are explained by variables that relate to the characteristics of hospital activity that impact on costs and that are outside the scope of management; definition of UCs depends on the empirical results of the model and is presented in the empirical section (section 4.4).

Figure 1: Decomposition between avoidable and UCs for each group of hospitals



4 Empirical models and results

This section describes the data, variables and sample characteristics, displays results of the estimation of the HFEM and MLM and presents the estimates of UCs per hospital group. It concludes with estimates of a relative index of UCs at the district level.

[15] This is a desirable feature for the model if it is to be used in a resource allocation formula: it minimises the scope for providers reaction in order to influence variables that impact on the estimation of unavoidable costs.

4.1 Data, variables and sample characteristics and estimation techniques

The database consists of 1998 data on: cost, expenditure and production (Instituto de Gestao Informatica e Financeira da Saude 2000); and an index of purchasing power at the small area level (Instituto Nacional de Estatistica, Direccao Geral do Centro, and Gabinete de Estudos Regionais 2000). The database covers 88 hospitals that belong to the NHS and are under public management status. Table 2 gives the set of independent variables at the hospital level that were included in the right hand side of the estimated models. A brief indication is given of the concept that each variable attempts to capture.

Table 2: Variables at the hospital level

Variable (level)	*Interpretation*
Case-mix index	Heterogeneity/complexity output and effective demand parameters.
Length of Stay	Complexity output and demand parameters.
Occupancy rate	Managerial use of beds, incentives and constraints imposed by mix of resources.
Number of doctors	Hospital size and input.
Ratio nurses to doctor	Input mix.
Ratio beds to doctor	Input mix.
Ratio other employees to doctor	Input mix.
Consumption costs as a percentage of total costs and/or consumption costs per unit of production	Intermediate input mix and intermediate input price.
Outsourcing costs as a percentage of total costs and/or outsourcing costs per unit of production	Intermediate input mix and intermediate input price.
Personnel costs as a percentage of total hospital cost and/or personnel costs per unit of production	Input mix and input price.
Other costs (than consumption, outsourcing or personnel costs) as a percentage of total hospital cost and/or other costs per unit of production	Input mix and input price.
Purchasing Power Index of the area where the hospital is located	Input prices.
Non-NHS revenue as a percentage of hospital revenue	Proxy for other output (work for the private).
Number of specialties available	Complexity of output and other hospital outputs.
Dummy for teaching activity	Other hospital outputs.
Growth in hospital expenditure in the last two years	Reflects payment systems for management given finance mostly by historical reimbursement.
Overtime payments by doctors/nurses/doctors, divided by the number of doctors	Reflects system of incentives for management and doctors and nurses, and constraints imposed by the current level and mix of resources.

The model was designed making assumptions and using information as follows:

1. We assumed that hospital output (including case complexity) is adequately captured by the output index (defined in equation 1) together with the case-mix index and the length of stay (that are covariates in the right hand side of equations 6 and 7).
2. We used the hospital administrative group classification described above: central and general hospitals, central and specialised hospitals (includes cancer centres), district hospitals and level I hospitals.
3. We were unable to find adequate proxies for quality, technology and cost of capital as explanatory variables. The list of explanatory variables excludes indicators of these effects. There is no reliable information at the hospital level on quality and technology for Portugal; available data to compute the cost of capital as calculated in previous studies was unreliable (Folland and Hofler 2001).
4. We used doctors as a proxy for hospital size, as they constrain the use of other resources and are closely associated with productive capacity (Oliveira and Bevan 2001).

A summary of statistics is presented in Table 7 in appendix[16].

