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Estimating the costs of specialised care

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Silvio Daidone
Andrew Street

Centre for Health Economics, University of York, YO10 5DD

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Centre for Health Economics
Alcuin College
University of York
York, UK
www.york.ac.uk/che

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Executive summary

In most sectors of the economy, specialisation is associated with lower costs. Yet some specialised hospitals claim to require more generous funding than general hospitals. This claim is based on the assertion that their patients are different, and that these differences outweigh the cost advantages of specialisation. Unless the basis for this claim can be established, the financial incentives introduced by Payment by Results to encourage cost reducing behaviour will be diluted.

We estimate various multiple regressions in order, firstly, to establish the extent to which the receipt of specialised care is associated with higher treatment costs and, secondly, to evaluate hospital performance in controlling costs. We explore how robust the results are to a range of analytical choices by conducting various sensitivity analyses.

We use the Hospital Episode Statistics and Reference Cost databases to analyse the characteristics and costs of all patients treated in the NHS during 2008/9. Patients are identified as having received specialised care on the basis of specific diagnostic and procedure codes recorded in their medical record. These codes are agreed by clinicians and form the Specialised Services National Definition Sets.

We estimate multiple regression models to assess the extent to which receipt of specialised care increases the cost of treatment. We test the robustness of results to choices about how costs are calculated, how the regression models are specified and how patients are identified as having received specialised care. In addition we assess each hospital's relative efficiency in controlling costs, after allowing for differences in factor prices and a wide range of patient characteristics.

We find that, after allowing for the hospital in which treatment is provided, costs are higher than for other patients allocated to the same Healthcare Resource Group (HRG) if a patient receives one of the following types of specialised service:

- cancer (18% higher cost)
- spinal (28%),
- neurosciences (23%),
- cystic fibrosis (38%),
- infectious disease (21%),
- children (20%),
- rheumatology (13%),
- vascular diseases (21%),
- colorectal (21%) and
- orthopaedic (21%).

The implication for Payment by Results is that 'top-up' payments for patients with these markers might be made over and above the tariff associated with the HRG to which they are allocated. We recommend that the size of additional top-up amounts to the percentage increase in costs as reported above, these estimates being derived from our preferred model specification.

However, different values could be adopted, justified on other grounds. These grounds may include:

- Transitional arrangements, notably for children's services, where the recommended value of 20% is substantially lower than the current 78% top-up;
- Materiality, where an additional top-up would have limited financial consequence for those types of specialised services that are delivered to only a small number of patients;
- Sensitivity to model specification. The other model specifications generally imply lower top-up values than those recommended above, with the exception of a model that fails to allow for each hospital's influence on costs.

Our analysis demonstrates that there is substantial variation in the average cost of treatment across the hospital sector, and that this variation is due neither to differences in the factor prices faced by hospitals, nor to the provision of specialised services, and nor to the casemix, socio-demographic and diagnostic characteristics of each hospital's patients. After controlling for these diverse reasons for cost variation, we are able to rank hospitals according to their relative cost efficiency. Those hospitals rated as relatively inefficient will struggle financially under Payment by Results.

1. Introduction

This paper reports work undertaken for the Department of Health's Payment by Results (PbR) team to investigate whether:

1. The costs associated with specialised activity are significantly different from non-specialised activity within the same HRG;
2. Any differences in costs between specialised and non-specialised activity are due to differences in cost efficiency.

This helps address the following PbR objectives:

- PbR gets the price 'right' for services, by paying a price that ensures efficiency and value for money for the taxpayer, and incentivises the provision of care that is responsive to individual needs;
- The system is fair and transparent, through consistent fixed price payments to providers based on volume and complexity of activity.

In broad terms, our analysis of data from 2008/9 explores whether patients who receive specialised services as part of their care package have higher costs than those who do not. If so, hospitals that treat more patients who receive specialised care might require top-up payments over and above their PbR tariff income.

In our assessment we also take account of other factors that might explain costs. These factors include the Healthcare Resource Group (HRG) to which the patient is assigned, various socio-demographic, diagnostic and treatment-related characteristics of the patient, and the hospital in which the patient is treated.

In what follows we first briefly set out the reasons why differential payments might be required for specialised services. We then describe how we identify patients as having received specialised care, assign costs to each patient record in HES, assess the costs of provider spells and decide upon an analytical sample. We specify our multiple regression models before providing some descriptive statistics comparing specialised to non-specialised activity. We then estimate models that investigate the extent to which variations in cost are explained by whether or not a patient received a specialised service.

2. Payment by Results and specialised care

In April 2002 the Department of Health in England started to introduce a new system of hospital reimbursement, called Payment by Results (PbR). Similarly to other healthcare systems, PbR uses a fixed prospective payment that links a hospital's income to the number and case mix of patients treated. Under PbR, payments for hospital care are defined in terms of the healthcare resource group (HRG – the English version of diagnosis related groups) to which each patient is allocated. Some specialist hospitals in England are paid 'top-up' payments over and above their PbR income, with the top-up calculated as a percentage of the relevant HRG tariff. In 2010/11 the top-up amounted to 78% of the tariff for specialised children's care and to 30% of the tariff for specialised orthopaedics services (Department of Health, 2009).

England is not alone in making differential payments to specialist hospitals: such hospitals in other countries with prospective payment also receive additional income over and above that which they would receive from prospective payments alone (Mechanic et al., 1998, Langenbrunner and Wiley, 2002). However, if PbR is to promote efficiency and ensure value for money both the justification for and size of the higher 'top-up' payments need to be established.

2.1 Specialisation ought to reduce costs

It is not immediately apparent why specialist hospitals should claim higher payments at all. The practice seems to go against received economic wisdom dating back at least to Adam Smith's reflection on specialisation and comparative advantage: by specialising in specific types of activity, providers should have lower costs than those providers that undertake a more diverse range of activities. These lower costs are derived from two primary, though not exclusive, sources (Schneider et al., 2008):

- Economies of scale, whereby the unit cost of treatment falls as volume increases, and
- Specialisation, where it is cheaper to concentrate on providing a limited rather than diverse range of activities.

Most sectors of the economy have witnessed a move toward greater specialisation as providers have sought comparative advantage (Essletzbicher, 2003). Similarly in healthcare over the past twenty years the number of specialist orthopaedic, cardiac or general surgery hospitals in the United States has grown from 29 in 1990 to 91 in 2005 (Shactman, 2005, Schneider et al., 2008). But in 2005 the US government imposed a moratorium on further development, concerned primarily that such hospitals were specialising merely on the most profitable procedures (Shactman, 2005). In contrast, the English government has encouraged specialisation through the creation of treatment centres that specialise in selected elective procedures such as hip or knee replacement or cataract removal, the belief being that treatment centres are able to deliver care at lower cost than can be achieved by hospitals (Department of Health, 2002).

If the argument that specialisation reduces costs holds in most other sectors of the economy, for specialist hospitals in the United States and for treatment centres in England, why does if it not apply to English specialist hospitals?

2.2 Patients receiving specialised care might have higher costs

The reason that the argument might not hold is that, compared to general hospitals, specialist hospitals are treating different types of patients. If so, cost-reducing gains from specialisation might be offset because specialist hospitals attract patients with more complex care requirements.

This potential problem arises because HRGs are imperfect measures of casemix: any system of categorisation will inevitably combine patients with below and above average costs. This is not problematic if there is little variation around the average and if the variation is random. But it would be problematic if *particular* types of patients have significant higher costs than other patients allocated to the same HRG. These particular patients may be those that require more expensive specialised care. If HRGs fail to account for systematic differences between patients, the PbR price attached to the HRG would be imperfect. Moreover, because patients receiving specialised care are more likely to be

treated in specialist hospitals, the payment system would systematically disadvantage these hospitals. The justification for specialist 'top-up' payments, then, is to correct potential imperfections in the HRG classification system.

The objective of the analysis that follows, therefore, is to determine whether and the extent to which patients who receive specialised care are more expensive than those allocated to the same HRG who do not require specialised care.

3. Data Issues

There are four major issues regarding the data that need to be addressed:

- How to determine whether or not a patient received specialised care;
- How to assign costs to each patient record in the Hospital Episode Statistics;
- How to determine the cost of a provider spell for those patients who have multiple consultant episodes;
- How to arrive at an analytical sample.

3.1 Identifying whether a patient received specialised care

For each individual patient treated in an English hospital during 2008/9 we need to ascertain whether or not specialised care was received. To do this we look at the routine information recorded in the Hospital Episode Statistics (HES) about every hospital patient treated during the financial year. Each HES patient record includes a number of data 'fields', containing demographic (e.g. age, gender) and clinical information (e.g. diagnosis, procedures performed).

Information in each patient's diagnostic and procedural fields is examined to ascertain whether or not specialised care was received. A patient is assigned a specialised care marker if:

- One of the ICD10 or OPCS codes[a] designated in the Specialised Services National Definition Set (SSNDS) is present in their HES record (an individual might have more than one marker) (NHS Specialised Services, 2010);
- They were treated at an eligible provider, because non-eligible providers should not be providing specialised services.[b]

Specialised activity may not necessarily be more costly or complex, since the SSNDS defines activity as specialised if it requires a planning population of over 1 million people, without any specific relation to resource use.

3.2 Mapping of Reference Costs to HES records

Costs are not reported in HES. But all English hospitals have to report so-called 'Reference Costs' to the English Department of Health about all of the patients they treat. We map the cost data from each hospital's Reference Costs to the data about each hospital's patients recorded in HES.

In making their Reference Cost returns, hospitals report five pieces of cost information for each HRG (*h*) in each of their specialties. So, for any given specialty, *j*, each hospital *k* will report:

- Average cost per day case in HRG *h*: c^{d}_{hjk}
- Average cost for elective patients in HRG *h* with a length of stay below the HRG-specific trimpoint value: c^{e}_{hjk}
- Excess *per diem* cost for an elective patient in HRG *h* who stays in hospital beyond the HRG-specific trimpoint: ex^{e}_{hjk}
- Average cost for non-elective (including maternity, baby or a transfer) patients in HRG *h* with a length of stay below HRG-specific trimpoint value: c^{n}_{hjk}
- Excess *per diem* cost for a non-elective patient in HRG *h* who stays in hospital beyond the HRG-specific trimpoint ex^{n}_{hjk}

[a] ICD10: International Statistical Classification of Diseases and Related Health Problems 10th Revision; OPCS: Office for Population Censuses and Surveys Classification of Surgical Operations and Procedures
[b] In sensitivity analysis we relax this second condition.

