QQUIP Quest for Quality and Improved Performance

The link between healthcare spending and health outcomes for the new English primary care trusts

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The Health Foundation

QQUIP and the Value for Money project

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Abstract

English programme budgeting data have yielded major new insights into the link between healthcare spending and health outcomes. This paper updates two recent studies that used programme budgeting data for 295 primary care trusts (PCTs) in England to examine the link between spending and outcomes for several programmes of care (Martin, Rice and Smith 2008a; 2008b). We use the same economic model employed in the two previous studies.

The paper focuses on the dilemmas facing decision-makers who must allocate a fixed budget across programmes of care so as to maximise social welfare, given a health production function for each programme. We estimate two equations – a health outcome equation and an expenditure equation – for each programme (data permitting). The two previous studies employed expenditure data for 2004/05 and 2005/06 for 295 PCTs and found that in several care programmes – cancer, circulation problems, respiratory problems, gastro-intestinal problems, trauma burns and injury, and diabetes – expenditure had the anticipated negative effect on the mortality rate.

Each health outcome equation was used to estimate the marginal cost of a life year saved. In 2006/07 the number of PCTs in England was reduced – largely through a series of mergers – to 152. In addition, several changes were made to the methods employed to construct the programme budgeting data. This paper employs updated budgeting and mortality data for the new 152 PCTs to re-estimate health production and expenditure functions, and also presents updated estimates of the marginal cost of a life year saved in each programme. Although there are some differences the results we obtained are broadly similar to those presented in our two previous studies.

1 Introduction

A central issue in health policy concerns the extent to which additional healthcare expenditure yields patient benefits in the form of improved health outcomes. In two recent studies we took advantage of the availability of a major new data set to examine the relationship between healthcare expenditure and mortality rates for several disease categories (Martin, Rice and Smith 2008a; 2008b). This data set presents expenditure on 23 broad programmes of care at the level of geographically defined local health authorities in England, known as primary care trusts (PCTs), and embraces most items of publicly-funded expenditure including inpatient, outpatient and community care, and pharmaceutical prescriptions. Such data facilitate a study of the link between aggregate expenditure in a programme of care and the health outcomes this achieves, notably in the form of disease-specific mortality rates.

Our model assumes that each PCT receives an annual financial lump sum budget from central government's Department of Health (DH) and allocates its resources across the 23 programmes of care to maximise the health benefits associated with that expenditure. For each programme of care we modelled:

- expenditure as a function of the need for healthcare, competing calls on resources from other care programmes and PCT income
- health outcome as a function of expenditure and need.

Using programme budgeting data for the financial year 2004/05 we found that in the two care programmes examined – cancer and circulation problems – this expenditure was positively associated with both income and need and negatively associated with other calls on resources. Health outcomes improved with expenditure but were adversely associated with need (Martin, Rice and Smith 2008a). We were also able to use the health outcome equation to estimate the expenditure required to 'save' an additional year of life in each disease category. We found that this was about £13,000 for cancer and about £8,000 for circulation problems.

In a subsequent study we employed the same model to estimate health outcome and expenditure equations using expenditure data for 2005/06 for just over half of the 23 care programmes (Martin, Rice and Smith 2008b). The results for the cancer and circulation programmes were similar to those obtained using 2004/05 expenditure data. We also obtained results in line with our model's predictions for five other programmes of care:

- diabetes (PBC 4a)
- neurological system (PBC 7)
- respiratory system (PBC 11)
- gastro-intestinal problems (PBC 13)
- trauma, burns and injuries (PBC 16).

We also sought to develop models for three other programmes of care for which a mortality indicator is available:

- infectious diseases (PBC 1)
- genito-urinary conditions (PBC 17)
- neonate conditions (PBC 19).

However, we were unable to find satisfactory outcome equations for these other budgeting categories. This was probably because the available outcome indicator (the mortality rate) is less relevant to these care programmes than the other budgeting categories where our outcome model has enjoyed more success.

In addition, although we did not have an outcome (mortality) indicator for several categories of care we did still estimate expenditure functions for them. Plausible results were obtained for five categories:

- endocrine/metabolic (PBC 4)
- mental health (PBC 5)
- eye/vision (PBC 8)
- musculo-skeletal (PBC 15)
- poisoning (PBC 20)

In 2006/07 the number of PCTs was reduced from 303 to 152, largely through a series of mergers.[1] In addition, DH made two major changes to the methods used to construct the programme budgeting data. First, DH employed expert medical opinion to re-evaluate the existing mapping from inpatient diagnosis codes to programme budget category (PBC). This led to the re-assignment of just over 10 per cent of all the diagnosis codes (taken from the International Classification of Diseases Version 10 – ICD-10) from one PBC to another.[2] [3] Second, activity to be costed used the newly introduced version 4 of the Healthcare Resource Group (HRG) software which, among other things, changed the methodology for calculating non-admitted patient care costs. HRG4 reflected advances in clinical practice and was designed to generate a much more accurate costing of complex cases.

These three major changes – the changes to PCT boundaries, the re-allocation of some diagnosis codes to a different programme category and the use of new costing software – have effectively broken the programme budgeting data time series. Although this break precludes the application of panel data methods to the data for 2004/05, 2005/06 and 2006/07, it is still possible to analyse the expenditure data for 2006/07 using the cross-section method previously applied to the data for 2004/05 and 2005/06 separately.

Given the changes to the way in which the expenditure data is constructed, we wanted to discover whether our earlier results would be reproduced using the new PCT boundaries. In addition, our two previous studies used mortality data for the three-year period from 2002 to 2004. However, mortality data from 2004 to 2006 for the new PCTs have recently been released by the National Centre for Health Outcomes Development (NCHOD). Therefore, this paper employs the most recent budgeting and

1 In a small number of cases the geographic area covered by an existing PCT was split between two or more new PCTs.

2 This figure ignores intra-category changes (for example, where an ICD-10 code is re-allocated from category 1A to 1B) and only counts cross-category changes (for example, where the code is switched from category 1 to category 2).

3 This expert review also led to the introduction of 40 additional sub-categories including 10 sub-categories for the cancer and tumour programme.

mortality data for the 152 PCTs to re-estimate health production and expenditure functions. It uses these results also to present updated estimates of the marginal cost of a life year saved in each programme and compares these estimates with those published previously.

As this report is closely related to our earlier studies (Martin, Rice and Smith 2008a; 2008b), it necessarily covers some of the same material, particularly the literature review and the model underlying the outcome and expenditure equations to be estimated. Readers who are familiar with either of our earlier studies should be able to skip these sections in this paper without any loss of continuity. However, some readers may not be familiar with our previous studies. Therefore we have incorporated summary versions of some of the material presented previously so that this paper can be read without reference to our earlier work.

1.1 Structure of this report

Section 2 provides a brief review of the literature on the relationship between healthcare spending and outcomes.

Section 3 provides some background information about programme budgeting as well as some descriptive statistics for 2006/07 budgeting data.

In section 4 we present a simple theoretical model of the budgetary problem faced by a PCT manager who is seeking to allocate limited funds between competing programmes of care.

Section 5 describes our estimation strategy.

In Section 6 we develop well-specified econometric models that estimate the budgetary expenditure choices and health outcomes achieved by PCTs in six selected programmes of care. We also use the results from the outcome equation to construct a quantitative estimate of the marginal cost of a life year saved in five programmes of care.

Section 7 presents expenditure equations for five budgeting categories for which no relevant mortality data are available. These illustrate the applicability of our expenditure model to programmes of care even when the absence of a mortality measure precludes the application of our outcome model.

Finally, in section 8 we discuss the important policy implications of our estimates of the marginal cost of a life year saved.

2 Previous studies

There is a considerable literature on the impact of healthcare and other related explanatory variables on some measure of healthcare outcomes (Nolte and McKee 2004). However, most attempts to analyse the magnitude of the link at a macro level between spending and health have been inconclusive. For example, in an early cross-sectional study of 18 developed countries, Cochrane, St Leger and Moore (1978) applied regression analysis to the statistical relationship between mortality rates and per capita consumption of inputs such as healthcare provision. They found that the indicators of healthcare were generally not associated with outcomes (in this case mortality rates). This failure to identify strong and consistent relationships between healthcare expenditure and health outcomes (after controlling for other factors) has become a consistent theme in the literature (Nolte and McKee 2004, p 58; Young 2001; St Leger 2001).

However, Gravelle and Backhouse (1987) have highlighted some of the difficulties associated with the empirical investigation of the determinants of mortality rates (these include the potential lag between expenditure and outcomes and, particularly with international comparisons, the problem of data heterogeneity). One fundamental obstacle to any statistical analysis is the difficulty of disentangling cause and effect. Areas or countries with relatively high health needs and poor outcomes may tend (other things being equal) to direct high levels of spending to healthcare. For policy-makers the issue is whether – after adjusting for need – extra spending leads to better health outcomes.