[16] These statistics show systematic differences between hospital administrative groups: the administrative classification clearly relates to levels of capacity, as indicated by the number of doctors; standardised costs vary across a wide range; they are higher for central and specialised hospitals and lower for level I hospitals; general and specialized hospitals have more complex case-mix and general hospitals have higher levels of LOS; occupancy rates are higher for central and general hospitals; larger hospitals are associated with a higher proportion of consumption costs in total hospital costs, and with higher levels of outsourcing per unit of output; case-mix and

The HFEM was estimated by GLM, using an identity link function with the natural logarithm of the standardised cost as the dependent variable. This model produces similar coefficient estimates to OLS estimation but generates statistics that are directly comparable with the results of the MLM[17]. The HFEM was estimated in the STATA statistical software (Stata Corporation 2001) and conventional tests for GLM models were applied. The MLM model was estimated using MLWin software (Rasbach et al. 2000). The method of estimation used the restricted (or residual) maximum likelihood estimation. The corresponding algorithm is the restrictive iterative generalized least squares. Hypothesis testing on single parameters and on specification were carried using the tests suggested by the literature (Snijders and Bosker 1999)[18]. The statistical comparison on the goodness of fit and specification between the HFEM and the MLM has made use of an adapted version of the Akaike Information Criteria, in the version suggested in the MLWin software guide (Rasbach et al. 2000)[19].

4.2 Results and analysis

Table 3 shows the estimates generated by the two models. The results need to be interpreted with caution because: residual variations at the hospital level might reflect the lack of controls for some variables, such as quality and non-measured outputs for the private carried out by public hospitals; insufficient control for the complexity of output of the hospital[20]; and random intercepts and slopes might also capture systematic variations in technical inefficiency.

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length of stay are correlated with cost per unit of output, and with high levels of outsourcing and consumption; the proportion of personnel costs to total costs is inversely related to hospital size; large and central hospitals are located in areas with higher purchasing power; the ratios of nurses to doctors, beds to doctors and other employees to doctors are higher for smaller hospitals.

[17] The alternative would be the use of GLM with a log link and the use of the standardised cost as the dependent variable, but results would not be comparable with outputs estimated by the MLM model. Estimation by GLM enables estimates to be produced of values in the original scale and of the loglikelihood of the model. The software package in use for the MLM model does not offer the possibility of carrying on GLM estimation with a log-link function. This would be the ideal estimation technique for the estimation of the MLM.

[18] These included: Wald test for hypothesis involving fixed parameters; and likelihood ratio test for hypothesis involving random-effect parameters (for nested models). Residuals were checked for homoscedasticity and specification: analysis of standardised residuals (with variance equal to one); analysis of plots of standardised residuals for individual hospitals against fitted values or level 1 variables allowed for checking model specification and homoscedasticity; analysis of plots of level two residuals against fitted values or level 2 allowed for control of level two variance; comparison of residuals at level one and level two; and the model was checked for the impact of outliers.

[19] Under this version, it should be chosen the model with the smallest AIC, and the AIC is equal to the sum of the loglikelihood statistic with the double of the number of parameters estimated in the model.

[20] *Ad hoc* models have been criticised on how they treat the impact of more complex cases on costs, and it has been pointed that an inadequate control for this type of biases implies a downwards accounting for economies of scale (McGuire and Hughes 2002).