Trimpoints are defined for length of stay outliers in each HRG according to whether the patient was admitted as an elective or non-elective. We define t_h^e as the elective trimpoint in days and t_h^n as the nonelective trimpoint for HRG *h.*

The costs provided by each hospital are assigned to each patient record in HES, according to whether the patient was a day case (a^d), elective admission (a^e) or non-elective admission (a^n) and how long each patient stays in hospital, as follows:

- Day case: $if \quad a_{ihjk}^d \rightarrow c_{hjk}^d$

Elective with length of stay at or below the elective trimpoint: $if\,(a_{ihjk}^e, L_{ihjk} \leq t_h^e) \rightarrow c_{hjk}^e$

-
- Elective with length of stay above the elective trimpoint:
  $if\,(a_{ihjk}^e, L_{ihjk} > t_h^e) \rightarrow c_{hjk}^e + \left[ex_{hjk}^e \times (L_{ihjk} - t_h^e) \right]$
- Non-elective with length of stay at or below the non-elective trimpoint:
  $if\,(a_{ihjk}^n, L_{ihjk} \leq t_h) \rightarrow c_{hjk}^n$
- Non-elective with length of stay above the non-elective trimpoint:
  $if\,(a_{ihjk}^e, L_{ihjk} > t_h^n) \rightarrow c_{hjk}^n + \left[ex_{hjk}^n \times (L_{ihjk} - t_h^n) \right]$

3.3 Assessing the cost of provider spells

Each observation in HES comprises a Finished Consultant Episode (FCE, hereafter "episode"), measuring the time the patient spends under the care of a particular consultant. Similarly hospitals report their costs on the basis of episodes.

Around 90% of patients remain under the care of a single consultant during their entire hospital stay. The remainder are cared for by more than one consultant, most usually because they are transferred from one specialty to another. We can track the episodes pertaining to each individual patient, allowing us to construct a Provider Spell for each patient, measuring the time from admission to discharge. By linking successive episodes for each patient, we are able to take account of the information in all of the records for those patients with multiple episodes.

Multi-episode spells are likely to be more costly than single-episode spells, but there is no agreed method for determining the additional cost. This is important for our analysis because patients who receive specialised care are more likely to have multi-episode spells. In the absence of an agreed methodology we assess the sensitivity our results to three means of determining the cost of multi-episode provider spells:

- SUM: the cost of the provider spell is equivalent to the sum of the costs of each episode in the spell;
- MAX: the cost of the provider spell is equivalent to the most expensive episode in the spell;
- EPI1: the cost of the provider spell is equivalent to the first episode in the spell.

Table 1: Mean (SD) costs by type of activity (£)

	Not specialised	Specialised	Total
Sum	1,385	1,884	1,436
	(2,079)	(3,790)	(2,320)
Max	1,219	1,673	1,265
	(1,730)	(3,210)	(1,940)
Epi1	1,142	1,540	1,183
	(1,587)	(2,929)	(1,777)

Summary statistics of the costs calculated in each of the three ways are provided in Table 1 for all patients treated in 2008/9 and according to whether or not they received specialised care. As would be expected there are differences among the three ways of computing spell costs but these are not particularly marked because 90% of spells are single-episode.

Irrespective of the way in which costs are calculated, there are clear differences in costs between patients who do and do not receive specialised care. This raises the question of what drives these differences in cost.

3.4 Selection of the analytical sample

From an initial sample of 17.4m HES episodes, our analytical sample is reduced to 13.5m episodes (and 12m spells) for the following reasons:

- We consider only those patients treated in NHS acute hospitals. Hence, patients treated in mental health, ambulance and primary care trusts and private providers are excluded;
- HES episodes with missing identifier codes (*epikey*) are dropped, because they cannot be matched to the Reference Cost database;
- We exclude duplicate observations and those showing data inconsistencies, such as admission date posterior to discharge or patients with different ethnicity codes within a spell;
- Reference costs are not reported comprehensively for some types of activity, notably renal dialysis, well babies, mental health, and cystic fibrosis. Details are providing in Appendix Tables A1 and A2;
- The Reference Costs for some hospitals were not provided in a form that allowed them to be matched to HES records.[c] For all hospitals the numbers of provider spells with unmatched costs are reported in Appendix Table A3 and as a proportion of total activity in Appendix Table A4;
- We excluded those episodes with a length of stay in excess of 365 days.

In Table 2 we report how we reduced the full HES dataset to our analytical sample.

Table 2: Eligibility and selection criterion

Step	# episodes	# episodes dropped
Starting observations	17,411,542	
Acute care trusts only		425,179
	16,986,363	
Missing epikey		5,843
	16,980,520	
Duplicates and inconsistent coding		846,483
	16,134,037	
HRG4 missing link		144,822
	15,989,215	
Unmatched reference cost		2,357,777
	13,631,438	
Unmatched trimpoint and excess bed days		79
	13,631,359	
Zero cost per episode day		57,599
Total episodes	13,573,760	3,837,782
Total spells	12,154,599	

[c] This was particularly so for South London Healthcare Trust (RYQ), which may be due to its recent creation as an amalgamation of three smaller hospitals; Western Sussex Hospital NHS Trust (RYR), which may also be due to its recent creation as a merger of the Royal West Sussex and Worthing & Southlands Hospitals; and Cambridge University Hospitals NHS Foundation Trust (RGT).

4. Estimation models

The analytical purpose is to examine the extent to which patients who receive specialised care have different costs to other patients allocated to the same HRG. This requires careful construction of the dependent variable.

First, we adjust reported costs by Market Forces Factor (MFF) of the hospital in which the patient was treated. The MFF is an index of geographical variation in the prices of land, buildings, and labour (Department of Health, 2008) and is designed to capture unavoidable factor price differentials that impact on the actual costs incurred by hospitals in producing healthcare services. By adjusting for MFF, we wash out these unavoidable differentials in costs across hospitals.

Second, there are significant estimation problems when comparing jointly the overall population of some 12m patients, who receive very diverse types of treatment. It would be unfeasible to include dummy variables for all 1,400 HRGs as these would introduce incidental parameter biases. To overcome the need to include dummy variables, we instead standardize each patient's cost by the mean cost of all other patients allocated to the same HRG. Thus our dependent variable is defined as the patient's cost standardised to the average cost of patients in the same HRG: $y_{ik} = {}^{c_{ihk}}/_{\widehat{c_h}}$ where c_{ihk} is the cost of patient *i* in HRG *h* in hospital *k* and $\widehat{c_h}$ is the national average cost of all patients allocated to HRG *h*.

We then need to ascertain why the costs of patients allocated to the same HRG differ. Other than simple random variation, there are three main possibilities:

1. Some patients receive specialised care while others do not;
2. Some hospitals are more cost-efficient than others;
3. Some patients may have cost-driving characteristics not allowed for completely in the construction of HRGs.

We construct four different multiple regression models designed to determine the extent to which the above possibilities explain variation in costs.

Our base model simply regresses each patient's standardised cost against the full set (*n*=1…*N*) of specialised care markers (*S*), which take the form of dummy variables. The model is specified as:

$$y_i = \propto + \sum_{n=1}^{N} \beta_n S_{ni} + \varepsilon_i \qquad \text{(equation 1)}$$

Where the $\beta's$ are the parameters of interest: if positive and significant, a patient with the specialist care marker has higher costs than do other patients allocated to the same HRG. ε_i captures random error, which is assumed to be normally distributed. Much of the actual variation in costs from one patient to another is unobservable, so the explanatory power of equation 1 (and the models that follow) will be low, as indicated by the R^2 statistic. This is not surprising given that the purpose of the model is ***not*** to explain exactly why costs vary from one patient to another. There will be many individual and idiosyncratic reasons driving each individual's costs, hence making them virtually impossible to observe. Rather the purpose is to assess what influence various specific identified factors, most importantly the specialist markers, have in explaining costs. In this base model we assume that the myriad unidentified reasons are randomly distributed among patients and hospitals, with their influence being captured by the random error term. This assumption is relaxed in the other models.

In interpreting the results, note that the coefficients on specialised markers, the $\beta's$, represent the difference in standardised costs between patients who do and do not receive specialised services. In fact, if we think about expectations, since we are assuming the zero mean conditional assumption $E(y_i|S_i, \boldsymbol{S}, \boldsymbol{X}) = 0$, then $\beta_n = E(y_i|S_i = 1, \boldsymbol{S}, \boldsymbol{X}) - E(y_i|S_i = 0, \boldsymbol{S}, \boldsymbol{X})$. In order to get a more easily interpretable measure like the percentage increase in costs associated with receipt of specialised care, g_n, we need to compute the marginal mean for unspecialised services, so that:

$$g_n = \frac{E(y_i|S_i = 1, \boldsymbol{S}, \boldsymbol{X}) - E(y_i|S_i = 0, \boldsymbol{S}, \boldsymbol{X})}{E(y_i|S_i = 0, \boldsymbol{S}, \boldsymbol{X})} * 100$$

Costs may vary from one patient to another because of the hospital in which they are treated. Our second model explores this possibility. To do so, equation 1 is estimated as a random effects model[d]

$$y_{ik} = \propto + \sum_{n=1}^{N} \beta_n S_{nik} + u_k + v_{ik} \qquad \text{(equation 2)}$$

Equation 2 thus recognises the multi-level structure of the dataset, with patients (*i*=1…*I*) clustered within hospitals (*k*=1…*K*). The u_k is the random effect. This captures the effect of the hospital on the cost of any particular patient treated in the hospital over and above the other explanatory variables included in the model (here, whether and what type of specialised care the patient received). Provided some assumptions are satisfied (which we'll come to) the random effect can be interpreted as a measure of relative hospital performance in controlling costs or, in other words, of relative hospital efficiency. Due to the grouped nature of the data, we estimate standard errors clustered by hospital, capturing the intra-class correlation in the error term v_{ik}.

*This second equation is the preferred model on which **top-up payments** should be based, this model accounting for the clustering of patients within hospitals but ignoring other patient characteristics that may not be adequately captured by the HRG to which the patient is allocated.*

While accounting for the hospital in which they are treated, equation 2 includes only the specialised care markers to explain why the costs of any individual patient might differ from the costs of other patients allocated to the same HRG. In reality, of course, an individual's costs will vary because of other characteristics than merely whether or not they received specialised care and the hospital in which they are treated. To some extent the HRG to which the patient is allocated accounts for these characteristics, but HRGs can only do this imperfectly. There will always be imprecision in the way that patients are categorised to a limited set of HRGs, with some patients having higher or lower costs than others categorised to the same HRG. If the characteristics that might explain an individual's cost are imperfectly accounted for in the construction of HRGs and are not included as explanatory variables in the regression model, their omission might lead to two problems:

- First, the influence of the explanatory variables that are included in the model might be biased. Here this would imply that the estimated influence on cost of whether or not a patient receives specialised care would be imprecise. The influence of specialised care would be *over*-estimated if the omitted variables are both cost-increasing and positively correlated with receipt of specialised care. This might be the case, for instance, for patients with more complex diagnoses than typical for other patients in their HRG. If these diagnostic characteristics were also included in the model, the result would be a lower estimated influence of specialised care on cost.
- Second, the estimated hospital (random) effects might be biased and, if so, would provide an imperfect measure of relative hospital efficiency. This bias would arise if there are *systematic* differences across hospitals in the type of patients treated within each particular HRG. For instance, one hospital might attract more complex patients with more diagnostic problems. If this is not taken into account the hospital will appear to have higher costs than it should have given the (inaccurately measured) profile of the patients that it treats.