A study by Cremieux et al (1999) sought to overcome data heterogeneity problems by examining the relationship between expenditure and outcomes across 10 Canadian provinces over the 15-year period 1978–1992. They found that lower healthcare spending was associated with a significant increase in infant mortality and a decrease in life expectancy. Although challenging the received empirical wisdom their estimated regression equation consisted of a mixture of potentially endogenous variables (such as the number of physicians, health spending, alcohol and tobacco consumption, and expenditure on meat and fat) and exogenous variables (such as income and population density). The authors' chosen estimation technique (generalised least squares – GLS) did not allow for this endogeneity and consequently the coefficients on the endogenous variables may be biased (Gravelle and Backhouse 1987, p 428). Or's (2001) study of the determinants of variations in mortality rates across 21 OECD (Organisation for Economic Co-operation and Development) countries between 1970 and 1995 may suffer from the same weakness. She found that the contribution of the number of doctors to reducing mortality in OECD countries was substantial, but her estimation technique assumed that the number of doctors was exogenous to the health system.

Using macro-level data Nixon and Ulmann (2006) provided a detailed review of 16 studies that have examined the relationship between healthcare inputs and health outcomes. They also undertook their own study using data for 15 EU countries over the period 1980–1995. They employed three health outcomes measures – life expectancy at birth for males and females, and the infant mortality rate – and several explanatory variables including per capita health expenditure, number of physicians (per 10,000 head of population), number of hospital beds (per 1,000 head of population), the average length of stay in hospital, the inpatient admission rate, alcohol and tobacco consumption, nutritional characteristics and environmental pollution indicators. Nixon and Ulmann concluded that, although health expenditure and the number of physicians have made a significant contribution to improvements in infant mortality, 'healthcare expenditure has made a relatively marginal contribution to the improvements in life expectancy in the EU countries over the period of the analysis'. Again, however, the study does not allow for the possibility that some of the explanatory variables may be endogenous.

Although loosely based on the notion of a health production function, the traditional empirical study described above has rarely been informed by an explicit theoretical model. This is understandable as the processes giving rise to observed health outcomes are likely to be very complex and any theoretical model will become unwieldy. However, it leads to an atheoretical search for measures demonstrating a statistically significant association with health outcomes. In contrast, in this study we seek to inform our empirical modelling with a theoretical model (see section 4). We believe that this may lead to a more convincing and better specified model of health outcomes than that used in many previous studies.

3 Programme budgeting in England

The English National Health Service (NHS) is financed almost entirely from national taxation, with access to care generally free to the patient. Primary care is an important element of the system and general practitioners (GPs) act as gatekeepers to secondary care and pharmaceuticals. The system is organised geographically with PCTs being responsible for most of the local expenditure on healthcare. Since October 2006 England has had 152 PCTs with an average population of about 330,000.[4] PCTs are allocated fixed annual budgets by the DH and they are expected to meet expenditure on most aspects of healthcare – including inpatient, outpatient and community care, primary care and prescriptions – from these fixed budgets.

Since April 2003 each PCT has prepared expenditure data disaggregated according to 23 programmes of healthcare (programme budget categories – PBCs). These programmes are defined with reference to the ICD-10 codes at the four digit level; most PBCs reflect broad ICD-10 chapter headings. In most cases the 23 categories are broken down into further sub-categories. Table 1 presents summary programme budgeting data for 2005/06 and 2006/07.[5] The first two columns show the national average NHS expenditure per person by PBC in 2005/06 and 2006/07 respectively.

3.1 National expenditure on programme budget categories (PBCs)

Across England the NHS expenditure per person was £1,314; this was an increase of 2.8 per cent on 2005/06.[6] The category attracting the most expenditure was 'other' (PBC 23) with per capita expenditure of almost £207 in 2006/07. This category includes primary care expenditure, workforce training expenditure and a range of other miscellaneous expenditure items. Of these components, primary care expenditure is by far the largest element at £141 per head. In 2006/07 there were 2 other categories with expenditure of over £100 per head: mental health (budget category 5) at £164 per person and circulation (budget category 10) at £121 per person.

These are followed by 8 PBCs with an annual expenditure of between £55 and £81 per person: cancers and tumours (£81), gastro-intestinal problems (£73), genito-urinary problems (£69), musculo-skeletal problems (£66), respiratory problems (£65), maternity and reproductive conditions (£57), trauma and injuries (£57), and neurological problems (£55).

Three categories – learning disability (£46), dental problems (£44) and endocrine/nutritional/metabolic problems (£36) – are allocated about £40 per person with the remaining 9 categories attracting between £6 (hearing) and £28 (skin problems) per person.

4 Until October 2006 there were 303 PCTs with an average population of about 160,000. At this time, some PCTs were merged with one or more neighbours to form a new larger PCT, while the boundaries of other PCTs remained unchanged. In a few cases the geographic area covered by an existing PCT was split between two or more new PCTs. The total number of PCTs was reduced to 152.

5 See Table A1 in the Appendix for details of the sub-categories.

6 The population figure used by the DH increased by 2.6 per cent in 2006/07 (this was up from 49,175,998 in 2005/06 to 50,476,231 in 2006/07) so total expenditure increased by just over 5 per cent.

Table 1: Expenditure per person by programme budget category, per person, all England and by PCT, 2005/06 and 2006/07

	Programme budgeting category	National spend per head £			PCT spend per head £, 2006/07			
				% growth	Mean	Minimum	Maximum	CV
		2005/06	2006/07	in 2006/07				
1	Infectious diseases	23.7	21.4	-11.4	23.2	8.7	198.2	0.91
2	Cancers and tumours	82.8	80.9	-1.8	82.0	43.0	151.5	0.22
3	Disorders of blood	17.4	16.5	-5.1	16.9	5.1	31.8	0.35
4	Endocrine/nutritional/metabolic	37	36.4	-1.6	37.1	11.9	65.5	0.22
5	Mental health disorders	156.9	163.9	4.7	172.0	105.5	376.5	0.27
6	Learning disability	44.7	46.2	4.1	46.8	5.8	100.6	0.34
7	Neurological	40.8	54.7	34.6	55.9	29.4	116.4	0.25
8	Vision problems	28	26.8	-4.3	27.6	7.9	55.4	0.31
9	Hearing problems	6.2	6.1	-1.6	6.5	1.3	17.2	0.46
10	Circulation problems	123.6	121.1	-1.8	124.2	67.6	200.2	0.21
11	Respiratory system	69.2	64.7	-6.5	67.2	32.1	120.9	0.24
12	Dental problems	23.3	44.3	108.4	46.3	5.2	84.4	0.29
13	Gastro-intestinal problems	80.9	72.9	-9.8	75.3	39.4	134.2	0.24
14	Skin problems	26.6	28.1	5.6	28.6	15.3	69.4	0.28
15	Musculo-skeletal problems	74.2	65.5	-11.4	66.7	-1.6	129.7	0.31
16	Trauma and injuries	75.9	56.8	-25	58.5	19.3	99.9	0.3
17	Genito-urinary problems	67.2	68.5	2.4	70.0	35.3	131.7	0.26
18	Maternity and reproductive	59.9	57.2	-4.6	60.1	24.7	119.3	0.29
19	Conditions of neonates	13.3	13.1	-1.5	13.7	0.7	38.2	0.47
20	Adverse effects, poisoning	14.2	14.5	2.1	14.7	8.7	29.4	0.26
21	Healthy individuals	24.6	25.2	2.3	25.8	2.6	104.5	0.55
22	Social care needs	27.7	23.2	-9.8	24.1	-27.0	107.4	0.7
23	Other	168.1	206.6	22.1	208.1	131.0	540.2	0.29
	Of which: GMS/PMS	145.5	140.6	-3.4	141.1	0.0	298.1	0.22
All	Total spend on all categories	1286.2	1314.5	2.8	1351.3	992.7	1927.0	0.13

Note: Descriptive statistics across PCTs are unweighted. For any given PCT its expenditure per head figure reflects its raw population adjusted for unavoidable cost variations. The coefficient of variation (CV) is a measure of dispersion and is calculated as the standard deviation divided by the mean.