Table 3: Coefficient estimates of the HFEM and MLM

	A	*B*	*C*	*D*	*HFEM*
	No covariates	Control for case-mix	All covariates except geographic	All covariates	All covariates
Ln (casemix)		0.719 (0.09392)***	0.300 (0.06777)***	0.340 (0.065)***	0.264 (0.089)***
Ln (occupancy rate)			-.520 (0.08664)***	-0.500 (0.082)***	-0.380 (0.102)***
Ln (personnel costs per doctor)			0.611 (0.08446)***	0.619 (0.078)***	0.436 (0.107)***
Consumption over total costs			0.012 (0.00231)***	0.012 (0.002)***	0.013 (0.002)***
Ln (outsourcing per unit output)			0.466 (0.05907)***	0.406 (0.060)***	0.526 (0.048)***
Ln (doctors)			0.093 (0.02351)***	0.096 (0.022)***	0.070 (0.025)***
Ln (nurses per doctor)			0.251 (0.06091)***	0.233 (0.058)***	
Dummy Algarve					0.125 (0.064)*
Dummy Alentejo				0.128 (0.062)**	
Dummy interior north				0.136 (0.050)***	0.010 (0.046)**
Constant	6.067 (0.13900)***	6.020 (0.10201)***	0.112 (0.880) (*)	0.219 (0.819)(*)	1.051 (1.389)(*)
Dummy District					-0.209 (0.055)***
Dummy Level I					-0.239 (0.082)***
Ln (beds per doctor)			-0.124 (0.06875)**	-0.135 (0.069)**	
$\sigma^2_{\mu 0}$	0.203 (0.09394)	0.107 (0.05024)	0.0013 (0.0016)	0.0016 (0.0014)	
$\sigma^2_{\mu 2}$			0.0181 (0.0103)	0.0212 (0.0112)	
σ_{02}			0.0058 (0.0033)	0.0071 (0.0035)	
σ^2_{e0}	0.064 (0.01035)	0.039 (0.00634)	0.0125 (0.002)	0.0111 (0.0018)	
-2*ln(likelihood)	36.99	-8.73	-121.88	-133.13	-114.8

(*)- Not statistically significant; *- Statistically significant at 10% level; ** Statistically significant at 5% level ; ***- Statistically significant at 1% level.

Results from the HFEM (last column of Table 3) show that:

- Case-mix, outsourcing per level of output, relative weight of consumption in the costs structure and the level of personnel costs per doctor have a positive impact on standardised costs. Occupancy rates decrease standardised costs. The coefficient for case-mix is lower than one unit, as the case-mix is correlated with outsourcing per output and consumption costs over total costs. The coefficient for occupancy rates has the expected sign: the higher the turnover, the lower the standardised cost[21].
- The number of doctors has a positive impact on standardised costs. Nevertheless, this result should be analysed together with the dummy coefficients for the district and level hospitals, as these variables also capture hospital capacity. Analysing these dummy variables, using as baseline the central and general hospitals located in the South coast region shows that: specialised hospitals have a similar level of costs; district hospitals have lower standardised costs in comparison to central hospitals; level I hospitals have lower standardised costs in comparison to district hospitals; hospitals located at Algarve and in the Northern interior have comparative higher levels of costs (where there is poor access to hospital care).
- In this model, the coefficients of the variables of ratios of nurses to doctors and beds to doctors are found not to be statistically significant. As described below, this finding differs with the results of the MLM. The HFEM itself is statistically highly significant[22].

Results show that factors that explain standardised costs tend to reflect previous systems of finance based on historical reimbursement: for example, higher levels of consumption and outsourcing. Results indicate diseconomies of scale with hospital size. This result accords with previous findings: there is more

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[21] Nonetheless, as the occupancy rate might capture variations on quality or efficiency or economies of scale, the interpretation of this result should be taken with caution. These issues will be described below.

[22] The corresponding R^2 statistic from the OLS estimation is 91.5%.

consensus from studies using *ad hoc* specifications that small hospitals experience economies of scale, and large hospitals experience diseconomies of scale (McGuire and Hughes 2002).

Results from the estimation of the MLM are presented in columns A-D in Table 3. Columns A-C show:

- Model A: when no control is made for any covariate, 76% of the random variation is explained by group variation, while the rest is explained by variation at the hospital level. This corresponds to a random intercepts multilevel model where the intra class correlation is computed as the ratio $\rho = \sigma_{u0}^2 / (\sigma_{u0}^2 + \sigma_{e0}^2) = 76\%$ (Snijders and Bosker 1999) and can be interpreted as the proportion of total variation of the dependent variable that is explained by the area level (e.g., by the administrative classification)[23].
- Model B: with an additional control for case-mix, the new level of random variations explained by group level variation is 73.3% ($\rho = 73.3\%$);
- Model C: inclusion of other covariates that are associated with hospital complexity (such as consumption over costs and outsourcing level per unit of output) implies that the relevance of the case-mix index decreases. Analysis of the coefficients of this model is similar to analysis of the HFEM (the coefficients have the same signs and similar statistical significance); the ratios bed to doctor and nurses to doctor start being statistically significant.