The solution to both problems is, of course, to take these characteristics into account by including them as explanatory variables in the model. In our third model we consider the extent to which patient characteristics, over and above whether they have received specialised services, explain costs. To do this, we include a set (*m*=1…*M*) of additional explanatory variables (*X*) describing each patient:

$$y_i = \propto + \sum_{n=1}^{N} \beta_n S_{ni} + \sum_{m=1}^{M} \gamma_m X_{mi} + \varepsilon_i \qquad \text{(equation 3)}$$

[d] We estimated also a fixed effects specification and compared the models by Hausman tests. The difference in coefficients is not statistically significant, which is not surprising, given the large amount of observations per hospital. The random effects model is preferred as it is more efficient.

The choice of what variables to take account of is, of course, constrained by the available data. The variables we include to describe patient characteristics are derived from information contained in each of the HES records comprising the provider spell for each individual patient. We construct a series of variables measuring the following:

- The socio-economic conditions of the area in which the patient is resident (variables labelled "imd*");
- The presence of various diagnostic markers that may influence cost over and above the HRG to which the patient is allocated and whether or not they receive specialised care. These markers depend on the presence of specific ICD10 or OPCS codes in the HES record and include such things as hypertension, allergies, obesity, diabetes, and history of past disease;
- Whether a patient was transferred into the hospital or is transferred to another hospital, and whether the hospitals in question were eligible or non-eligible providers of specialist services (labelled "tr_*");
- Whether the patient died;
- Whether the patient was admitted as an emergency;
- The number of episodes comprising the patient's provider spell;
- Regional and urban location of the hospital;
- Whether the patient was white;
- The patient's age and gender (and interactions of these).

Our fourth model allows for whether or not a patient received specialised care, for the other patient characteristics that might explain costs and for clustering of patients within each hospital. Estimated as a random effects model, this model takes the general form:

$$y_{ik} = \propto + \sum_{n=1}^{N} \beta_n S_{nik} + \sum_{m=1}^{M} \gamma_m X_{mik} + u_k + v_{ik} \qquad \text{(equation 4)}$$

*The random effect from this fourth model is the basis on which judgements about the **relative cost efficiency** of hospitals should be made. The random effects from this model are purged of the influence on costs of whether or not patients received specialised care and of their other characteristics. Patients treated in hospitals with higher random effects have higher costs than elsewhere. These higher costs are not due to the type or characteristics of these patients being treated.*

We conduct various sensitivity analyses to assess the robustness of, firstly, the estimates of the additional cost implications of whether or not the patient received specialised care and, secondly, of the relative cost efficiency of individual hospitals. Specifically we investigate whether:

- Results are robust to the four formulations of the regression model as set out in equations 1 to 4;
- Results are robust to estimating the model with the dependent variable in linear or logarithmic form and to employing a generalised linear model[e];
- Results depend on how the cost of the patient spell is determined;
- Results are dependent on whether patients are defined as receiving specialised care only if they are treated in eligible providers;
- The majority of HRGs comprise a mix of patients who do and do not receive specialised care. However, for some HRGs virtually everyone classified to them received specialised care; for other HRGs virtually no-one did. We assess whether results are sensitive to whether or not patients allocated to these HRGs are included in the analysis.

[e] The generalised linear model would be the preferred specification but the random effects models (equations 2 and 4) could not be estimated using this form.

5. Descriptive statistics

In 2008/09, for approximately 1.5m (12.5%) of patients it was indicated that some kind of specialised activity was delivered as part of the treatment package. Table 3 reports the number of patients with particular conditions who receive specialised services, and shows that, for instance, 360,000 patients received renal care specialised services. For the vast majority of patients, just one specialised service was delivered but around 30,000 patients received more than one specialised service.

Table 3: number of spells receiving specialised services

Service	#		Service	#
Cancer	14,035		Dermatology	10,790
BMT	1,050		Rheumatology	358
Haemophilia	146		Endocrinology	7,028
Women	22,551		Respiratory	71,824
Spinal	2,167		Vascular diseases	801
Neurosciences	23,848		Pain Management	753
Cystic fibrosis	91,868		Ear surgery	1,704
Renal	360,957		Colorectal	6,838
Intestinal failure	2,380		Orthopaedic	3,671
Cardiology	89,127		Morbid obesity	7,905
Cleft lip	222,939		Metabolic disorders	3,182
Infectious diseases	2,203		Ophthalmology	6,345
Liver	14,807		Haemoglobinopathy	146,403
Children	104,764		More than 1 service	32,311

Some organizations are or have been eligible for top-up payments for some specialised services. We can see from Table 4 that, as would be expected, hospitals which are or have been eligible for top-ups now or in the past undertake more specialised spells than do other hospitals. The difference can be quite marked, as in the case of specialised neurosciences services, where the list of eligible providers treated ten times the number of patients treated by non eligible providers. The proportion of patients receiving specialised services varies considerably among providers (see Appendix Table A4). Overall 12% of patients received specialised services, but the proportion of an individual provider's activity ranged 0.5% to almost 69% (at Papworth).

Table 4: Specialised spells by eligibility

Specialised spells (%)			Specialised spells (%)		
Spinal	Not eligible	0.029	Liver	Not eligible	0.234
	Eligible	0.098		Eligible	0.417
Neurosciences	Not eligible	0.085	Children	Not eligible	1.200
	Eligible	0.862		Eligible	3.430
Cardiology	Not eligible	0.445	Respiratory	Not eligible	1.483
	Eligible	2.778		Eligible	2.300

In Table 5 we provide some descriptive statistics of the explanatory variables used in the right-hand side of equations 3 and 4. Patients receiving specialised services are more likely to be male, younger (probably mainly because infants are more likely to require specialised activity, 16% of them at birth), have fewer multi-episode spells, and to have been transferred between hospitals. Some of the patients' characteristics were constructed by referring to ICD10 codes, so there might be some overlap with the diagnostic markers used for the definition of specialised services. However, other than a very small correlation between obesity and morbid obesity services, we found no correlation between the specialised markers and the patients' characteristics.

Table 5: Descriptive statistics of explanatory variables (st.dev. in parenthesis)

	NOT SPEC	SPEC	TOT		NOT SPEC	SPEC	TOT
female	0.574	0.445	0.560	alcohol	0.0170	0.00732	0.0160
	(0.495)	(0.497)	(0.496)		(0.129)	(0.0852)	(0.125)
age	51.61	49.94	51.44	smoke	0.0369	0.0348	0.0367
	(24.24)	(25.70)	(24.40)		(0.189)	(0.183)	(0.188)
urban	0.818	0.817	0.818	obesity	0.00720	0.0140	0.00791
	(0.386)	(0.387)	(0.386)		(0.0845)	(0.118)	(0.0886)
episodes	1.118	1.108	1.117	allergy	0.0276	0.0191	0.0267
	(0.426)	(0.545)	(0.440)		(0.164)	(0.137)	(0.161)
emerg	0.383	0.159	0.360	diabetes	0.0785	0.0626	0.0769
	(0.486)	(0.366)	(0.480)		(0.269)	(0.242)	(0.266)
die	0.0155	0.0181	0.0158	hypertens	0.171	0.121	0.165
	(0.124)	(0.133)	(0.125)		(0.376)	(0.326)	(0.372)
tr_in_eli	0.0000394	0.000164	0.0000522	haemorr	0.00393	0.00899	0.00445
	(0.00628)	(0.0128)	(0.00723)		(0.0626)	(0.0944)	(0.0666)
tr_in_noneli	0.0265	0.0414	0.0280	histdis	0.108	0.0866	0.106
	(0.161)	(0.199)	(0.165)		(0.310)	(0.281)	(0.307)
tr_out_eli	0.00501	0.00491	0.00500	riskfact	0.00729	0.00265	0.00681
	(0.0706)	(0.0699)	(0.0705)		(0.0851)	(0.0514)	(0.0822)
tr_out_noneli	0.0113	0.0135	0.0116	congmalf	0.0113	0.0487	0.0151
	(0.106)	(0.115)	(0.107)		(0.106)	(0.215)	(0.122)
pregnancy	0.104	0.00528	0.0941	risk_phys	0.000643	0.00119	0.000700
	(0.306)	(0.0725)	(0.292)		(0.0254)	(0.0345)	(0.0265)
drug	0.00324	0.00203	0.00312	risk_psysoc	0.00384	0.00157	0.00361
	(0.0568)	(0.0450)	(0.0557)		(0.0619)	(0.0395)	(0.0600)

6. Results

We have estimated various equations and explored the sensitivity of estimates to a range of modelling choices. The specialised markers where estimates are statistically significant appear in bold if p<0.001 and in italics if p<0.05. Rather than reporting the coefficients, we report the predicted percentage increase in costs for specialised services, g_n, calculated as described previously. The full regression results for equation 4 are reported in Appendix Table A5.

In our main analysis we present estimates for the four estimated equations and compare results when applying different functional forms, namely linear, logarithmic and generalised linear models. In all of these analyses, the cost of a provider spell is calculated as the sum of the cost of the constituent episodes and each patient is assigned a specialist marker if one of the SSNDS ICD10 and OPCS codes appears in their record and they were treated as an eligible provider.

We consider the sensitivity of these estimates to choices about how the costs of provider spells are calculated, to dropping the requirement that specialised care is defined as being provided in eligible providers only, and to exclusion from the analysis of patients in particular HRGs.

6.1 Estimates across equations and by functional form

Table 6 presents results from the four equations, going from the base specification which includes the dummies for specialised services only (equation 1), two intermediate models (equations 2 and 3) and the full model with patients' characteristics and hospital random effects (equation 4). These equations are estimated with the dependent variable in both linear and logarithmic form. Equations 1 and 3 are also estimated as generalised linear models (GLM), assuming a gamma distribution with a log link. It was not possible to estimate equations 2 and 4 by applying GLM methods, the models failing to converge because of the size and heterogeneity of the data and the complexity of GLM methods.

In considering the results, there are some general issues to note.

- The level of significance for most specialist markers tends to be consistent across equations and whether estimated in linear, logarithmic or generalised linear form. This means that we can be confident in interpreting (i) a significant (p<0.001) positive coefficient as indicating that the specialist marker has a significant positive impact on cost and (ii) a non-significant coefficient as indicating no significant impact of the marker on costs. Thus, for most specialist markers, significance is not due to incorrect model specification.
- For equations 1 and 3, the linear and generalised linear estimates are very similar. The estimates from the logarithmic models differ, but not in a consistent direction – sometimes the estimates are higher (eg spinal and rheumatology), sometimes lower (eg children, colorectal).
- The size of the estimates is lower in the full specification (equation 4) than in the base model (equation 1). The difference is due to the fact that full specification includes patient characteristics and hospital effects and their inclusion partially purges the effect of specialised services.
- The significance level for cardiology varies according to model specification. In the linear form of equation 1 and in every log specification, cardiology patients who receive specialised care are found to have significantly higher costs than those who do not. In the other linear models, the predicted effects are not significant. These unstable results may be due to the construction of cardiology HRGs, whereby many are populated almost entirely by patients who received a specialised service. This is particularly true for patients receiving coronary artery bypass grafts, valve procedures, and percutaneous coronary interventions. We explore the implications of omitting HRGs such as these in section 6.4.
- For infectious diseases and vascular services, the specialist markers are significant in (some of) the linear models but insignificant in the log models. This instability may be due to the relatively small number of patients classified as having these specialised services.