Source: calculated by the authors from data from the programme budget section of the DH's website at www.dh.gov.uk

Table 1 shows the growth in expenditure per person by PBC for 2006/07. Across all categories expenditure per person increased by 2.8 per cent, but there were some dramatic changes for individual categories (for example, expenditure on dental problems more than doubled). The growth rates for 2006/07 are unusual because of the relatively large number of categories with a negative growth rate. These growth rates will partly reflect real changes in expenditure levels. However, they will also reflect changes in the construction of the programme budgeting data. For example, responsibility for commissioning dental services passed from Dental Practice Boards to PCTs on 1 April 2006, but pilot transfers ran during 2005/06. This transfer of commissioning accounts for the large increases in dental expenditure per head by PCTs in 2005/06 and 2006/07. In addition, the large increase in expenditure for category 23x in 2006/07 is due to a change in the methodology used to map non-admitted patient care (NAPC) expenditure to particular budgeting categories. There is rarely a diagnosis code associated with NAPC. Prior to 2006/07 apportioning NAPC expenditure across PBCs was carried out on the basis of admitted patient care apportionment: if 10 per cent of the admitted patient care spend was allocated to a particular PBC then so too was 10 per cent of the NAPC spend that could not be mapped directly to a category. However, the NAPC mapping was changed in 2006/07 and all expenditure that could not be directly mapped to a particular category was included in category 23x. Therefore, category 23x in 2006/07 includes costs, such as those for Accident and Emergency, whereas previously these would have been apportioned over the 23 PBCs. [7]

3.2 Regional variations in spending

Apart from the net national spend per head data, Table 1 also presents some statistics that indicate the degree of variation in expenditure levels across PCTs by PBC. For each category the unweighted average of the PCT per capita expenditure figures – adjusted for the unavoidable geographical variation in costs – are reported in the second column of Table 1 followed by the observed minimum and maximum spend.[8] The final column shows the coefficient of variation. As was the case for 2005/06 the variation in expenditure levels across PCTs in 2006/07 is considerable. For example, expenditure per head on cancers and tumours averages £82 across all PCTs, but this varies between £43 and £152 per head. Similarly, expenditure per head on circulation problems averages £124 across all PCTs, but this varies between £68 and £200 per head. Although there is considerable variation within these two particular PBCs it is small relative to that in some other programmes of care. For example, infectious diseases and hearing problems have much larger coefficients of variation and this indicates substantially more variation than the cancer and circulation categories.

To further illustrate the geographic variation in expenditure levels Figure 1 shows (input price adjusted) expenditure per head by PCT for 2006/07 with each PCT allocated to one of five quintiles (quintile 1 contains the 30 PCTs with the smallest spend per head and quintile 5 contains the 30 PCTs with the largest spend per head).[9] This shows that per capita expenditure is typically greatest around London

7 Similarly in 2006/07 'burns' became a sub-category of 'problems of the skin' (PBC 14) where previously it would have been mapped to 'problems due to trauma and injuries' (PBC 16).

8 This cost adjustment reflects the fact that health economy input prices vary considerably across the country and are up to 40 per cent higher in London and south-east England than elsewhere. We have used the Market Forces Factor (MFF) indices that feed into the Payment by Results tariffs for 2007/08 to adjust expenditure for local input prices (Department of Health 2007).

9 We would like to thank Stephen Clark of the City Development Directorate, Leeds City Council and Peter Halls of the University of York Computing Service for their assistance with the construction of the PCT maps. Both maps are Crown Copyright 2007. All rights reserved. Ordnance Survey Licence number 100018355.

Figure 1: Expenditure per person by PCT, 2006/07

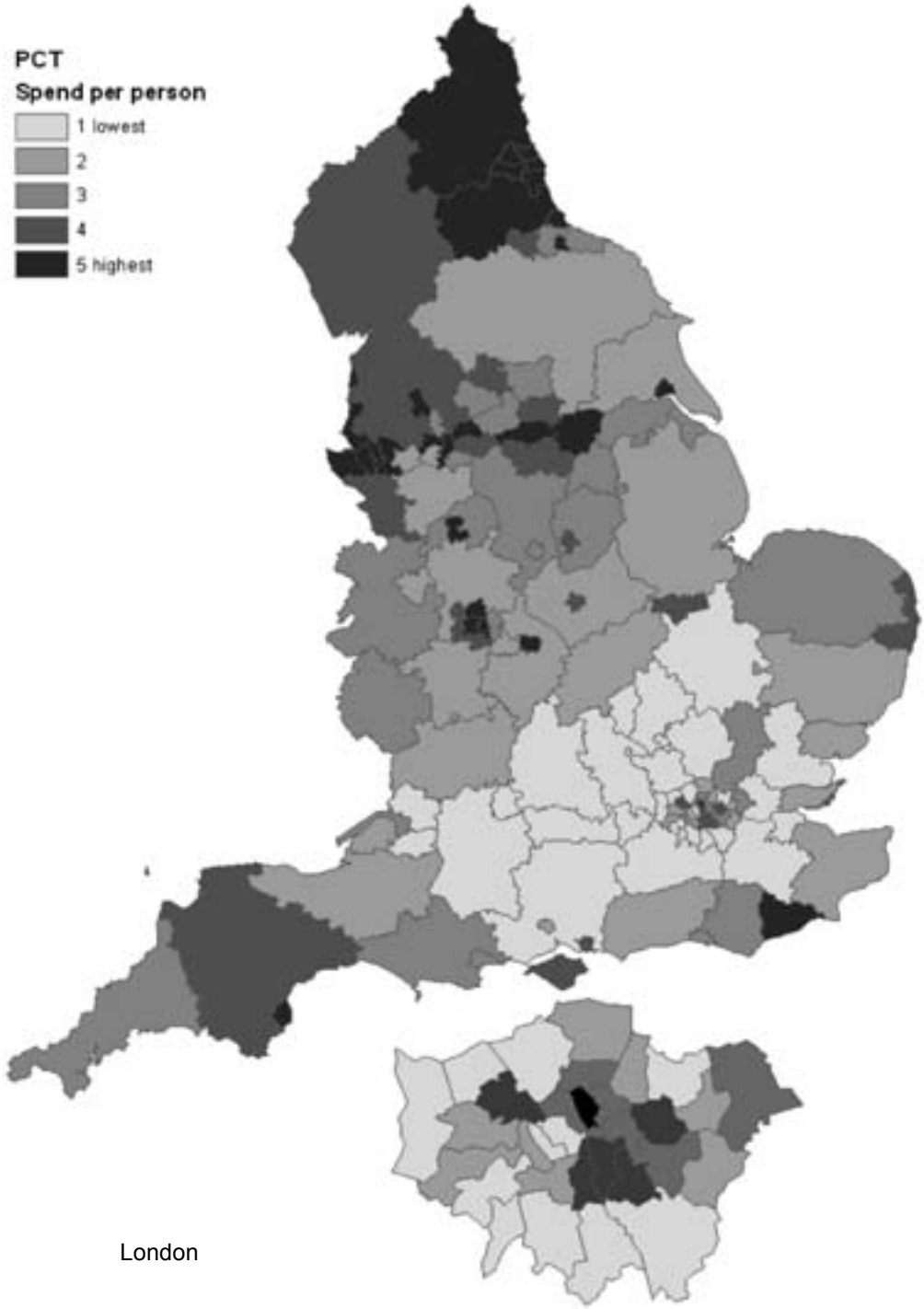
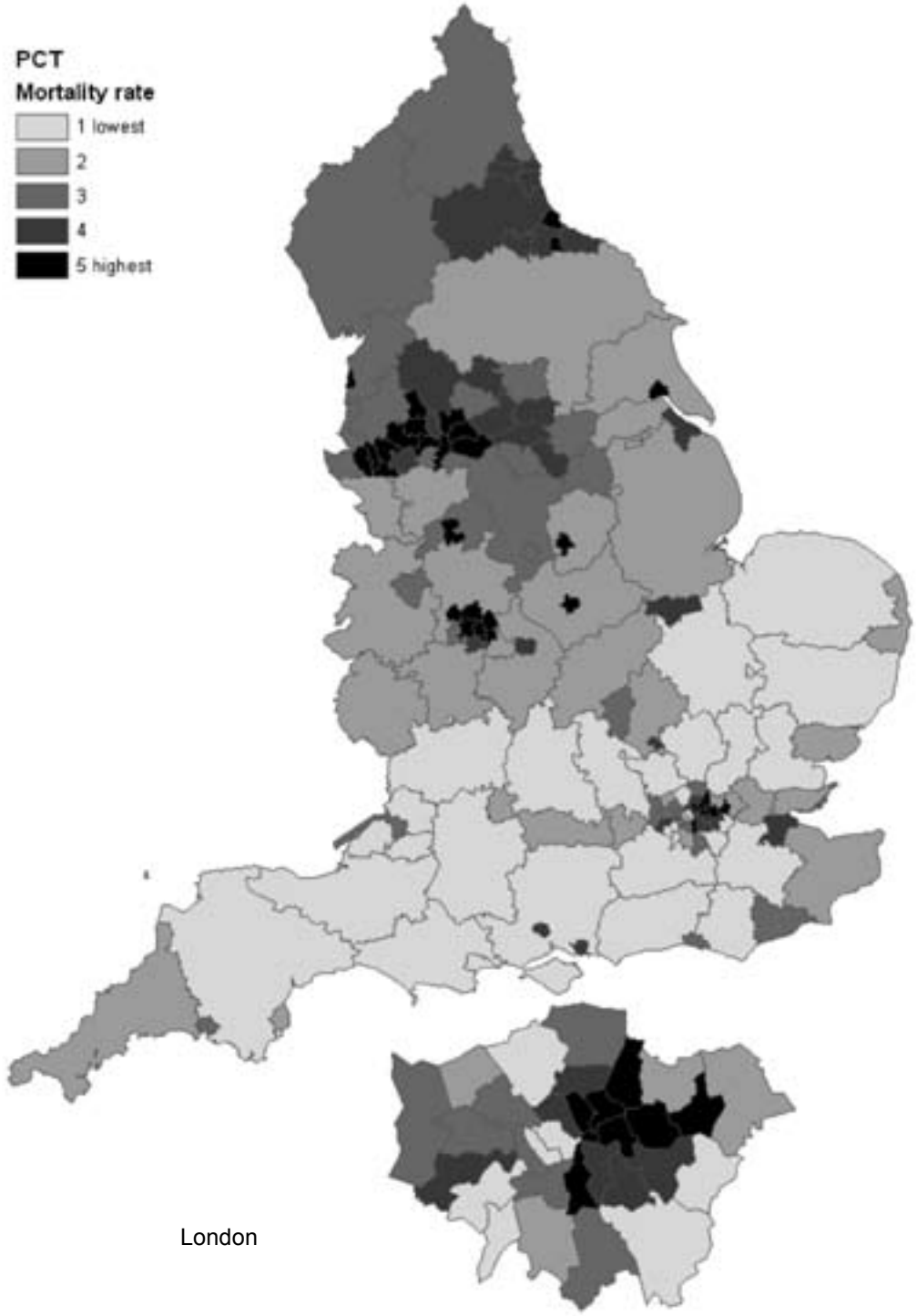