From model C to D, the difference is the adding of the geographic variables; the MLM shows that after controlling for internal differences between models and between variations across hospital types, two regions with low accessibility to hospital care have higher levels of costs –the Alentejo and the interior North regions. Model D is thus the most complete and final model. The results of this model are those that follow:

1. When compared with the HFEM, the use of random intercepts and random slopes implies that the ratio of nurses to doctors and the ratio of beds to doctors start being statistically significant; this implies that accounting for inter and intra-group variation changes the results from estimation;
2. A higher ratio of beds to doctors implies reduced standardised costs, while a higher ratio of nurses to doctors implies increased standardised costs; the lower costs implied by higher ratios of beds to doctors might be understood as associated with a technology less intensive on labour and more intensive on other inputs, and which translates in lower levels of costs and the use of beds has been constrained by the availability of doctors in rural hospitals. The positive coefficient for the ratio nurses to doctors might be interpreted as a result from the substitutability between nurses and doctors;
3. The random intercept for hospital type and the random slope for the beds to doctor ratio were found to be statistically significant, while the random slope of the nurses to doctors variable was found as statistically not significant. Consequently, the impact of the mix of beds to doctors on standardised costs will depend on the group of hospitals. A more detailed analysis on the results of the random coefficients is presented below.

Comparison between the HFEM and MLM on the AIC statistic has shown that the MLM[24] outperforms the HFEM.

The interpretation of the values of the random estimates follows (on intercepts, slopes, and residuals at the hospital level), although these statements requires strong assumptions to be made. Random intercepts and slopes might be interpreted as capturing variations in allocative efficiency. It is more difficult to interpret residuals at the hospital level as they reflect a set of effects for which control was not made. Lower and negative values of the random parameters might be interpreted as meaning higher efficiency,

[23] This analysis can only be carried for models with random intercepts. The use of random slopes implies that the coefficient will depend on the sample values and on the groups to be compared.
[24] It is worth making two additional observations on the results of the MLM model (model D). First, it has a high level of covariance between the random coefficients, which is higher than the product of the variances. This result seems striking but is expected as explained in (Snijders and Bosker 1999). Second, the deviance, computed as 2*loglikelihood, has a negative value. The negative value is explained by: the likelihood is a function of the probabilities and for some type of distribution the probability density function may be greater than one (when the dependent variable is continuous), and thus the loglikelihood can be positive.

as they represent a negative influence on standardised costs. Figure 2 and Table 4 (and Figures 5 and 6, appendix) suggest the following:

- *Hospital level random component*. It is difficult to interpret hospital level residuals, as they include variations for which the model does aim to control: for example, variations in quality, technical inefficiency. If this component is interpreted as technical inefficiency, then these findings suggest that the three biggest hospitals are performing well (Figure 5, appendix).
- G*roup level random component*. There are two types –random intercepts and random slopes-, which capture allocative inefficiency:

a. *The random slopes component* (Figure 2) might be interpreted as a component of allocative inefficiency related to the ratio of beds to doctor. Table 3 shows that the ratio beds to doctor have a negative impact on standardised costs; and level I and district hospitals have higher beds to doctor ratio. Nevertheless, the negative impact of the beds to doctors ratio on standardised costs is lower (more negative) for district and level I hospitals and higher (although negative) for central hospitals.

b. *The group level random intercepts component* (Table 4) captures systematic variations between hospital administrative groups and can be interpreted as unexplained variations across groups of hospitals: the remaining allocative inefficiencies after the model has controlled for group variations on costs implied by the beds to doctor ratio. Specialized hospitals are the most inefficient and are followed by general hospitals, while level I hospitals are the most efficient.