As indicated earlier, we recommend equation 2 as the basis for determining the size of the mark-up on specialist services, should the estimate be statistically significant. In the case of every specialised marker the predicted effects are larger in equation 1 than in equation 2. This is because equation 1

Table 6: Estimates of additional costs associated with receipt of specialised care

	Linear models				Logarithmic models				Generalised linear models	
	EQ1	EQ2	EQ3	EQ4	EQ1	EQ2	EQ3	EQ4	EQ1	EQ3
Cancer	**0.2173**	**0.1842**	**0.2168**	**0.1879**	*0.1445*	**0.1320**	**0.1459**	**0.1339**	**0.2159**	**0.2138**
BMT	-0.0551	-0.1045	-0.0499	-0.0897	-0.0178	-0.0331	-0.0126	-0.0240	-0.0389	-0.0251
Haemophilia	-0.0886	-0.1435	-0.1839	-0.2022	-0.1593	-0.1644	-0.1139	-0.1060	-0.0895	-0.1506
Womens	-0.0031	-0.0192	-0.0071	-0.0157	0.0310	0.0183	0.0214	0.0170	-0.0024	-0.0020
Spinal	**0.3231**	**0.2755**	**0.3043**	**0.2729**	**0.3982**	**0.3117**	**0.3691**	**0.2932**	**0.3153**	**0.2926**
Neurosciences	**0.2791**	**0.2286**	**0.2051**	**0.1691**	**0.2490**	**0.2448**	**0.2002**	**0.1962**	**0.2747**	**0.2055**
CysticFibrosis	**0.3965**	**0.3792**	**0.3499**	**0.3347**	**0.2694**	**0.2580**	**0.2113**	**0.1984**	**0.3927**	**0.3358**
Renal	-0.1118	-0.1117	-0.0803	-0.0868	0.0127	0.0150	0.0357	0.0360	-0.1136	-0.0871
IntestinalFailure	-0.0074	0.0017	-0.0253	-0.0196	0.0715	0.0732	0.0453	0.0465	-0.0050	-0.0223
Cardiology	**0.1382**	0.0007	0.0567	-0.0600	**0.2625**	**0.1976**	**0.1875**	**0.1287**	**0.1374**	0.0611
CleftLip	-0.0171	-0.0423	-0.0032	-0.0144	0.0161	0.0026	0.0099	0.0033	-0.0180	0.0032
InfectiousDiseaes	**0.2644**	**0.2129**	**0.2312**	**0.2049**	-0.0365	-0.0669	-0.0594	-0.0808	**0.2432**	**0.2005**
Liver	0.0978	0.0754	0.0809	0.0637	0.0529	0.0442	0.0294	0.0293	0.0980	0.0774
Children	**0.2804**	**0.1997**	**0.2524**	**0.1742**	**0.1748**	**0.1457**	**0.1158**	0.0911	**0.2775**	**0.2414**
Dermatology	0.0087	-0.0087	0.0135	-0.0037	-0.0658	-0.0715	-0.0638	-0.0707	0.0086	0.0162
Rheumatology	**0.1827**	**0.1298**	**0.2019**	**0.1618**	**0.3332**	**0.2477**	**0.3503**	**0.2720**	**0.1840**	**0.2178**
Endocrinology	0.0451	-0.0071	0.0517	0.0110	0.0404	0.0094	0.0451	0.0196	0.0422	0.0517
Respiratory	0.0458	-0.0381	-0.0059	-0.0743	-0.0905	-0.1214	-0.1322	-0.1518	0.0414	-0.0123
VascularDiseases	**0.2461**	**0.2112**	*0.1981*	*0.1753*	*0.1269*	0.1015	0.0812	0.0593	**0.2340**	**0.1777**
PainManagement	0.1878	0.1902	0.2278	0.2200	-0.2563	-0.2100	-0.2315	-0.1965	0.1645	0.2322
EarSurgery	0.0570	-0.0006	0.0847	0.0183	0.0794	0.0441	0.0995	0.0555	0.0574	0.0872
Colorectal	**0.2136**	**0.2105**	**0.2181**	**0.2150**	**0.1758**	**0.1813**	**0.1720**	**0.1791**	**0.2129**	**0.2212**
Orthopaedic	**0.2443**	**0.2130**	**0.2581**	**0.2248**	**0.2550**	**0.1997**	**0.2925**	**0.2283**	**0.2382**	**0.2546**
MorbidObesity	-0.0268	-0.0075	-0.0438	-0.0106	0.0271	0.0329	-0.0100	0.0157	-0.0265	-0.0412
MetabolicDisorders	0.0215	-0.0155	0.0506	0.0023	-0.3371	-0.3043	-0.3252	-0.3039	0.0144	0.0258
Ophthalmology	0.0800	0.0570	0.0923	0.0784	0.1194	0.0741	0.1327	0.0923	0.0770	0.0993
Haemoglobinopathy	0.0128	0.0031	0.0140	0.0131	*-0.1042*	**-0.1112**	*-0.0998*	*-0.1013*	0.0100	0.0025
N	12,154,599	12,154,599	12,154,599	12,154,599	12,154,599	12,154,599	12,154,599	12,154,599	12,154,599	12,154,599
R2 / Log-pseudolikelihood	0.0022	0.0020	0.0088	0.0080	0.0033	0.0032	0.0266	0.0257	-11831417	-11777757
R2 within		0.0017		0.0058		0.0028		0.0240		
R2 between		0.1656		0.1029		0.1283		0.0668		
RHO		0.0239		0.0169		0.0402		0.0331		

ignores the influence on costs associated with the hospital in which care was delivered and, consequently, this specification risks over-estimating the impact of the receipt of specialised services on an individual's cost.

- For the colorectal specialist marker the difference between the estimates is negligible. This implies that the higher costs observed for patients who receive specialised colorectal care are not due to the hospital in which they were treated. This would suggest that, for these services, there is little variation among hospitals in the costs of specialised care for these types of patients.
- For other types of treatment, though, the predicted effects differ more markedly, most obviously for spinal, children's and rheumatology specialised services. The differences imply that higher costs are not due solely to whether the patient received specialised services but are also related to the hospital that provided the care. It could be that some hospitals systematically attract more patients with other characteristics that explain higher costs; it could be that these hospitals exert less cost control and are less efficient. Consideration of the other specifications will help disentangle these explanations.

We first consider the former possibility that other patient characteristics explain variation in costs. Compare equation 1 with equation 3, both of which ignore the clustering of patients within hospitals. This comparison allows us to assess what impact there might be on the specialised markers of taking into account other patient characteristics that might explain costs. Again concentrating only on those specialist markers that are significant, three patterns emerge:

- For some specialist markers there is very little difference between the two estimates. This is the case for the cancer and colorectal markers and implies that patient characteristics do not explain variation in patient costs over and above the influence of the specialist marker.
- For other specialist markers the estimates in equation 3 are lower than those from equation 1. This is so for spinal, neurosciences, cystic fibrosis and children's specialist services. The differences are because patients receiving these types of specialist care also have other characteristics that drive their higher costs. Equation 1 ignored these characteristics and, consequently, their influence was partially captured by the specialist markers.
- In contrast, the estimates for some markers are higher in equation 3 than in equation 1, as seen for rheumatology and orthopaedic specialist markers. This implies a negative correlation between receipt of these specialised services and those patient characteristics that drive costs. At first sight this might seem surprising but consider again the descriptive statistics for these characteristics reported in Table 5. Those who received specialised services are not always more likely than those who did not to have the potentially cost increasing characteristics.

6.2 Sensitivity to calculation of the cost of provider spells

There is no correct way of calculating the cost of a provider spell composed of multiple episodes. For the results presented thus far the cost of the spell is calculated as the sum of the consistent episodes recorded for each patient (SUM). The spell cost could instead be based on the highest episode cost (MAX) or the first episode in the spell (EPI1). We examine what impact this might have on the results by considering the linear form of equation 2, this being chosen because the estimates from the linear specification are very similar to the preferred but un-estimable generalised linear model.

As Table 7 shows, the ***significance*** of the estimates does not depend on the calculation, though significance is reduced for vascular diseases when spell costs are based on the highest episode cost (Max).

The ***size*** of the estimates varies according to the specialist marker, but usually by less than 2%. There is, however, a difference of 8.3% for cystic fibrosis and a 5.4% difference for vascular diseases.

Table 7: Sensitivity of estimates to calculation of the cost of provider spells

	Linear model - Equation 2		
	Sum	Max	Epi1
Cancer	**0.1842**	**0.1773**	**0.1935**
BMT	-0.1045	-0.1440	-0.0083
Haemophilia	-0.1435	-0.1507	-0.1199
Womens	-0.0192	-0.0337	-0.0136
Spinal	**0.2755**	**0.2618**	**0.2734**
Neurosciences	**0.2286**	**0.2166**	**0.2346**
CysticFibrosis	**0.3792**	**0.4314**	**0.3486**
Renal	-0.1117	*-0.1303*	-0.0995
IntestinalFailure	0.0017	-0.0220	0.0054
Cardiology	0.0007	-0.0157	0.0405
CleftLip	-0.0423	-0.0577	-0.0340
InfectiousDiseaes	**0.2129**	**0.2375**	**0.2035**
Liver	0.0754	0.0738	0.0763
Children	**0.1997**	**0.1920**	**0.2118**
Dermatology	-0.0087	-0.0204	0.0003
Rheumatology	**0.1298**	**0.1147**	**0.1391**
Endocrinology	-0.0071	-0.0106	-0.0061
Respiratory	-0.0381	-0.0031	-0.0566
VascularDiseases	**0.2112**	*0.1976*	**0.2517**
PainManagement	0.1902	0.1742	0.1976
EarSurgery	-0.0006	-0.0173	0.0106
Colorectal	**0.2105**	**0.2069**	**0.2140**
Orthopaedic	**0.2130**	**0.2026**	**0.2179**
MorbidObesity	-0.0075	-0.0293	0.0063
MetabolicDisorders	-0.0155	-0.0250	-0.0136
Ophthalmology	0.0570	0.0451	0.0629
Haemoglobinopathy	0.0031	-0.0079	0.0139
N	12,154,599	12,154,599	12,154,599
R2	0.0020	0.0023	0.0019
R2 within	0.0017	0.0020	0.0015
R2 between	0.1656	0.1566	0.1860
RHO	0.0239	0.0223	0.0239

6.3 Sensitivity to considering specialist care in non-eligible hospitals

As a further sensitivity analysis we assess the impact of allowing for the eligibility of the provider on the results. For the results considered thus far a patient was defined as receiving specialised care if one of the SSNDS ICD10 or OPCS codes was present in their medical record ***and*** they were treated as an eligible provider. In Table 8 we re-present the effects for the specialist markers followed by the effects generated after relaxing the condition that specialised services have to be delivered by eligible providers. Both sets of results are derived from the linear specification.