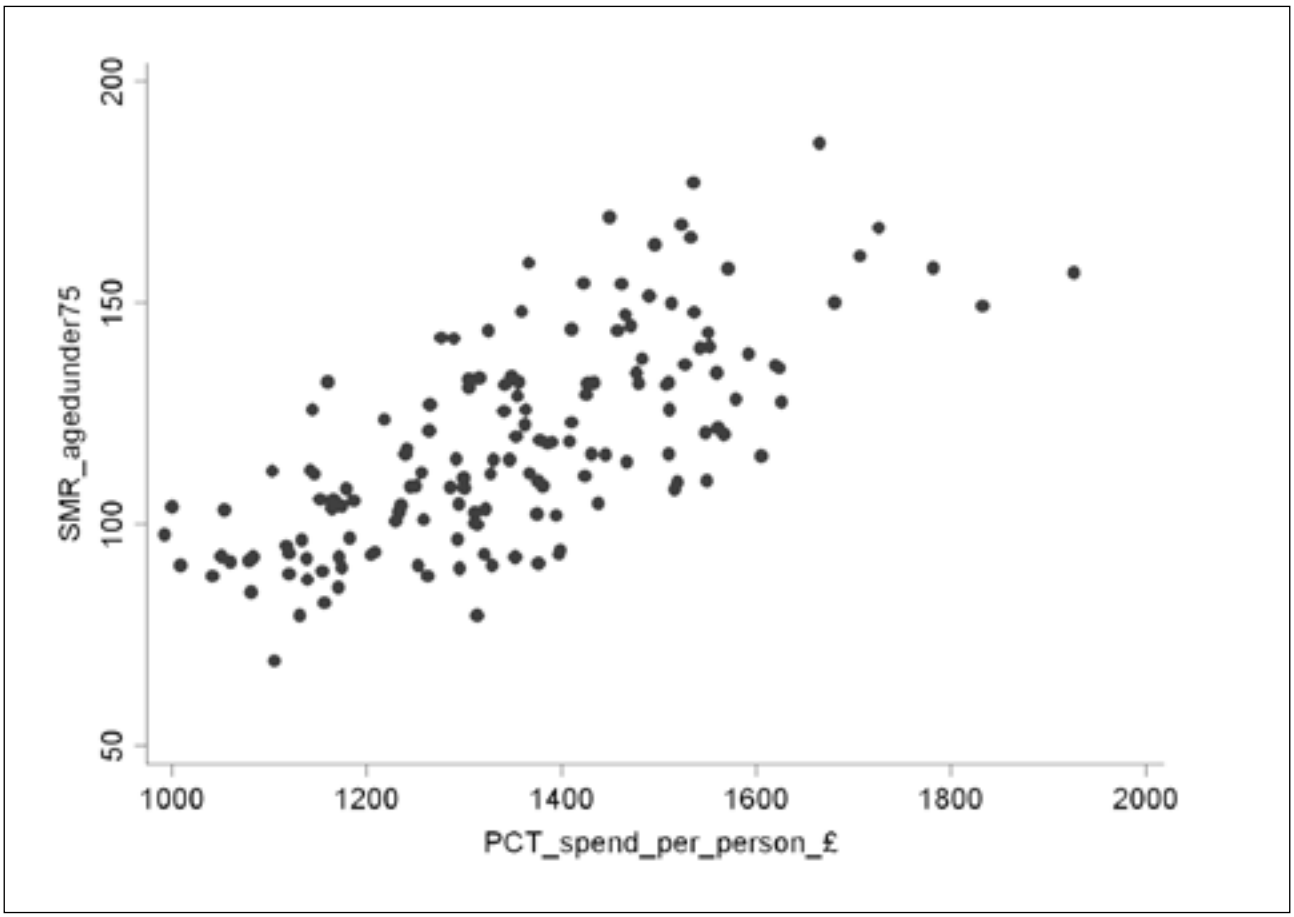
Figure 2: Mortality rate by PCT, 2004–06



and the traditional industrial heartlands in north-east and north-west England, west Yorkshire and the West Midlands. Figure 2 uses an age and sex standardised mortality rate (SMR) to allocate PCTs to one of five mortality quintiles (quintile 1 contains the 30 PCTs with the smallest SMR and quintile 5 contains the 30 PCTs with the largest SMR).[10] Mortality rates seem to be greatest in those areas with the largest expenditure.

These maps illustrate a major barrier to analysing the relationship between expenditure and health outcomes: the difficulty of disentangling cause and effect. Areas with high health needs and poor health outcomes tend to attract high levels of healthcare spending. This phenomenon is confirmed by examining the link between programme budgeting expenditure and health outcomes using standardised mortality rates (SMRs) among the 152 PCTs. Figure 3 shows the link between expenditure (adjusted for local input prices) and aggregate health outcomes (in the form of the under-75 SMR for all causes of death deemed amenable to healthcare).[11] It reveals a clear positive relationship between these two variables (with a correlation coefficient 0.7077) and shows the usual pattern of poorer health outcomes in areas with higher levels of spending.

Figure 3: PCT expenditure adjusted for local input prices and the SMR for people aged under 75 years



10 The SMR is for people aged under 75 years and relates to all causes of death considered amenable to healthcare over the period 2004–06.

11 For details of deaths considered amenable to healthcare see Martin, Rice and Smith (2008b).

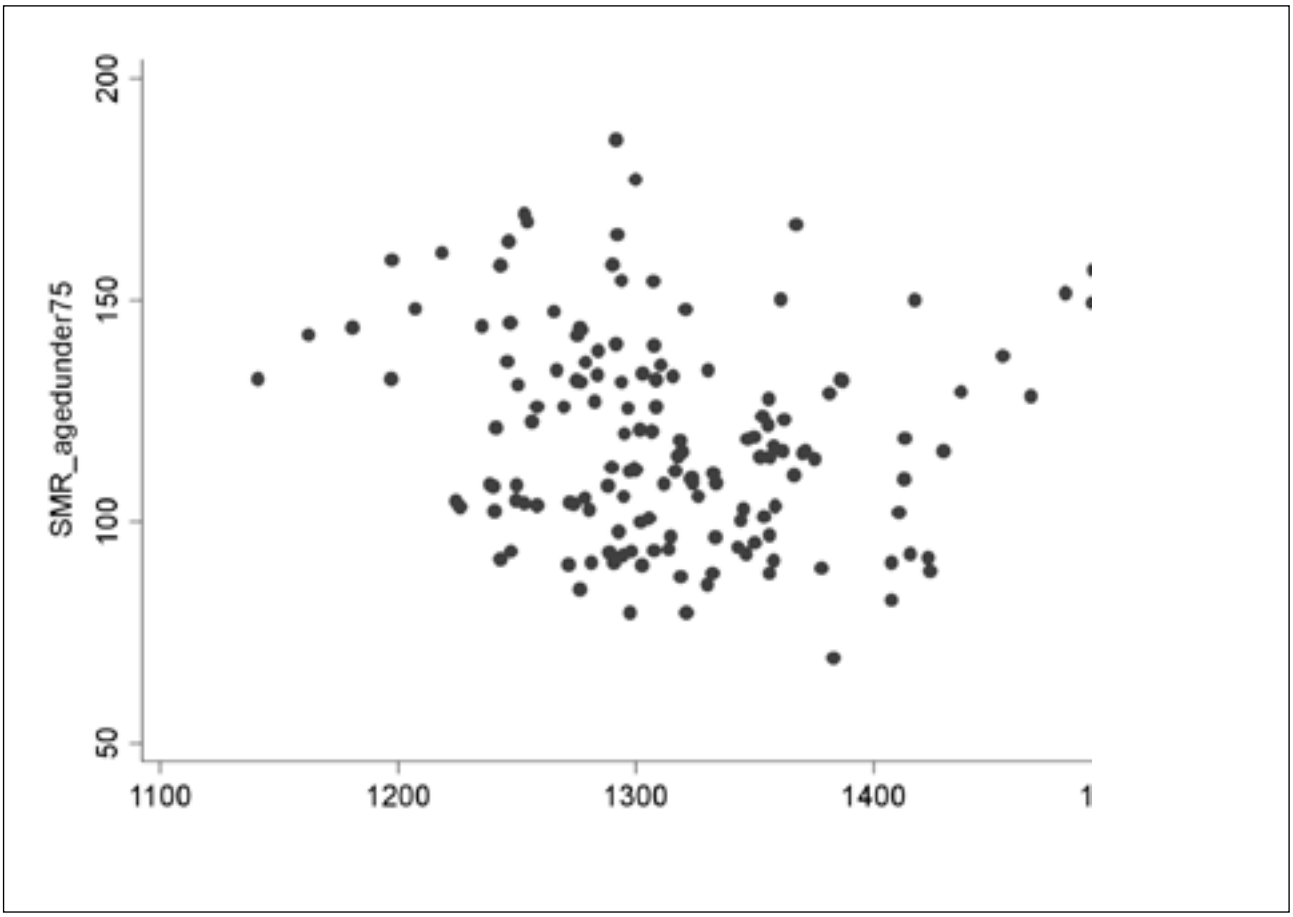
Therefore, the programme budgeting data appear to indicate a positive relationship between healthcare spending and adverse outcomes, apparently contradicting the hypothesis that more expenditure on healthcare achieves better health outcomes. However, the interpretation of Figure 3 is not straightforward as much of the variation in expenditure across PCTs will reflect different levels of the need for healthcare. Areas with a relatively large proportion of older people, or operating in relatively deprived locations, can be expected to spend at relatively high levels. Adjusting for the relative healthcare needs of different populations is therefore a central requirement of any analysis in this field.