- Average estimates of allocative inefficiency for the group level and for the hospital level residuals are shown in Table 4 (though these are very approximate). General and specialized hospitals are the most inefficient; district hospitals have the lowest residuals at the hospital level while specialised hospitals have the highest positive residuals. The highest (and undesirable) impact of the beds to doctor ratio on costs is found for specialised hospitals, while the highest random intercepts are observed for general hospitals.

Figure 2: Allocative inefficiency –random slopes coefficients for the ratio beds to doctor

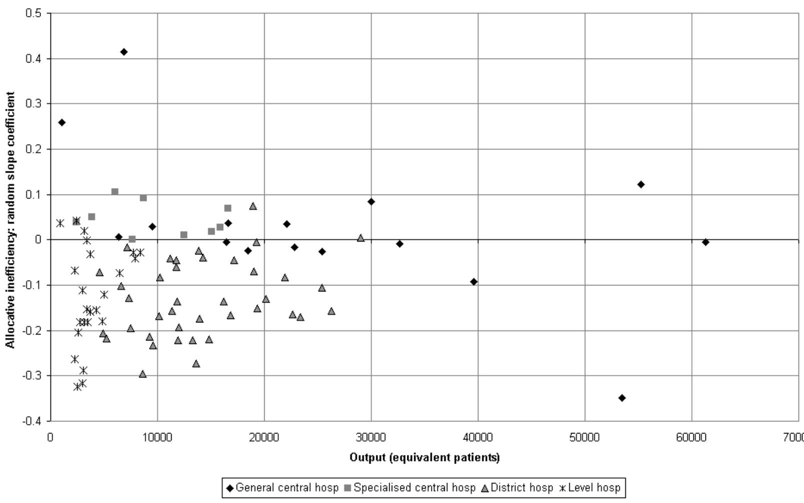


Table 4: Average of allocative inefficiency estimates and hospital level residuals variations for the group level

	Average hospital level residual	*Average random intercept*	*Average random slope*
General	0.024	0.037	0.029
Specialised	0.032	0.019	0.046
District	-0.012	-0.025	-0.129
Level I	0.008	-0.042	-0.125

4.3 Estimates of unavoidable costs and geographic redistribution

This section defines UCs and presents empirical results on the levels of UCs per hospital and for the district level. There are no clear rules on which variables should be seen as avoidable or unavoidable determinants of hospital costs. The criteria for defining the components of UCs of Portuguese hospitals in this study are:

- Costs that lie outside control of hospital management or that represent short run constraints. This applies to the additional costs arising from the mix of nurses and beds in relation to doctors, and the components of allocative inefficiency;
- And costs that do not generate perverse incentives if hospitals were to be reimbursed for those costs. Analysis of results of the empirical model has shown that some of the variables that explain hospital costs relate to the current structure of incentives and to the current financing system. For example, levels of purchase (of goods and services) and outsourcing are very significant in explaining costs. If all the costs of consumption, outsourcing and personnel costs were classified as UC and if the formula was used to allocate resources, this would create perverse incentives for hospitals to increase those components of expenditure.

Consequently, model D needs to be adapted to estimate UCs. The components of the model that are classified as UCs are:

a) Allocative inefficiencies across hospital groups (that is the impact of both random intercepts and random slopes on costs);
b) Geographic variations in costs;
c) Lowest average at the group level for the variables consumption costs over total costs, outsourcing levels per unit of output, and personnel costs per doctor;
d) For all the other deterministic covariates, 100% of their value is considered UC.

It is assumed that the random component of the hospital level fully represents hospital technical inefficiency, and thus an avoidable cost. Nonetheless, this is a strong assumption.

The application of these rules to UC has implied that on aggregate (national level), unavoidable standardised costs are 78% of the 1998 standardised cost. This means that 22% of the national cost per unit of output might be explained by inefficiencies in the system. Figure 3 contains the UC per output at the hospital level, standardised by the national level of UC per output. It shows that general and specialised hospitals would be the relative winners from the redistribution of UCs, while level I hospitals the major losers. This is clarified in Table 5: on average, general and central hospitals have standardised costs 23% above the national average, while level I hospitals are 26% below the national average, which implies significant redistribution between these types of hospital.