Again concentrating only on the specialist markers that are statistically significant, there are two types of impact:

- For some specialist markers, the effect is not sensitive to whether or not specialised care is defined as being confined to eligible providers. This is the case for the cancer, cystic fibrosis, infectious diseases, rheumatology, colorectal and orthopaedic markers.
- For other markers, the effect on costs of having received specialised care is lower if this care is recognised as having been delivered by non-eligible providers. This is the case for spinal, neurosciences and children's specialised care.

Table 8: Sensitivity of estimates to recognition of specialised services by non-eligible providers

	Linear models, specialised care in eligible hospitals only				Linear models, specialised care in any hospital			
	EQ1	EQ2	EQ3	EQ4	EQ1	EQ2	EQ3	EQ4
Cancer	**0.2173**	**0.1842**	**0.2168**	**0.1879**	**0.2185**	**0.1845**	**0.2169**	**0.1876**
BMT	-0.0551	-0.1045	-0.0499	-0.0897	-0.0469	-0.1006	-0.0436	-0.0870
Haemophilia	-0.0886	-0.1435	-0.1839	-0.2022	-0.0889	-0.1437	-0.1857	-0.2028
Womens	-0.0031	-0.0192	-0.0071	-0.0157	-0.0026	-0.0192	-0.0093	-0.0174
Spinal	**0.3231**	**0.2755**	**0.3043**	**0.2729**	**0.1950**	**0.1738**	**0.1931**	**0.1813**
Neurosciences	**0.2791**	**0.2286**	**0.2051**	**0.1691**	**0.2293**	**0.1893**	**0.1713**	**0.1472**
CysticFibrosis	**0.3965**	**0.3792**	**0.3499**	**0.3347**	**0.3981**	**0.3783**	**0.3536**	**0.3366**
Renal	-0.1118	-0.1117	-0.0803	-0.0868	-0.1120	-0.1126	-0.0816	-0.0882
IntestinalFailure	-0.0074	0.0017	-0.0253	-0.0196	-0.0086	0.0015	-0.0261	-0.0198
Cardiology	**0.1382**	0.0007	0.0567	-0.0600	**0.0795**	-0.0116	0.0103	-0.0673
CleftLip	-0.0171	-0.0423	-0.0032	-0.0144	-0.0180	-0.0433	-0.0060	-0.0157
InfectiousDiseaes	**0.2644**	**0.2129**	**0.2312**	**0.2049**	**0.2654**	**0.2116**	**0.2299**	**0.2029**
Liver	0.0978	0.0754	0.0809	0.0637	0.0640	0.0693	0.0462	0.0551
Children	**0.2804**	**0.1997**	**0.2524**	**0.1742**	**0.1311**	**0.0879**	**0.1032**	**0.0711**
Dermatology	0.0087	-0.0087	0.0135	-0.0037	0.0114	-0.0097	0.0121	-0.0064
Rheumatology	**0.1827**	**0.1298**	**0.2019**	**0.1618**	**0.1821**	**0.1270**	**0.1995**	**0.1583**
Endocrinology	0.0451	-0.0071	0.0517	0.0110	0.0456	-0.0072	0.0511	0.0106
Respiratory	0.0458	-0.0381	-0.0059	-0.0743	0.0269	0.0063	-0.0299	*-0.0452*
VascularDiseases	**0.2461**	**0.2112**	*0.1981*	*0.1753*	**0.2618**	**0.2112**	*0.2050*	*0.1717*
PainManagement	0.1878	0.1902	0.2278	0.2200	0.1853	0.1871	0.2247	0.2169
EarSurgery	0.0570	-0.0006	0.0847	0.0183	0.0610	-0.0008	0.0852	0.0164
Colorectal	**0.2136**	**0.2105**	**0.2181**	**0.2150**	**0.2119**	**0.2090**	**0.2159**	**0.2130**
Orthopaedic	**0.2443**	**0.2130**	**0.2581**	**0.2248**	**0.2469**	**0.2144**	**0.2579**	**0.2246**
MorbidObesity	-0.0268	-0.0075	-0.0438	-0.0106	-0.0273	-0.0085	-0.0467	-0.0122
MetabolicDisorders	0.0215	-0.0155	0.0506	0.0023	0.0233	-0.0205	0.0499	-0.0026
Ophthalmology	0.0800	0.0570	0.0923	0.0784	0.0797	0.0564	0.0908	0.0771
Haemoglobinopathy	0.0128	0.0031	0.0140	0.0131	0.0131	0.0034	0.0141	0.0130
N	12,154,599	12,154,599	12,154,599	12,154,599	12,154,599	12,154,599	12,154,599	12,154,599
R2	0.0022	0.0020	0.0088	0.0080	0.0018	0.0017	0.0085	0.0078
R2 within		0.0017		0.0058		0.0015		0.0057
R2 between		0.1656		0.1029		0.1310		0.0851
RHO		0.0239		0.0169		0.0236		0.0157

6.4 Sensitivity to exclusion of patients in particular HRGs

Some HRGs are almost exclusively populated by patients who received specialised services. Similarly, there are some HRGs in which no patients received specialised services. The former type of HRG arises because the ICD10 or OPCS codes used to indicate the receipt of specialised care sometimes also serve to indicate the HRG to which patients should be allocated.[f] Including patients allocated to these HRGs in the analysis may bias the estimated effect on costs of the specialist markers. This is because for the HRGs in which all patients receive specialised care there is no comparative reference group that consists of patients allocated to the same HRG who did not receive specialised care. We assess the impact on the estimated effects of excluding patients allocated to these HRGs from the analysis. We define three categories for exclusion:

- Dropping patients in those HRGs in which everyone is identified as having received specialised care and those HRGs in which no-one is identified as having received specialised care (TRIM1). This reduces the analytical sample by 2.1% (256,517 patients).

[f] As noted earlier, this is particularly true for patients receiving cardiac care, although the coefficient for the cardiology specialist marker is significant only under the linear form of equation 1.

- Dropping patients in those HRGs in which there are fewer than 10 patients who did not receive specialised care and those HRGs in which there are fewer than 10 patients who did receive specialised care (TRIM2). This reduces the analytical sample by 7.4% (877,285 patients).
- Dropping patients in those HRGs in which more than 99% of patients or less than 1% are identified as having receiving specialised care (TRIM3). This has a dramatic effect on the analytical sample, reducing it by 52.6% (5,933,359 patients).

Results are presented in Table 9, again for the linear form of equation 2. To summarise:

- The predicted effects are not sensitive to the first method of exclusion (TRIM1), except for the specialist marker for bone marrow transplantation, which is now significant, and for vascular diseases, which increases from 21% to 28%.
- Compared to the original estimates, the predicted effects increase when applying the second and third methods of exclusion (TRIM2 and TRIM3) for the following markers: bone marrow transplantation, spinal, neurosciences, and vascular diseases. For the rheumatology and colorectal markers, the effects are now insignificant. The effects for the other markers are not substantially changed.

Table 9: Sensitivity of estimates to exclusion of particular HRGs

	Linear model - Equation 2			
	Full	Trim1	Trim 2	Trim3
Cancer	**0.1842**	**0.1822**	**0.1820**	**0.1828**
BMT	-0.1045	**0.1637**	**0.1663**	**0.1860**
Haemophilia	-0.1435	-0.1452	-0.1464	*-0.2113*
Womens	-0.0192	-0.0207	-0.0175	-0.0316
Spinal	**0.2755**	**0.2729**	**0.3374**	**0.4262**
Neurosciences	**0.2286**	**0.2267**	**0.2907**	**0.3076**
CysticFibrosis	**0.3792**	**0.3861**	**0.3860**	**0.3693**
Renal	-0.1117	-0.1152	-0.1171	*-0.1407*
IntestinalFailure	0.0017	0.0027	0.0028	0.0187
Cardiology	0.0007	0.0467	0.0526	0.0169
CleftLip	-0.0423	-0.0423	-0.0417	-0.0319
InfectiousDiseaes	**0.2129**	**0.2174**	**0.2163**	**0.2086**
Liver	0.0754	0.0727	0.0710	0.0384
Children	**0.1997**	**0.1988**	**0.2052**	**0.1868**
Dermatology	-0.0087	-0.0102	-0.0145	-0.0294
Rheumatology	**0.1298**	**0.1303**	**0.1285**	0.0819
Endocrinology	-0.0071	-0.0093	-0.0107	-0.0035
Respiratory	-0.0381	-0.0404	-0.0459	-0.0770
VascularDiseases	**0.2112**	**0.2825**	**0.2872**	**0.2911**
PainManagement	0.1902	0.1886	0.1885	0.2174
EarSurgery	-0.0006	0.0290	0.0221	0.0076
Colorectal	**0.2105**	**0.2104**	**0.2111**	0.0335
Orthopaedic	**0.2130**	**0.2135**	**0.2119**	**0.2051**
MorbidObesity	-0.0075	-0.0091	-0.0094	-0.0270
MetabolicDisorders	-0.0155	-0.0192	-0.0229	-0.0100
Ophthalmology	0.0570	0.0563	0.0568	0.0621
Haemoglobinopathy	0.0031	0.0042	0.0054	0.0147
N	12,154,599	11,898,082	11,277,314	6,221,240
R2	0.0020	0.0021	0.0023	0.0045
R2 within	0.0017	0.0017	0.0018	0.0041
R2 between	0.1656	0.1801	0.1919	0.0925
RHO	0.0239	0.0253	0.0266	0.0546

6.5 Estimates of cost efficiency

As already noted, the models that we have estimated have a low R^2. This is because they are not intended to identify the many reasons why costs might vary among patients. Nevertheless, we are able to assess what proportion of the variation in costs is due to the hospital in which patients are treated. This is indicated by the 'R^2 within' and 'R^2 between' statistics. The latter is consistently much higher than the former, suggesting that patients within the same hospital tend to be more similar to one another than they are to patients seen in other hospitals.

The random effect captures the hospital's influence on costs over and above the influence of the other patient-level variables accounted for in the model. Consequently these random effects can be interpreted as measures of each hospital's cost efficiency. The cost of a typical patient in a hospital with a relatively large random effect is higher than the cost of a comparable patient treated in a hospital with a lower random effect. Interpretation of these random effects as measures of relative cost efficiency is conditional upon having properly accounted for other factors that might explain variation in patient costs.

Consider equations 2 and 4 both of which account for the clustering of patients in hospitals. In equation 2 we account for the HRG to which the patient is allocated and whether or not they received specialised care. Thus the random effects are not contaminated by these factors. But they might be contaminated by other patient characteristics if there are systematic differences in the types of patients that hospitals treat that are not already captured by HRGs and the specialised markers. Equation 4 accounts for these characteristics and, therefore, the random effects from this specification provide a more accurate indication of each hospital's relative cost efficiency than does equation 2.

That said there is little practical difference between the two sets of random effects, the correlation amounting to 97.3%. This implies that patients do not differ systematically across hospitals in terms of the set of characteristics that are accounted for in equation 4.