To illustrate this issue, Table A2 in Appendix A reports the correlation between expenditure per head and selected socioeconomic variables in four major programmes of care: cancer, mental health, circulatory disease and gastro-intestinal diseases. These correlation coefficients confirm the strong link between deprivation and expenditure. Table A3 reports the correlations between mortality rates and the same socioeconomic variables for three of the four programmes of care (we do not have a reliable outcome measure for the mental health programme). Again, we find a set of strong positive correlation coefficients.

DH has a well-developed weighted capitation formula that it uses as the basis for allocating healthcare funds to PCTs (Smith, Rice and Carr-Hill 2001). The current 'needs' formula is derived from an adjustment for the demographic profile of the PCT and a series of econometric analyses of the link between healthcare expenditure and other socioeconomic factors at a small area level within England (Department of Health 2005).

The plot in Figure 4 is similar to that in Figure 3 but holds constant the local need for healthcare. It plots total PCT per capita expenditure in 2006/07, adjusted for local cost and need conditions, against the PCT mortality rate for people aged under 75 for deaths from all causes considered amenable to healthcare from 2004 to 2006. The positive association between expenditure and deaths observed in Figure 3 is removed and the correlation coefficient between the two variables is now negative (-0.1675). This suggests that – once the need for healthcare is held constant – more expenditure is associated with a better outcome (that is, a lower death rate).

Figure 4: PCT expenditure adjusted for both local input prices and the local need for healthcare, and the SMR for people aged under 75 years



Some of the 'within programme' variation in (cost-adjusted) per capita expenditure across PCTs revealed in Table 1 will reflect different levels of the need for healthcare. Consequently, the degree of variation in expenditure across PCTs declines for most of the PBCs when the expenditure per head data in Table 1 is adjusted for each PCT's need for healthcare. However, this decline is relatively small and there are still substantial differences in expenditure per head even after allowing for differences in local cost and need. For example, for cancer and tumours the minimum and maximum spend per head is £43 and £152 using the cost-adjusted expenditure data (from Table 1), but £47 and £117 using the cost- and need-adjusted population data. Similarly, expenditure per head in the circulation problems category varies between £68 and £200 using cost-adjusted expenditure data (from Table 1) but lies between £75 and £167 using cost- and need- adjusted population data.

Such variation in expenditure levels raises the issue of whether PCTs that spend more in a particular programme of care achieve a better outcome. Clearly, for each disease category expenditure per head varies considerably geographically and this variation – holding constant input prices and the need for healthcare – offers the opportunity to examine whether PCTs that spend more on healthcare achieve a better outcome and, if so, at what cost.

The remainder of this paper outlines a model of expenditure and outcomes, and estimates the strength of these relationships for various PBCs. The next section presents a theoretical model of PCT expenditure allocation across the 23 PBCs. This is followed by details of our estimation strategy in section 5 and empirical results in sections 6 and 7.

4 Theoretical model[12]

We assume that each PCT i receives an annual financial lump sum budget y_i from the DH and that total expenditure cannot exceed this amount. The PCT must then decide how to allocate the budget across the *J* programmes of care (*J*=23). For each programme of care there is a 'health production function' $f_i(.)$ that indicates the link between local spending x_{ij} on programme *j* and health outcomes in that programme h_{ij}. Health outcomes might be measured in a variety of ways, but the most obvious is to consider some measure of improvement in life expectancy, possibly adjusted for quality of life, in the form of a quality adjusted life year (QALY).

The nature of the specific health production function confronted by a PCT will depend on two types of local factors: the clinical needs of the local population relevant to the programme of care (which we denote n_{ij}) and broader local environmental factors z_{ij} relevant to delivering the programme of care (such as input prices, geographical factors or other uncontrollable influences on outcomes). Both clinical and environmental factors may be multidimensional. Increased expenditure then yields improvements in health outcomes as expressed, for example, in improved local mortality rates, but at a diminishing rate. That is:

$$h_{ij} = f_j(x_{ij}, n_{ij}, z_{ij});\ \partial f_j / \partial x > 0;\ \partial^2 f_j / \partial x^2 < 0 \qquad (1)$$

We assume there is a PCT social welfare function *W*(.) that embodies health outcomes across the *J* programmes of care. Assuming no interaction between programmes of care each PCT allocates its budget so as to maximise total welfare subject to local budget constraints and the health production functions for each programme of care:

$$\begin{aligned} &\max && W(h_{i1}, h_{i2}, \ldots, h_{iJ}) && (2) \\ &\text{subject to} && \sum_j x_{ij} \le y_i \\ & && h_{ij} = f_j(x_{ij}, n_{ij}, z_{ij}); \quad j = 1, \ldots J \end{aligned}$$

Of course, it can be argued quite plausibly that decision-makers do not discriminate between health outcomes in different programmes of care, and that *W*(.) is merely the sum of such outcomes. However, there is no need for that assumption in our formulation.

Each PCT allocates expenditure across the 23 programmes of care so that the marginal benefit of each pound spent in each programme of care is the same. Solving the constrained maximisation problem yields the result that the optimal level of expenditure in each category, x_{ij}*, is a function of the need for healthcare in each category (n_{i1}, n_{i2},..., n_{iJ}), environmental variables affecting the production of health outcomes in each category (z_{i1}, z_{i2},..., z_{iJ}) and PCT income (y_i) so that:

$$x_{ij}^* = g_j(n_{i1}, \ldots n_{iJ}, z_{i1}, \ldots z_{iJ}, y_i); \quad j = 1, \ldots, J \qquad (3)$$

Therefore, for each programme of care there is an expenditure equation (3) that explains the expenditure choices of PCTs and a health outcome equation (1) that models the associated health outcomes that these spending choices achieve. The next section describes how we estimate these equations empirically for each programme of care.

12 This model was first presented in our initial study (Martin, Rice and Smith 2008a). It is repeated here for the benefit of those who are unfamiliar with our earlier study. The reader who is familiar with our earlier work should be able to skip this section without any loss of continuity.

5 Estimation: issues and strategy[13]

The theoretical model explained in section 4 suggests that there needs to be specification and estimation of a system of equations, with an expenditure and health outcome equation for each of the 23 programmes of care. However, this approach makes infeasible data demands because it requires variables to identify expenditure, need, environmental factors and health outcomes in each programme of care.

At the time of this study health outcome indicators (that is, mortality rates) were available for only ten disease categories. Moreover, convincing data on all the environmental factors likely to affect the production of healthcare were not available. As a result, we concentrate on modelling these ten programmes of care separately. In line with the theoretical model presented in section 4, for each programme we specify the following expenditure (4) and health outcome (5) models:

$$x_{il} = \alpha_1 + \beta_1 n_{il} + \lambda y_i + \varepsilon_{1il} \qquad i = 1,\ldots,m; \quad l = 1,\ldots,10. \qquad (4)$$

$$h_{il} = \alpha_2 + \beta_2 n_{il} + \delta x_{il} + \varepsilon_{2il} \qquad (5)$$

Ideally we should employ a programme-specific indicator of the level of need for each care programme, but these too were not available. Therefore, we proxy healthcare need in each programme using the 'needs' component of the DH's resource allocation formula. This needs element is specifically designed to adjust PCT allocations for local healthcare needs; accordingly, all else being equal, we would expect to see a positive relationship between expenditure χ_{il} and n_{il} need for each programme of care. We would also expect a positive relationship between need and adverse health outcomes h_{il}.