Figure 3: Individual hospital 'winners' and 'losers'

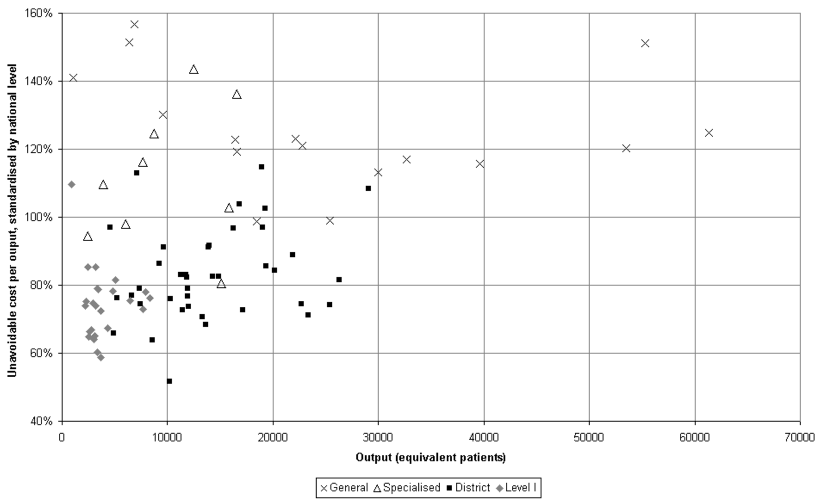


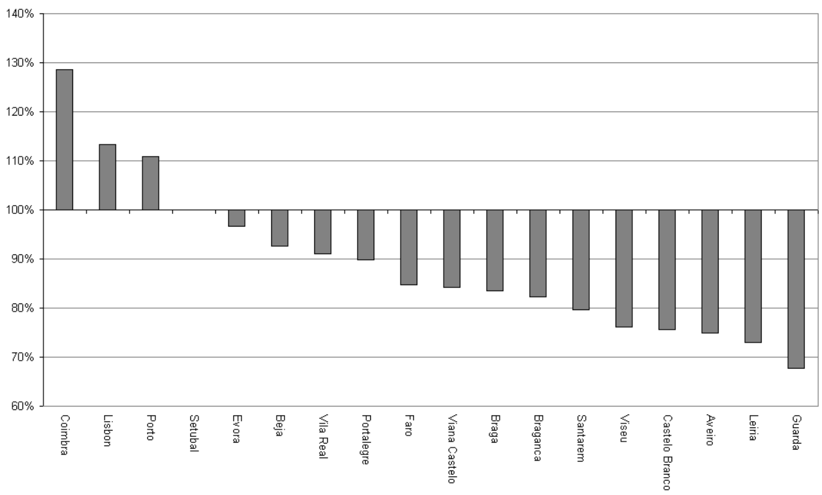
Table 5: UC per output, as a percentage of national UC per output

	Unavoidable costs per output
General hospitals	123%
Specialised hospitals	114%

District hospitals	85%
Level hospitals	74%

An UC index to the district level weights the hospital unavoidable standardised costs for each hospital of the district by the hospital size. The values obtained for the UC index at the district level are presented in Figure 4. These values directly reflect the structure of the hospital system of the district. These values for the hospital system in Coimbra, Lisbon and Porto imply additional UCs of 28%, 13% and 11% above the national average, respectively; and for Aveiro, Leiria and Guarda, 25%, 26% and 32% below the national average. This is because Coimbra has a small number of large hospitals; and Lisboa and Porto have a large number of small and large hospitals. The district index implies a redistribution that ranges between 68% and 128% of the national average, approximately. Lisboa, Porto and Coimbra are the districts that concentrate a disproportionate level of hospital resources, higher than needs levels, and if the method is to be used for resource allocation, it seems to reward the *status quo*. Comparison of the results of the district unavoidable cost index generated by the HFEM and MLM shows that results from the two models significantly differ (Figure 7, appendix). These differences mainly reflect the more adequate treatment of allocative inefficiency and differences between hospital groups in the MLM.