Hospitals can be ranked according to their cost efficiency as captured by the random effect, ordered from those with the lowest average costs for their patients to those with the highest average costs. The orderings from the linear and logarithmic forms of equation 4 are depicted in Figure 1.

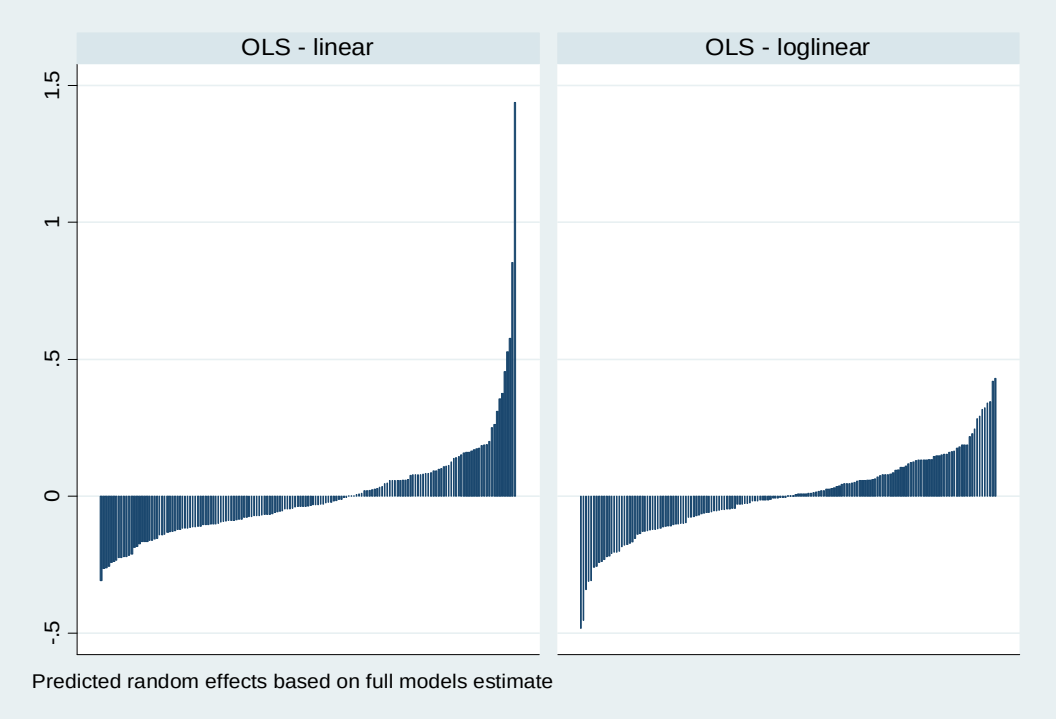

Figure 1: Hospitals ranking distribution based on random effects estimates

7. Conclusion

Unless the basis for the claims that specialist hospitals require top-up payments can be established, the financial incentives introduced by prospective payment to encourage cost reducing behaviour will be diluted. In this paper we have explored the basis for these claims by assessing the marginal costs associated with receipt of specialised care for all patients treated in English hospitals during 2008/09.

We estimate various multiple regressions in order, firstly, to establish the extent to which the receipt of specialised care is associated with higher treatment and, secondly, to evaluate hospital performance in controlling costs. We explore how robust the results are to a range of analytical choices by conducting various sensitivity analyses.

For some specialised markers our analysis suggests that costs are indeed higher than for other patients allocated to the same HRG. Our preferred model for evaluating the costs associated with receipt of specialised care accounts for the clustering of patients within hospital but ignores other patient characteristics that may not be adequately captured by the HRG to which the patient is allocated. We recommend a linear rather a logarithmic specification, as the estimates from the former are closer to those derived from generalised linear models, which could not be computed when allowance was made for clustering of patients in hospitals.

We find that, after allowing for the hospital in which treatment is provided, costs are higher than for other patients allocated to the same HRG if a patient receives one of the following types of specialised service:

- cancer (18% higher cost)
- spinal (28%),
- neurosciences (23%),
- cystic fibrosis (38%),
- infectious disease (21%),
- children (20%),
- rheumatology (13%),
- vascular diseases (21%),
- colorectal (21%) and
- orthopaedic (21%).

The implication for Payment by Results is that ‘top-up’ payments for patients with these markers might be made over and above the tariff associated with the HRG to which they are allocated. This would ensure that the payment policy relating to specialised services is consistent with the patient-based reimbursement arrangements of Payment by Results. Additional payments would not be made in the presence of the other specialised care markers, there being insufficient evidence to suggest that the costs associated with these types of specialised care drive higher costs.

We recommend that the size of additional top-up amounts to the percentage increase in costs as reported above, these estimates being derived from our preferred model specification (the linear form of equation 2). However, different values could be adopted, justified on other grounds. These grounds may include:

- Transitional arrangements, notably for children’s services, where the recommended value of 20% is substantially lower than the current 78% top-up;
- Materiality, where an additional top-up would have limited financial consequence for those types of specialised services that are delivered to only a small number of patients;
- Sensitivity to model specification. The other model specifications generally imply lower top-up values than those recommended above, with the exception of a model that fails to allow for each hospital’s influence on costs.

Our analysis demonstrates that there is substantial variation in the average cost of treatment across the hospital sector, and that this variation is due neither to differences in the factor prices faced by hospitals, nor to the provision of specialised services, and nor to the casemix, socio-demographic and diagnostic characteristics of each hospital's patients. After controlling for these diverse reasons for cost variation, we are able to rank hospitals according to their relative cost efficiency. Those hospitals rated as relatively inefficient will struggle financially under Payment by Results.

8. References

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Appendix tables

We have seen in Table 2 that there has been a loss of approximately 2.3 million episodes due to the mismatch between the HES and the HRG4 databases. One of the reasons for this mismatch is that Reference Costs are not reported for some types of activity. These are reported in Table A1. There remain 1.8m HES records without an associated Reference Cost. These are described by HRG chapter in Table A2 and by provider in Table A3.

Table A1: Mismatch frequencies by areas of treatment

Mismatch	Freq.	Percent
Other areas	1,807,827	76.68
Renal dialysis	316,152	13.41
Well babies	113,609	4.82
Undefined/Used	96,777	4.10
Mental health	8,395	0.36
Cystic fibrosis	8,264	0.35
Intermediate care	4,249	0.18
Chemotherapy	2,504	0.11
Total	2,357,777	

Table A2: Mismatch frequencies by HRG chapter

HRG chapter	Freq.	Percent		HRG chapter	Freq.	Percent
FZ	381,756	21.12		PB	25,447	1.41
NZ	202,737	11.21		BZ	24,868	1.38
PA	127,387	7.05		HA	24,707	1.37
DZ	111,445	6.16		MB	23,200	1.28
LB	81,089	4.49		HC	19,271	1.07
WA	79,741	4.41		JD	17,567	0.97
EB	75,512	4.18		AB	14,893	0.82
CZ	69,597	3.85		GB	14,176	0.78
LA	59,835	3.31		KC	11,576	0.64
JA	55,832	3.09		GA	6,762	0.37
SA	54,327	3.01		KB	6,546	0.36
AA	51,369	2.84		VA	5,569	0.31
JC	48,122	2.66		KA	4,310	0.24
HD	47,419	2.62		JB	3,470	0.19
QZ	41,832	2.31		HR	1,709	0.09
HB	33,579	1.86		WF	329	0.02
EA	28,249	1.56		MC	54	0.00
GC	26,864	1.49		Total	1,807,827	100
MA	26,681	1.48				

Table A3: Mismatch frequencies by provider code

Code	Freq.	Percent		Code	Freq.	Percent		Code	Freq.	Percent		Code	Freq.	Percent
RYQ	168,831	9.34		RJE	12,625	0.70		RNZ	5,718	0.32		RXF	3,144	0.17
RGT	122,841	6.79		RBA	12,563	0.69		RNH	5,576	0.31		RFR	2,820	0.16
RYR	119,142	6.59		RXK	12,157	0.67		RXC	5,530	0.31		RQX	2,804	0.16
RXN	40,657	2.25		RTK	11,807	0.65		RDU	5,420	0.30		RJF	2,620	0.14
RK5	40,581	2.24		REF	11,365	0.63		RF4	5,443	0.30		RCC	2,372	0.13
RQ8	40,115	2.22		RGQ	11,386	0.63		RJ7	5,483	0.30		RC9	2,125	0.12
RNJ	38,565	2.13		RNQ	10,938	0.61		RN3	5,456	0.30		RCB	2,169	0.12
RTE	31,500	1.74		RCU	10,310	0.57		RV8	5,466	0.30		RRF	2,082	0.12
RBN	28,802	1.59		RVW	10,111	0.56		RCX	5,293	0.29		RCF	2,056	0.11
RJZ	27,353	1.51		RDZ	9,916	0.55		RWF	5,239	0.29		RBZ	1,807	0.10
RW3	24,702	1.37		RD7	9,633	0.53		RBL	5,053	0.28		RGM	1,792	0.10
RHU	24,417	1.35		RVR	9,520	0.53		RFS	5,040	0.28		RM3	1,836	0.10
RR8	24,057	1.33		RGC	9,344	0.52		RKE	5,079	0.28		RBD	1,552	0.09
RAS	21,381	1.18		RJ2	9,384	0.52		RN7	5,071	0.28		RC3	1,565	0.09
RHW	21,109	1.17		RTG	9,402	0.52		RXH	5,145	0.28		RD1	1,642	0.09
RTD	20,986	1.16		RHM	9,005	0.50		RC1	4,935	0.27		RM4	1,582	0.09
RVV	20,992	1.16		RL4	8,763	0.48		RDE	4,822	0.27		RWH	1,702	0.09
RM2	20,462	1.13		RWG	8,593	0.48		RJD	4,838	0.27		RA9	1,399	0.08
RQM	19,908	1.10		RA3	8,405	0.46		RQ3	4,855	0.27		RLT	1,472	0.08
RW6	19,820	1.10		RGR	8,382	0.46		RQW	4,914	0.27		RMP	1,421	0.08
RXW	18,761	1.04		RWD	8,143	0.45		RWW	4,824	0.27		RQ6	1,390	0.08
RH8	17,757	0.98		RBK	7,851	0.43		RPA	4,544	0.25		RE9	1,303	0.07
RDD	17,507	0.97		RXP	7,457	0.41		RK9	4,337	0.24		RNL	1,312	0.07
RHQ	17,603	0.97		RRK	7,171	0.40		RWY	4,140	0.23		RVY	1,312	0.07
RD8	17,357	0.96		RFF	6,975	0.39		RFW	3,974	0.22		RBV	1,167	0.06
RA7	16,994	0.94		RXR	7,125	0.39		RJ6	3,990	0.22		RL1	1,091	0.06
RAP	16,525	0.91		RNS	6,817	0.38		RAX	3,819	0.21		RWA	1,013	0.06
RTR	15,905	0.88		RTF	6,911	0.38		RT3	3,844	0.21		RA4	908	0.05
RR1	15,647	0.87		RTH	6,888	0.38		RVJ	3,767	0.21		RAN	903	0.05
RNA	15,284	0.85		RAL	6,751	0.37		RA2	3,547	0.20		RLQ	968	0.05
RP4	15,438	0.85		RVL	6,729	0.37		RAE	3,585	0.20		RPC	986	0.05
RAJ	15,120	0.84		RYJ	6,709	0.37		REP	3,524	0.19		RPY	840	0.05
RX1	15,256	0.84		RD3	6,439	0.36		RGN	3,470	0.19		REN	775	0.04
RTP	14,702	0.81		REM	6,525	0.36		RLU	3,471	0.19		RJC	755	0.04
RXL	14,360	0.79		RP5	6,514	0.36		RMC	3,483	0.19		RQQ	440	0.02
RWP	14,055	0.78		RRV	6,420	0.36		RXQ	3,434	0.19		RBF	147	0.01
RJL	13,915	0.77		RGP	6,246	0.35		RR7	3,297	0.18		RET	152	0.01
RWJ	13,867	0.77		RKB	6,317	0.35		RBT	3,051	0.17		RRJ	168	0.01
RJ1	13,779	0.76		RJR	6,170	0.34		RCD	3,025	0.17		RBB	85	0.00
RLN	13,495	0.75		RTX	6,146	0.34		RJN	3,060	0.17		RBQ	30	0.00
RM1	13,440	0.74		RWE	6,202	0.34		RN5	3,015	0.17		Total	1,807,827	100.00
RBS	12,565	0.70		RN1	5,846	0.32		RP6	3,029	0.17				