For each programme of care we estimate models using two alternative measures of health outcome: one is the disease-specific SMR for people aged under 75 and the other is based on a measure of the avoidable years of life lost (YLL) to the disease. YLL is calculated by summing the number of deaths at each age over ages 1 to 74 years multiplied by the number of years of life remaining up to age 75 years. The crude YLL rate is simply the number of years of life lost divided by the resident population aged under 75 years. Like conventional mortality rates, YLL can be age-standardised to eliminate the effects of differences in population age structures between areas, and this age-standardised YLL rate (SYLL) is our second health outcome variable (Lakhani et al 2006, p 379).

The expenditure equation to be estimated also requires a proxy for need across the other programmes of care. In our first study – where we were modelling only two (cancer and circulation) care programmes – we employed the circulation mortality rate as the proxy for the need for competing programmes in the cancer expenditure equation, and we employed the cancer mortality rate as the proxy for the need for competing programmes in the circulation expenditure equation (Martin, Rice and Smith 2008a). As these are both programmes that attract considerable expenditure it is not implausible that expenditure in one of the programmes will have an impact on expenditure in the other and, in this study, we have persevered with this approach when re-estimating the expenditure functions for the cancer and circulation problems for 2006/07.

13 Our approach to model estimation is similar to that employed previously (see, for example, Martin, Rice and Smith 2008b). It is repeated here for the benefit of those who are unfamiliar with our earlier study. The reader who is familiar with our earlier work should be able to skip this section without any loss of continuity.

However, when we employed both the cancer and circulation death rates as proxies for the other calls on resources variables in the expenditure equations for other care programmes, we encountered co-linearity difficulties with the cancer and circulation death rate variables often having opposite signs. This result is to be expected given the strong correlation between the death rates, but it leads to difficulties in interpreting the signs of the estimated coefficients. Therefore, in the other estimated expenditure equations we have employed either the death rate from all causes amenable to healthcare for people aged under 75 year or the standard years of life lost (SYLL) rate for all deaths of people aged under 75 as the proxy for other calls on PCT resources. Although these proxy measures will include some 'own specialty' deaths, they will comprise a small proportion of the total. For example, in 2004 cancer and circulation problems accounted for over two-thirds of all deaths for people aged under 75 years and the third largest category – respiratory problems – accounted for less than one in ten of all deaths (NCHOD 2007 and ONS 2007). Therefore, we feel that the 'all causes' mortality indices are reasonable proxies for demands on a PCT budget from other specialties.

5.1 Estimation strategy

First we estimate equations (4) and (5) for each programme using ordinary least squares (OLS).[14] Assuming the exogeneity of health outcomes in the expenditure model (4), and of expenditure in the health outcome model (5), OLS is a consistent estimator of the model parameters.[15] However, should these variables be endogenous then we violate one of the assumptions of least squares as the endogenous variables will be correlated with the disturbance term in their respective models. We test for endogeneity using the test proposed by Durbin (1954). Under the null hypothesis of exogeneity, OLS will yield consistent parameter estimates.

Where there is evidence of endogeneity of expenditure and health outcomes we implement two-stage least squares (2SLS). This involves replacing the endogenous variables in the equation of interest with their predicted values from an OLS regression which regresses the endogenous variable on a set of instrumental variables. These excluded instruments should be strong predictors of the endogenous variable (they are relevant) but should be appropriately excluded from the equation of interest (they are valid).[16]

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14 The numbers in parentheses refer to the equations in section 4 and earlier in this section.

15 An exogenous variable is one whose value is independent of the value of other variables in the system. For example, in the cancer deaths model it is reasonable to assume that the need for cancer healthcare is exogenous as it will reflect factors such as living conditions and lifestyle (both past and present) that are outside the remit of the model. In contrast, an endogenous variable is the result of the inner-working or the relationships of the model; it is either an output of the model or correlated through unobserved terms with outputs of the model. Thus, in the cancer deaths model it is reasonable to assume that cancer expenditure is unlikely to be exogenous but will be influenced by, among other things, expenditure on other care programmes. This distinction between exogenous and endogenous variables is important because it affects whether OLS or alternative estimation methods should be employed.

16 We have a number of potential instruments available, mostly derived from the 2001 Population Census, and these are described in Martin, Rice and Smith (2008b). In both of our earlier studies we found that a small subset of these instruments proved sufficient to generate plausible results and we have recalculated these indicators for the new PCT boundaries. The construction of these instruments is shown in Table A4 (see Appendix A). These indicators reflect factors, such as socioeconomic deprivation and the availability of informal care in the community, that might indirectly have an impact on mortality rates and/or healthcare expenditure levels. From this set of indicators we select appropriate instruments on both technical and pragmatic grounds. From a pragmatic point of view, we require a parsimonious set of instruments that satisfy the necessary technical criteria. First, they should have face validity, that is, they should be plausible determinants of the endogenous variable being instrumented. Second, the instruments should be both relevant and valid. The relevance of an instrument set refers to its ability to predict the endogenous variable of concern, whereas validity refers to the requirement that instruments should be uncorrelated with the error term in the equation of interest. Three of the available instruments – the proportion of households that are lone pensioner households, the proportion of the population providing unpaid care and the population weighted index of multiple deprivation based on local authority Index of Multiple Deprivation (IMD) 2007 scores – were selected to be used as instruments on the basis of their theoretical and empirical relevance and validity. This set of instruments was modified if, for example, the Sargan test suggested that the set under test was not valid. Appendix B includes a discussion of the choice of instruments for each pair of expenditure and outcome equations, together with details of the first stage regression results for the models presented in section 6.

Should the instrument set be relevant and valid, 2SLS will produce consistent estimates of the parameters of the reduced form models. We subjected the instrument sets to tests for validity using the Sargan (1958) test of over-identifying restrictions and for relevance using the Anderson (1984) canonical correlations likelihood-ratio test and Shea's (1997) partial R-squared measure. The Anderson likelihood ratio statistic, which is based on the canonical correlations between the set of endogenous regressors and the set of instruments, offers a test of whether the model is identified under the null of under-identification and is distributed as chi-squared with degrees of freedom equal to $l - k + 1$, where is the number of instruments (included and excluded) and k is the total number of regressors. Failure to reject the null indicates that the model is under-identified. Shea's partial R-squared measure reflects the correlation between the excluded instruments and the endogenous regressor. Both tests provide valuable information on the relevance of the excluded instruments. However, even if valid and relevant, non-zero but small correlations between the instruments and the endogenous regressors can lead to the problem of weak instruments. This can be the case even where correlations are shown to be significant at conventional levels of testing and sample sizes are large (for example, see Bound, Jaeger and Baker 1995). The consequence of employing instruments that are weakly correlated with the endogenous regressors is a bias in the 2SLS estimates. The extent of the bias can be specified relative to the bias of OLS.

For the case of a single regressor, Staiger and Stock (1997) suggest applying the criterion that if the first-stage F-statistic – testing the hypothesis that the instrument set does not significantly predict the endogenous regressor – is less than ten then the instruments can be thought to be weak. Stock and Yogo (2002) extend these ideas to the case where there can be multiple endogenous regressors and propose a test for the null that the instruments are weak and provide appropriate critical values. This is an extension of the Cragg and Donald (1993) test for instrument relevance, which is similar to Anderson's canonical correlations test. For the case of a single endogenous regressor, the Cragg-Donald statistic is simply the F-statistic of the test of the hypothesis that the instruments do not enter the first-stage regression. Stock and Yogo provide critical values of the F-statistic (and the Cragg-Donald statistic for multiple endogenous regressors) that tabulates the ratio of 2SLS bias to the bias of OLS. The weakness or otherwise of the instruments can then be assessed by the relative bias exceeding a given threshold (for example, 2SLS bias exceeding 5 per cent of OLS bias).[17]

A general test of model specification is provided through the use of Ramsey's (1969) reset test for OLS and an adapted version of the test for instrumental variables (Pesaran and Taylor, 1999).[18] The tests are more properly thought of as tests of a linearity assumption in the mean function or a test of functional form restrictions and omitted variables (for example, see Wooldridge 2002) and can be useful as a general check of model specification. The standard reset test for OLS is distributed as an F–distribution while the 2SLS version follows a χ^2 distribution. Both have degrees of freedom equal to the number of polynomial terms chosen for the fitted values. We implement the test using the squared value of the predicted variable for 2SLS models and using $\hat{y}^2$, $\hat{y}^3$, and $\hat{y}^4$ for the OLS models (these are the default settings for the test statistics in Stata version 9.2).

17 For the case of a single endogenous regressor and three excluded instruments, Stock and Yogo (2002) critical values are, in terms of the bias of 2SLS relative to bias of OLS, as follows: relative bias 5 per cent critical value = 13.9; relative bias 10 per cent, critical value = 9.08; relative bias 20 per cent, critical value = 6.46; relative bias 30 per cent, critical value = 5.39.

18 Implementation of the 2SLS procedure and related tests were performed in Stata v9.2 using ivreg2, ivreset, ivendog. Standard errors are corrected for heteroscedasticity and the use of fitted values in the second-stage regression.