Figure 4: UC per unit of output, standardised by national average (MLM)



5 Discussion and further research

This study has proposed an alternative method to estimate UCs, making use of an integrated approach and attempting to disentangle for sources of allocative inefficiency. The study has produced evidence of the causes of inefficiency and the determinants of hospital expenditure, and should be used to inform policies that pursue equity and efficiency. The multilevel model with random intercepts and slopes has shown some advantages over alternative methods. UCs were computed so as to avoid the perverse incentives by rewarding hospitals for some categories of expenditure that result in inefficiencies. Results have suggested that additional costs are generated by the lack of flexibility of hospital managers and system of incentives of the Portuguese hospital system (such as financing based on retrospective reimbursement); and these characteristics could cause problems in aiming for equity. This is mainly because it is necessary to change the distribution of hospital resources, such beds and doctors, to correct geographic inequities in the system and to improve allocative inefficiency.

Further work could:

- Use a multilevel model with the assumption of a positive distribution of hospital level residuals, to compute the efficient frontier/envelope and develop a model using the microeconomic theory of the firm;
- Focus on the relationship between occupancy rates, staffed beds, reservation quality and reservation demand. For example, it is expected that occupancy rates are inversely related to inefficiency (Zuckerman, Hadley, and Iezonni 1994), occupancy rates might be seen as elements of economies of

scale but it is difficult to capture this (Scott and Parkin 1995) and might be related with unpredictable demand, as large hospitals benefit from lower reserve margin requirements (Aletras, Jones, and Sheldon 1997).

- Measure the cost of capital.

6 Concluding remarks

The results of this exploratory study provide further evidence in the controversy over the existence of economies of scale and scope and scope for controlling for inefficiency. Our findings indicate that policies that seek improvements in equity cannot ignore variations in UCs and incentives, and that any estimate of UCs should look at allocative inefficiencies. The planning system and methods for resource allocation should account for these findings. The estimates of UCs of the district level show that districts with concentration of the biggest hospitals and the highest levels of supply (Coimbra, Lisbon and Porto) will have a higher level of relative UCs.

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Appendix

Table 6: Geographic classification in use

Regional classification	*Districts*
North coast	Porto, Braga, Viana do Castelo
North interior	Vila Real, Braganca
Centre coast	Aveiro, Coimbra, Leiria
Centre interior	Viseu, Guarda, Castelo Branco
South coast	Lisboa, Setubal
South interior	Santarem
Alentejo	Beja, Evora, Portalegre
Algarve	Faro

Table 7: Average and standard deviation (in brackets) of selected variables

	Average	*General*	*Specialised*	*District*	*Level*
Doctors	183.0 (252.2)	538.8 (391.7)	160.1 (111.8)	136.7 (106.8)	29.6 (27.8)
Standardised Cost	410.4 (231.3)	736.1 (295.5)	524.6 (223.0)	323.3 (89.5)	291.8 (92.2)
Case-mix	1.04 (0.3)	1.44 (0.4)	1.15 (0.6)	0.87 (0.1)	1.00 (0.2)
LOS	8.0 (2.5)	10.3 (3.9)	8.0 (2.7)	6.9 (1.1)	8.2 (1.9)
Occupancy rates	71.6 (10.7)	76.2 (8.2)	66.0 (12.1)	72.1 (8.9)	69.8 (13.2)
Consumption costs/total costs	17.7 (8.6)	28.5 (6.6)	16.4 (11.3)	16.8 (6.2)	12.3 (5.4)
Outsourcing/output	73.5 (31.4)	111.1 (47.6)	72.5 (23.3)	61.2 (17.8)	68.7 (16.7)
Personnel costs/total costs	57.3 (8.6)	48.4 (8.2)	61.7 (12.0)	59.2 (6.7)	58.5 (6.6)
Purchaser Power Index	98 (36.9)	136 (36.8)	138 (33.6)	83 (28.0)	83 (18.2)
Nurses/doctors	2.5 (1.5)	1.4 (0.5)	1.7 (0.5)	2.4 (0.9)	3.7 (2.2)
Beds/doctors	2.8 (2.2)	1.7 (1.8)	1.6 (0.7)	2.4 (1.1)	4.6 (3.1)
Employees/doctors	4.3 (3.3)	2.4 (0.9)	3.1 (0.9)	3.4 (1.3)	7.4 (4.8)
Non-NHS revenue/total revenue	13.2 (4.2)	12.7 (3.8)	14.9 (6.3)	13.5 (4.3)	12.5 (3.0)
Growth expenditure last two years	31.8 (25.0)	21.2 (15.4)	26.1 (13.8)	36.6 (32.8)	33.3 (15.2)
Total extra-hour payments per doctor	8.85 (0.2)	8.82 (0.1)	8.94 (0.1)	8.85 (0.2)	8.83 (0.2)