Table A4: Provider information

Code	Name	Activity	% SPEC	% MISSING
RHQ	Sheffield Teaching Hospitals NHS Foundation Trust	262,260	41.60	4.87
RR1	Heart of England NHS Foundation Trust	239,786	5.69	28.78
RR8	Leeds Teaching Hospitals NHS Trust	219,508	12.16	9.59
RWE	University Hospitals of Leicester NHS Trust	217,118	12.15	2.65
RW6	Pennine Acute Hospitals NHS Trust	211,950	5.28	13.68
RTH	Oxford Radcliffe Hospitals NHS Trust	204,652	35.48	1.87
RXN	Lancashire Teaching Hospitals NHS Foundation Trust	187,670	7.40	21.20
RX1	Nottingham University Hospitals NHS Trust	186,265	12.92	7.64
RTD	The Newcastle Upon Tyne Hospitals NHS Foundation Trust	185,984	15.96	9.31
RJ1	Guy's and St Thomas' NHS Foundation Trust	172,111	14.23	7.62
RVJ	North Bristol NHS Trust	170,176	39.19	1.06
RM1	Norfolk and Norwich University Hospital NHS Trust	169,430	24.25	0.88
RTE	Gloucestershire Hospitals NHS Foundation Trust	167,014	4.53	13.90
RW3	Central Manchester and Manchester Children's University Hospitals NHS Trust	164,589	24.59	38.84
RYJ	Imperial College Healthcare NHS Trust	162,142	14.29	1.89
RAL	Royal Free Hampstead NHS Trust	161,915	9.47	56.47
RJE	University Hospital of North Staffordshire NHS Trust	161,382	19.27	7.53
RWA	Hull and East Yorkshire Hospitals NHS Trust	147,710	10.09	4.21
RWD	United Lincolnshire Hospitals NHS Trust	145,357	3.57	7.25
RVV	East Kent Hospitals NHS Trust	139,217	6.27	11.92
RTG	Derby Hospitals NHS Foundation Trust	139,135	5.82	2.87
RTR	South Tees Hospitals NHS Trust	138,797	11.06	10.29
RHU	Portsmouth Hospitals NHS Trust	137,697	6.60	13.82
RXF	Mid Yorkshire Hospitals NHS Trust	134,727	3.62	3.80
RXK	Sandwell and West Birmingham Hospitals NHS Trust	133,412	4.25	6.83
RF4	Barking, Havering and Redbridge Hospitals NHS Trust	128,014	5.37	1.58
RHW	Royal Berkshire NHS Foundation Trust	127,642	4.76	44.67
REF	Royal Cornwall Hospitals NHS Trust	125,050	7.46	11.01
RA7	United Bristol Healthcare NHS Trust	124,047	16.01	9.04
RH8	Royal Devon and Exeter NHS Foundation Trust	123,775	13.78	12.51
RXP	County Durham and Darlington NHS Foundation Trust	122,008	4.05	4.06
RKB	University Hospitals Coventry and Warwickshire NHS Trust	121,197	9.14	2.90
RHM	Southampton University Hospitals NHS Trust	120,915	19.95	1.44
RNA	Dudley Group of Hospitals NHS Trust	114,116	9.83	13.05
RL4	The Royal Wolverhampton Hospitals NHS Trust	111,776	14.89	6.25
RLN	City Hospitals Sunderland NHS Foundation Trust	111,194	5.33	8.78
RJ7	St George's Healthcare NHS Trust	110,070	13.04	3.76
RTF	Northumbria Healthcare NHS Foundation Trust	109,498	4.15	2.37
RXL	Blackpool, Fylde and Wyre Hospitals NHS Foundation Trust	108,808	7.32	8.38
RK9	Plymouth Hospitals NHS Trust	108,714	11.28	1.58

RM3	Salford Royal NHS Foundation Trust	108,013	17.76	1.36
RRK	University Hospital Birmingham NHS Foundation Trust	107,673	36.17	5.25
RXR	East Lancashire Hospitals NHS Trust	106,326	3.70	6.53
RWP	Worcestershire Acute Hospitals NHS Trust	104,757	3.96	9.69
RAE	Bradford Teaching Hospitals NHS Foundation Trust	104,325	5.11	1.99
RQ6	Royal Liverpool and Broadgreen University Hospitals NHS Trust	104,147	14.87	1.59
RJZ	King's College Hospital NHS Foundation Trust	102,280	24.89	20.45
RXC	East Sussex Hospitals NHS Trust	101,687	5.16	4.43
RDZ	The Royal Bournemouth and Christchurch Hospitals NHS Foundation Trust	101,650	2.66	10.44
RVL	Barnet and Chase Farm Hospitals NHS Trust	101,349	5.97	6.33
RWY	Calderdale and Huddersfield NHS Foundation Trust	100,291	4.02	0.65
RXH	Brighton and Sussex University Hospitals NHS Trust	99,849	10.71	4.78
RP5	Doncaster and Bassetlaw Hospitals NHS Foundation Trust	98,760	5.13	3.35
RRV	University College London Hospitals NHS Foundation Trust	97,927	16.61	5.64
RTX	University Hospitals of Morecambe Bay NHS Trust	95,646	3.66	11.13
RBL	Wirral University Teaching Hospital NHS Foundation Trust	94,009	3.37	3.74
RXW	Shrewsbury and Telford Hospital NHS Trust	93,811	7.32	14.50
REM	Aintree University Hospitals NHS Foundation Trust	91,782	20.54	1.77
RV8	North West London Hospitals NHS Trust	91,214	4.73	4.38
RNJ	Barts and The London NHS Trust	90,943	25.93	46.11
RQ8	Mid Essex Hospital Services NHS Trust	90,653	6.45	40.72
RDD	Basildon and Thurrock University Hospitals NHS Foundation Trust	89,919	11.03	18.45
RJL	Northern Lincolnshire and Goole Hospitals NHS Foundation Trust	89,911	6.91	32.28
RWH	East and North Hertfordshire NHS Trust	89,487	4.08	5.23
RWF	Maidstone and Tunbridge Wells NHS Trust	88,435	5.73	7.03
RXQ	Buckinghamshire Hospitals NHS Trust	87,992	4.43	1.75
RNS	Northampton General Hospital NHS Trust	86,029	5.00	7.80
RNL	North Cumbria Acute Hospitals NHS Trust	85,559	8.36	0.74
RVR	Epsom and St Helier University Hospitals NHS Trust	85,366	6.29	12.70
RVW	North Tees and Hartlepool NHS Foundation Trust	82,838	2.60	14.06
RBN	St Helens and Knowsley Hospitals NHS Trust	80,689	2.14	22.83
RAJ	Southend University Hospital NHS Foundation Trust	80,643	4.36	16.97
RWJ	Stockport NHS Foundation Trust	80,028	3.66	15.66
RWW	North Cheshire Hospitals NHS Trust	78,665	4.11	8.45
RRF	Wrightington, Wigan and Leigh NHS Trust	77,716	4.98	2.09
RK5	Sherwood Forest Hospitals NHS Foundation Trust	77,150	3.24	41.56
RBA	Taunton and Somerset NHS Foundation Trust	75,812	5.54	17.04
RM2	University Hospital of South Manchester NHS Foundation Trust	75,779	12.16	21.76
RDU	Frimley Park Hospital NHS Foundation Trust	75,397	3.95	4.02
RGQ	Ipswich Hospital NHS Trust	74,511	5.08	12.69

RD7	Heatherwood and Wexham Park Hospitals NHS Foundation Trust	74,244	4.74	8.02
RD3	Poole Hospital NHS Foundation Trust	73,557	5.96	8.67
RGN	Peterborough and Stamford Hospitals NHS Foundation Trust	73,346	5.10	0.92
RN3	Swindon and Marlborough NHS Trust	72,659	4.77	5.07
RGC	Whipps Cross University Hospital NHS Trust	71,471	5.97	11.30
RCB	York Hospitals NHS Foundation Trust	71,306	4.35	0.45
RMC	Bolton Hospitals NHS Trust	71,124	3.56	5.70
RDE	Essex Rivers Healthcare NHS Trust	70,918	5.12	7.52
RWG	West Hertfordshire Hospitals NHS Trust	70,882	5.44	8.97
RFR	The Rotherham NHS Foundation Trust	70,014	5.31	0.89
RC9	Luton and Dunstable Hospital NHS Foundation Trust	67,763	6.33	0.90
RFS	Chesterfield Royal Hospital NHS Foundation Trust	67,383	4.77	9.59
RGP	James Paget University Hospitals NHS Foundation Trust	67,292	4.12	24.72
RNQ	Kettering General Hospital NHS Trust	67,002	5.86	11.87
RTP	Surrey and Sussex Healthcare NHS Trust	65,759	3.56	23.11
RD1	Royal United Hospital Bath NHS Trust	64,724	6.45	1.76
RA9	South Devon Healthcare NHS Foundation Trust	64,289	6.66	0.57
RBT	Mid Cheshire Hospitals NHS Trust	64,282	2.97	1.20
RJR	Countess of Chester Hospital NHS Foundation Trust	63,654	4.83	23.45
RJ6	Mayday Healthcare NHS Trust	63,533	5.00	5.27
RQM	Chelsea and Westminster Hospital NHS Foundation Trust	63,501	8.49	28.17
RPA	Medway NHS Trust	63,483	4.38	11.75
RTK	Ashford and St Peter's Hospitals NHS Trust	62,933	5.75	16.43
RCX	The Queen Elizabeth Hospital King's Lynn NHS Trust	61,506	3.65	3.26
RJD	Mid Staffordshire NHS Foundation Trust	60,626	4.35	7.60
RBK	Walsall Hospitals NHS Trust	60,306	5.45	10.44
RQW	The Princess Alexandra Hospital NHS Trust	59,603	5.43	6.68
RD8	Milton Keynes Hospital NHS Foundation Trust	58,759	4.24	27.71
RAX	Kingston Hospital NHS Trust	58,615	4.47	4.93
RA2	Royal Surrey County Hospital NHS Trust	58,545	9.46	4.41
RVY	Southport and Ormskirk Hospital NHS Trust	58,077	3.94	7.49
RNZ	Salisbury NHS Foundation Trust	57,283	6.08	8.05
RFF	Barnsley Hospital NHS Foundation Trust	56,922	5.31	8.81
RNH	Newham University Hospital NHS Trust	55,627	1.57	3.42
RJ2	The Lewisham Hospital NHS Trust	53,741	7.51	21.31
RBD	Dorset County Hospital NHS Foundation Trust	53,512	4.93	3.03
RAS	The Hillingdon Hospital NHS Trust	52,981	4.17	40.14
RCF	Airedale NHS Trust	52,426	4.16	7.85
RGR	West Suffolk Hospitals NHS Trust	51,777	4.30	11.67
RPY	The Royal Marsden NHS Foundation Trust	51,303	1.68	1.96
RN5	Basingstoke and North Hampshire NHS Foundation Trust	49,507	3.46	6.07
RMP	Tameside Hospital NHS Foundation Trust	49,022	3.54	0.85