6 Empirical results: programmes with plausible outcome and expenditure equations

In our initial study we presented outcome and expenditure equations using expenditure data for 2004/05 for cancer and circulation problems (Martin, Rice and Smith 2008a). With the release of budgeting data for 2005/06 we validated our models for cancer and circulation problems using this new data and extended our initial study by applying the expenditure and outcome models to the other 21 categories (Martin, Rice and Smith 2008b). However, the only available reliable outcome measures relate to condition-specific mortality and so the outcome model could only be applied to those PBCs where a suitable mortality indicator was available. In 2006/07 a series of mergers reduced the number of PCTs from 303 to 152. Here we update the results for 2005/06 (which we estimated across 295 PCTs with mortality data for 2002/04) by employing expenditure data for 2006/07 and mortality data for the three-year period from 2004 to 2006.[19] We estimate these models for 2006/07 across 152 PCTs.

We chose cancer and circulation problems as the first categories for the earlier study because these encompass medical conditions that are regularly associated with death (in England, in the three-year period from 2002 to 2004, 190,000 people aged under 75 died from cancer and 155,000 aged under 75 died from circulation problems). Moreover, for these conditions the specialty coverage of the mortality data corresponds very closely to the specialty coverage of the budgeting data. However, for most of the remaining budgeting categories death is much less frequent and is potentially a less relevant outcome measure. Furthermore, the death rates currently available sometimes reflect only a small number of conditions relative to the total number covered by the programme budgeting expenditure (for example, for the neurological category the only death rate available is that for epilepsy). For these reasons we would expect more difficulties when modelling these other care programmes and less satisfactory results than those obtained for cancer and for circulation problems. However, using expenditure data for 2005/06 we found that, even where mortality was not the most appropriate outcome measure, it was still possible to obtain plausible results (Martin, Rice and Smith 2008b). As we shall see, this is also possible using expenditure data for 2006/07.

6.1 Cancer programme of care

Table 2 shows the results for the cancer programme of care. Columns under (1) present ordinary least squares (OLS) results using SMRs as the measure of health outcome.[20] Columns under (2) present two-stage least squares (2SLS) estimates using SMRs as the measure of health outcome. Columns under (3) present 2SLS estimates using the SYLL rate as the outcome measure.[21] All variables have been log transformed; accordingly, parameter estimates can be interpreted as elasticities.[22]

We present OLS results as a starting point, but these are unlikely to be well-specified because they ignore the possibility that some of the explanatory variables may be endogenous to the system of equations. The OLS results suggest that expenditure on cancer services is negatively associated with cancer deaths. But this is insignificant at conventional levels and the effect is very small (the coefficient on the expenditure term is -0.032). With regard to the expenditure equation, other calls on expenditure –

19 The number of observations in the 2005/06 regression equations was 295 not 303. There were eight missing PCTs because the variables used in the regression models were constructed at slightly different dates and between these dates there were a small number of PCT boundary changes.

20 These direct SMRs are for those aged under 75 years.

21 This SYLL rate is calculated on the basis of a 75-year life expectancy.

22 Appendix C sets out descriptive statistics for various mortality rates and the census variables employed in the regressions.

as proxied here by the circulation death rate – has the anticipated negative effect on cancer expenditure. The estimated coefficient (-0.331) suggests that a 10 per cent increase in other calls on expenditure results in a 3.31 per cent reduction in cancer expenditure.

One major difference between the expenditure equation for 2006/07 and 2005/06 is that the coefficient on need more than doubled in 2006/07, while that on PCT income more than halved. As we shall see, this occurs in the expenditure equation for several PBCs. This might be because of the increasing co-linearity between the need and PCT income variables as, each year, PCTs move closer towards their target resource allocation.[23] [24] If the expenditure equation is re-estimated without the need variable the coefficient on PCT income jumps from 0.309 to 1.314 (with a robust standard error of 0.143). This supports the idea that the co-linearity between need and income makes it difficult to disentangle these two effects.

Table 2: Results for cancer programme of care, 2006/07

N = 152	**OLS (1)**		**2SLS (2)**		**2SLS (3)**	
	Cancer deaths	**Cancer expenditure**	**Cancer deaths**	**Cancer expenditure**	**Cancer SYLL**	**Cancer expenditure**
Constant	4.699 (0.109)	-1.153 (0.419)	3.689 (0.317)	0.270 (0.544)	4.139 (0.277)	0.356 (0.541)
Need	0.716 (0.058)	1.183 (0.288)	1.142 (0.161)	1.512 (0.288)	1.048 (0.142)	1.557 (0.284)
Cancer expenditure	-0.032 (0.043)		-0.425 (0.125)		-0.355 (0.109)	
Total budget		0.309 (0.275)		0.352 (0.272)		0.388 (0.271)
Circulation deaths SMR		-0.331 (0.094)		-0.654 (0.123)		
Circulation SYLL						-0.649 (0.118)
Test statistics:						
Sargan (χ^2_1)			0.59 (0.440)	1.24 (0.265)	0.39 (0.529)	0.70 (0.401)
Anderson (χ^2_2)			30.4 (0.000)	92.2 (0.000)	30.4 (0.000)	86.6 (0.000)
Cragg-Donald (F stat)			18.5 (<0.05)	113.6 (<0.05)	18.5 (<0.05)	97.5 (<0.05)
Partial R^2			0.200	0.607	0.200	0.570
Reset:						
F(3,146)	5.78 (0.000)					
F(3,145)		1.30 (0.276)				
Pesaran-Taylor (χ^2_1)			3.90 (0.048)	0.22 (0.642)	4.13 (0.042)	0.17 (0.677)
Endogeneity (χ^2_1):						
Cancer expenditure			27.6 (0.000)		23.3 (0.000)	
Circulation deaths				20.0 (0.000)		
Circulation SYLL						20.2 (0.000)

23 The DH's resource allocation formula generates a target allocation for each PCT. To avoid large changes in PCT allocations that might follow the introduction of a new funding formula actual annual allocations gradually moved towards the latest target.

24 The correlation coefficient between need and total PCT expenditure increased from 0.8768 in 2005/06 to 0.9341 in 2006/07.

Notes:

1. Parentheses show robust standard errors for parameter estimates and p-values for the test statistics.
2. The instrument set for cancer expenditure includes the proportion of households that are lone pensioner households and the proportion of the population providing unpaid care.
3. The instrument sets for circulation deaths (SMR) and circulation deaths (SYLL rate) include the proportion of households that are lone pensioner households and the proportion of the population providing unpaid care.
4. Similar results are obtained if expenditure data is adjusted for PCT lead/host commissioning arrangements and expenditure funded from PCT income.

The second set of results present 2SLS estimates under (2). These allow for the possibility that some of the explanatory variables may be endogenous. They suggest that both cancer deaths and expenditure are more elastic with respect to health needs than is suggested by the OLS results. However, the main difference between the OLS and 2SLS results is the increased negative coefficient on cancer expenditure in the outcome equation. This change is to be expected as 2SLS treats expenditure as endogenous to health outcomes and employs instruments to obtain independent variation in expenditure to identify its impact on health outcomes. The 2SLS results under (2) indicate that a 10 per cent increase in cancer programme expenditure results in approximately a 4.25 per cent reduction in adverse health outcomes, observed through cancer deaths. Generally the results are similar to those for 2005/06.

Substituting the SYLL rate for the SMR (see equations under (3)) generates substantively similar results. Moreover, these allow us to calculate the implied marginal 'cost' of saving a life year in the cancer disease category. They suggest that a 1 per cent increase in cancer expenditure per head – which was £80.90 in 2006/07 – leads to, all things being equal, a 0.355 per cent reduction in YLL. Between 2004 and 2006 the total number of life years lost to cancer deaths in England in those aged under 75 was 2,221,529 (it was 2,268,541 in 2002–04).[25] This is an average of 740,510 life years per annum; across the English population of 50 million this is an average of 0.0148 life years (5.406 days) per person. Thus, a 1 per cent increase in expenditure per head (£0.809) is associated with a 0.355 per cent reduction in life years lost (0.01919 days) and implies that one life year would cost £15,387 (£13,931 using expenditure data for 2005/06 and mortality data for 2002–04).

There is evidence that the OLS deaths model is misspecified ($F(3,146) = 5.78$; $p=0.000$) and that it should be rejected in favour of the 2SLS model, which shows little evidence of misspecification (Pesaran-Taylor statistic=3.90, p=0.048). Although the OLS expenditure model is not misspecified, neither is the 2SLS model and there is evidence from the relevant test that the circulation deaths term is endogenous. Further support for the 2SLS model is provided through the Sargan test of overidentifying restrictions, the Anderson and Cragg-Donald tests of instrument relevance and the partial R-squared values from the first stage regressions of the set of exogenous variables on the relevant endogenous variable. Taken together, these tests indicate that the instrument set is both valid and relevant.