Figure 5: Residuals at the hospital level

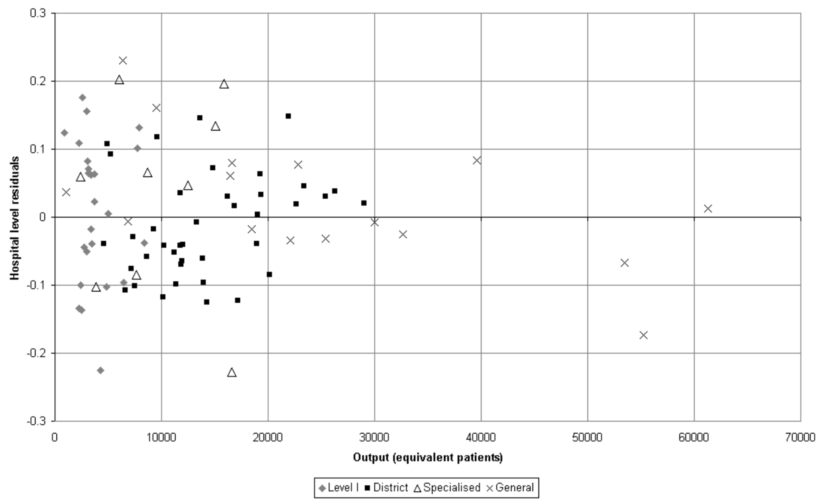

Figure 6: Allocative inefficiency –random intercepts

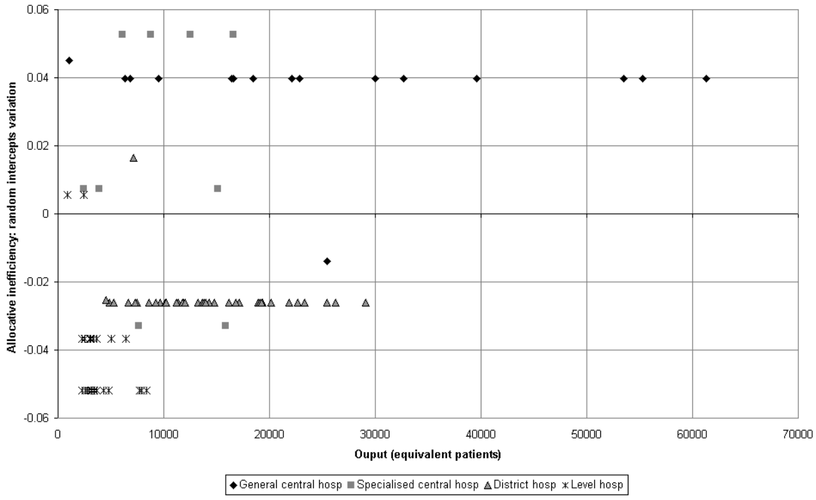

Figure 7: Unavoidable cost per output index in comparison (HFEM vs. HLM)