RKE	The Whittington Hospital NHS Trust	47,585	7.97	17.61
RJC	South Warwickshire General Hospitals NHS Trust	45,703	4.02	0.73
RN1	Winchester and Eastleigh Healthcare NHS Trust	45,700	5.46	8.84
RC3	Ealing Hospital NHS Trust	44,952	2.78	7.00
RJF	Burton Hospitals NHS Trust	44,505	3.34	1.61
RQX	Homerton University Hospital NHS Foundation Trust	44,268	4.11	4.36
RAP	North Middlesex University Hospital NHS Trust	43,709	4.90	34.81
RBZ	Northern Devon Healthcare NHS Trust	43,581	5.24	4.83
RC1	Bedford Hospital NHS Trust	42,717	6.34	13.41
RN7	Dartford and Gravesham NHS Trust	42,693	2.54	6.78
RCD	Harrogate and District NHS Foundation Trust	39,889	3.49	6.90
RCC	Scarborough and North East Yorkshire Health Care NHS Trust	38,958	3.35	4.98
RFW	West Middlesex University Hospital NHS Trust	38,358	5.25	3.11
RLT	George Eliot Hospital NHS Trust	38,145	4.20	2.87
RR7	Gateshead Health NHS Foundation Trust	37,185	2.06	5.55
RA4	Yeovil District Hospital NHS Foundation Trust	36,678	3.93	0.51
RJN	East Cheshire NHS Trust	35,844	3.75	5.53
RBS	Royal Liverpool Children's NHS Trust	34,807	32.99	23.19
RQQ	Hinchingbrooke Health Care NHS Trust	33,692	6.06	0.60
RE9	South Tyneside NHS Foundation Trust	32,041	3.30	0.60
RQ3	Birmingham Children's Hospital NHS Foundation Trust	32,040	55.42	20.92
RLQ	Hereford Hospitals NHS Trust	31,050	5.55	2.14
RA3	Weston Area Health NHS Trust	29,719	3.26	25.53
REP	Liverpool Women's NHS Foundation Trust	29,510	0.73	12.18
RM4	Trafford Healthcare NHS Trust	28,536	6.03	10.27
RP6	Moorfields Eye Hospital NHS Foundation Trust	27,336	4.65	11.65
RT3	Royal Brompton and Harefield NHS Trust	26,818	57.89	13.20
RCU	Sheffield Children's NHS Foundation Trust	23,875	31.51	40.40
RBV	Christie Hospital NHS Foundation Trust	22,730	18.02	5.41
RGM	Papworth Hospital NHS Foundation Trust	21,039	68.00	11.26
RP4	Great Ormond Street Hospital For Children NHS Trust	19,418	56.55	71.64
RPC	Queen Victoria Hospital NHS Foundation Trust	18,061	10.64	5.45
RLU	Birmingham Women's NHS Foundation Trust	17,006	1.40	21.70
RRJ	The Royal Orthopaedic Hospital NHS Foundation Trust	16,485	9.88	1.29
RAN	Royal National Orthopaedic Hospital NHS Trust	10,596	22.51	8.52
RBQ	The Cardiothoracic Centre - Liverpool NHS Trust	10,328	56.31	2.78
RL1	Robert Jones and Agnes Hunt Orthopaedic and District Hospital NHS Trust	10,239	6.56	10.61
RBF	Nuffield Orthopaedic Centre NHS Trust	9,518	3.57	1.82
RET	Walton Centre for Neurology and Neurosurgery NHS Trust	8,523	23.61	48.90
REN	Clatterbridge Centre for Oncology NHS Foundation Trust	4,433	8.13	17.64
RBB	Royal National Hospital for Rheumatic Diseases NHS Foundation Trust	3,533	0.32	2.92

Table A5: Full estimation results, equation 4

	Linear		Loglinear				Linear		Loglinear	
	b/signif		b/signif				b/signif		b/signif	
Cancer	0.186	***	0.127	***		obesity	0.013		0.013	
BMT	-0.089		-0.02			allergy	0.026	***	0.043	***
Haemophilia	-0.2	*	-0.104			diabetes	-0.008		-0.006	
Womens	-0.016		0.017			hypertens	0.047		0.044	***
Spinal	0.269	***	0.259	***		haemorr	0.081	**	-0.054	**
Neurosciences	0.167	***	0.181	***		histdis	0.02	*	0.03	***
Cystic fibrosis	0.33	***	0.181	***		riskfact	0.001		-0.009	
Renal	-0.086		0.038			congmalf	0.051	***	0.022	
Intestinal failure	-0.019		0.046			risk_phys	-0.007		-0.044	
Cardiology	-0.059		0.122	***		risk_psysoc	0.192	***	0.108	***
Cleft lip	-0.014		0.006			tr_in_eli	0.008		-0.031	
Infectious diseases	0.202	***	-0.082			tr_in_noneli	0.16	**	0.122	***
Liver	0.063		0.031			tr_out_eli	0.14	***	0.023	
Children	0.172	***	0.088	**		tr_out_noneli	0.129	***	0.05	***
Dermatology	-0.004		-0.072			die	0.072	***	0.004	
Rheumatology	0.16	***	0.241	***		emerg	-0.013		-0.079	***
Endocrinology	0.011		0.021			Episodes	0.108	***	0.201	***
Respiratory	-0.073		-0.159			East of England	0.115		0.033	
Vascular diseases	0.173	**	0.059			London	0.16	***	0.044	
Pain Management	0.217		-0.188			North-East	0.022		-0.021	
Ear surgery	0.018		0.057			North-West	0.009		-0.054	
Colorectal	0.212	***	0.166	***		South-East	0.068		0.048	
Orthopaedic	0.222	***	0.207	***		South-West	0.007		-0.038	
Morbid obesity	-0.01		0.018			West Midlands	0.044		0.016	
Metabolic disorders	0.002		-0.343	*		Yorkshire	0.055		0.059	*
Ophthalmology	0.077		0.091			Urban	-0.003		-0.003	
Haemoglobinopathy	0.013		-0.106	**		White	0.015	**	0.007	
imd04c	0		-0.003			Female	0.599		0.167	
imd04ed	0		0			Male	0.6		0.183	
imd04hd	-0.009		-0.008	*		Age	0.085		0.02	**
imd04hs	0		0	**		Age^2	-0.002		-0.001	***
imd04i	0.09	**	0.013			Age^3	0	*	0	***
imd04ia	-0.047	*	-0.018			Female*Age	-0.086		-0.022	**
imd04ic	-0.078	***	-0.029	*		Female*Age^2	0.002		0.001	***
imd04le	0		0			Female*Age^3	0	*	0	***
imd04rk	0	***	0	***		Male*Age	-0.087		-0.024	**
pregnancy	0.079	***	0.116	***		Male*Age^2	0.002		0.001	***
drug	-0.001		-0.038	***		Male*Age^3	0	*	0	***
alcohol	-0.041	***	-0.078	***		Constant	0.26		-0.537	***
smoke	-0.008		0.012			N	12,154,599		12,154,599	

Note: Significance level - *** 1%, ** 5%, * 10%. Clustered SE by hospital ID

Table A6 variable labels and definitions

Variable name	Description
imd04c	Index of Multiple Deprivation: Crime
imd04ed	Index of Multiple Deprivation: Education, Skills and training
imd04hd	Index of Multiple Deprivation: Health Deprivation and Disability
imd04hs	Index of Multiple Deprivation: Barriers to Housing and Services
imd04i	Index of Multiple Deprivation: Income deprivation
imd04ia	Index of Multiple Deprivation:Income Deprivation Affecting Older People
imd04ic	Index of Multiple Deprivation: Income Deprivation Affecting Children
imd04le	Index of Multiple Deprivation: Living Environment
imd04rk	Index of Multiple Deprivation: Overall ranking
pregnancy	=1, One of the patient diagnosis is: pregnancy,childbirth or puerperium
drug	=1, Patient is drug user or drug dependent
alcohol	=1, Patient is alcohol user or alcohol dependent
smoke	=1, Patient is tobacco user or tobacco dependent
obesity	=1, Patient with obesity problems
allergy	=1, Patient with personal history of allergy
diabetes	=1, Patient with diabetes problems
hypertens	=1, Patient with hypertension problems
haemorr	=1, Patient with haemorrage/coagulation problems
histdis	=1, Patient with personal history of diseases
riskfact	=1, Patient with other lifestyle risk factors
congmalf	=1, Patient with congenital malformations
risk_phys	=1, Patient exposed to physical risk factors
risk_psysoc	=1, Patient with problems related to psychosocial circumstances
tr_in_el	=1, Patient transferred from an eligible provider
tr_in_nonel	=1, Patient transferred from a non-eligible provider
tr_out_el	=1, Patient transferred to an eligible provider
tr_out_nonel	=1, Patient transferred to a non-eligible provider
die	=1, Patient died
emerg	=1, Patient admitted as emergency
episodes	Number of episodes in the spell
East of England	=1, Region of treatment: East of England
London	=1, Region of treatment: London
North-East	=1, Region of treatment: North-East
North-West	=1, Region of treatment: North-West
South-East	=1, Region of treatment: South-East
South-West	=1, Region of treatment: South-West
West Midlands	=1, Region of treatment: West Midlands
Yorkshire	=1, Region of treatment: Yorkshire
urban1	=1, Urban area
white1	=1, ethnicity is white
female1	=1, Patient is female

male1	=1, Patient is male
age	Patient age at the beginning of the spell
age2	Squared patient age
age3	Cubic power of patient age
femage	Interaction: Age*Female
femage2	Interaction: Squared age*Female
femage3	Interaction: Cubic age*Female
malage	Interaction: Age*Male
malage2	Interaction: Squared age*Male
malage3	Interaction: Cubic age*Male