The measure of the need for cancer care employed here is not condition-specific but rather an all-condition indicator of need. A more condition-specific measure is available from data collected from general practices as part of the new Quality and Outcomes Framework (QOF). From these indicators it is possible to calculate the percentage of the population registered with practices within each PCT that has been diagnosed with cancer. One obvious use of this cancer prevalence rate is to employ it as an indicator of the need for cancer care in both the outcome and expenditure equations. However, if the cancer prevalence rate is added to the expenditure equation it is statistically insignificant, but the need term remains significant. Alternatively, if the all-condition need variable is dropped and the prevalence rate is added the latter is now significant, although the other calls on resources term is now insignificant. If the prevalence rate is added to the outcome (death rate) equation both it and need become

25 See www.nchod.nhs.uk/

insignificant, and if the need term is dropped the prevalence rate becomes significant but with a negative sign. Overall, the cancer prevalence term appears to offer little improvement over the use of the more general need for healthcare variable. These findings are similar to those obtained using expenditure data for 2005/06.

6.2 Circulation programme of care

Table 3 shows the results for circulatory problems and these are similar to those presented previously for 2005/06 (see Martin, Rice and Smith 2008b). In general the estimated coefficients exhibit the same qualitative characteristics as for cancer; again, as we move from OLS to 2SLS we observe an increase in the absolute value of the estimated coefficients attached to the endogenous regressors. For example, the coefficient on circulatory expenditure in the 2SLS models is three times the size of the coefficient on the same variable in the OLS version. Further, the coefficient of -1.166 on circulatory expenditure in the 2SLS deaths models implies that circulatory deaths are more responsive to increases in expenditure than cancer deaths (where the comparable coefficient is -0.425), and that a 10 per cent increase in expenditure is associated with a 11.66 per cent reduction in the circulation death rate.

As was the case for 2005/06, two additional 'needs' variables – the percentage of the population in a 'white' ethnic group and the proportion of the population providing unpaid care – are included in the expenditure models.[26] The positive sign on the unpaid carer regressor implies either that lower levels of need exist in those areas with fewer unpaid carers (patients may buy care in more affluent areas) or that there is some unmet need in those areas with fewer unpaid carers. The positive sign on the white ethnic group variable might indicate some unmet need in those areas with a smaller proportion of the population in the white ethnic group.

Both pairs of death and expenditure equations (under (1) and (2)) show no evidence of misspecification (Pesaran-Taylor test). The cancer deaths term is clearly endogenous in both expenditure equations and the circulation expenditure term is clearly endogenous in both of the outcome equations. Although the instruments are relevant in all four equations (see the Anderson and Cragg-Donald tests) there is some evidence from the Sargan test that the validity of the instrument set is slightly borderline in three of the four equations (in these three cases the instruments 'pass' the Sargan test at the 1 per cent level but not at the 5 per cent level). However, we concentrate on the YLL outcome equation below where the validity of the instrument set, at 5 per cent, cannot be rejected.[27]

The results from the YLL version of the circulatory deaths model can be used in a similar manner to those for cancer to calculate the marginal cost of an extra life year. The coefficient on circulatory expenditure (-1.244) implies that a 1 per cent increase in expenditure gives rise to a 1.244 per cent reduction in life years lost. Across the period 2004–06, the total life years lost to all circulation deaths in those aged under 75 was 1,463,911 (1,607,171 life years in the years 2002–04).[28] This is 487,970 life years per annum which, across an English population of 50 million, is an average of 0.0097594 life years (3.562181 days) per person. Thus, a 1 per cent increase in expenditure per head (£1.211) is associated with a 1.244 per cent reduction in life years lost (0.0443135 days) and implies that one life year would cost £9,974 (£8,427 using expenditure data for 2005/06 and mortality data for 2002–04).

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26 According to the 2001 Census, a person is a provider of unpaid care if they give any help or support to family members, friends, neighbours or others because of long-term physical or mental ill-health or disability, or problems relating to old age. The 'white' ethnic group comprises 'white' British, 'white' Irish, and 'white' other.

27 The Sargan test statistics for the two expenditure equations can be substantially improved by dropping the need term from the regressor and instrument sets. This also has the effect of increasing the coefficient on the PCT budget term (from 0.861 to 1.288 in the first expenditure equation and from 0.836 to 1.316 in the second equation). Apart from this, there are no other major changes associated with the dropping of the need term.

28 See the NCHOD website at www.nchod.nhs.uk/

As was the case for the cancer equations, the measure of need employed here is not a condition-specific measure but rather an all-condition indicator of need. Again, a more condition-specific measure is available from data collected from general practices as part of the new QOF. From this data set it is possible to calculate the percentage of the population registered with practices within each PCT that has circulation problems (defined here as the sum of those on the coronary heart disease register, the stroke and transient ischaemic attack register and the hypertension register, divided by the total patient list size).

Table 3: Results for circulation programme of care, 2006/07

N = 152	**OLS (1)**		**2SLS (2)**		**2SLS (3)**	
	CHD deaths	**CHD expenditure**	**CHD deaths**	**CHD expenditure**	**CHD SYLL**	**CHD expenditure**
Constant	3.778 (0.135)	-0.857 (0.583)	1.971 (0.429)	2.380 (1.212)	1.982 (0.454)	3.246 (1.572)
Need	1.497 (0.098)	0.028 (0.233)	2.442 (0.239)	0.623 (0.354)	2.657 (0.256)	0.732 (0.389)
CHD expenditure	-0.318 (0.063)		-1.166 (0.202)		-1.244 (0.214)	
Total budget		0.801 (0.227)		0.861 (0.239)		0.836 (0.229)
Cancer deaths SMR		0.024 (0.125)		-0.765 (0.298)		
Cancer SYLL						-0.903 (0.365)
% white ethnic group		0.147 (0.068)		0.215 (0.078)		0.232 (0.083)
% pop unpaid carers		0.691 (0.143)		0.457 (0.204)		0.437 (0.212)
Test statistics:						
Sargan (χ^2_1)			9.35 (0.024)	4.54 (0.033)	6.81 (0.078)	4.55 (0.032)
Anderson (χ^2_2)			55.9 (0.000)	35.7 (0.000)	55.9 (0.000)	31.3 (0.000)
Cragg-Donald (F stat)			21.2 (<0.05)	22.3 (<0.05)	21.2 (<0.05)	18.8 (<0.05)
Partial R^2			0.367	0.235	0.367	0.206
Reset:						
F(3,146)	0.97 (0.410)					
F(3,143)		0.96 (0.413)				
Pesaran-Taylor (χ^2_1)			0.09 (0.769)	0.00 (0.946)	0.27 (0.600)	0.05 (0.819)
Endogeneity (χ^2_1):						
CHD expenditure			80.4 (0.000)		83.5 (0.000)	
Cancer deaths				10.45 (0.001)		
Cancer SYLL						8.70 (0.003)

Notes:

1. Parentheses show robust standard errors for parameter estimates and p-values for the test statistics.
2. The instrument set for CHD expenditure includes the proportion of households that are lone pensioner households, the proportion of the population providing unpaid care, the population weighted Index of Multiple

Deprivation (IMD) based on local authority level 2007 scores and the proportion of residents in the white ethnic group.

3. The instrument sets for cancer deaths (SMR) and cancer SYLL include the proportion of households that are lone pensioner households and the population weighted IMD based on local authority level 2007 scores.
4. The term 'CHD' is used as a shorthand for 'circulation problems'.
5. Similar results are obtained if expenditure data is used that adjusts for PCT lead/host commissioning arrangements and for expenditure funded from PCT income.

If the circulation problems prevalence rate is added to the expenditure equation it is statistically insignificant, as are four of the five other regressors. If the need term is dropped the prevalence rate remains insignificant. If the prevalence rate is added to the outcome equation it is insignificant, and if the need term is dropped both the prevalence rate and expenditure term become significant but with 'incorrect' signs. Overall, the use of a condition-specific circulation problems prevalence rate does not appear to offer any advantages over the use of the more generic all-condition need measure.

Our cost of a life year saved estimates for cancer and circulation problems are presented in terms of unadjusted life years. In order to give a very rough indication of how they might be adjusted to yield QALYs we have applied the utility scores made available by the HODaR (Health Outcomes Data Repository, University Hospital of Wales) project using the UK EQ-5D scoring algorithm. Quality of life scores are available by ICD-10 codes and can be assigned to the PBCs used here. Therefore, we have simply assigned scores to each of the ICD-10 categories within the areas of cancer and circulatory diseases where these match with the HODaR categories and averaged the scores across the categories.[29] Using this method, the cost of a QALY for cancer expenditure is £22,332 (=£15,387/0.689); for circulatory diseases the corresponding figure is £14,909 (=£9,974/0.669). We emphasise that these results are indicative at best and cannot offer an accurate calculation of a QALY saved. But they do suggest that the cost of a QALY from these programmes of care may be lower than many commentators have assumed.

The results for cancer and circulation problems for 2006/07 are very similar to those for 2005/06. However, cancer and circulation problems comprise just two of the 23 PBCs. Next, we attempt to apply the expenditure and outcome models to the other 21 PBCs. Unfortunately, the only outcome measures available are mortality rates and so we can apply our outcome model only to those categories where a suitable mortality rate is available. Relevant mortality rates are available for several PBCs, and below we present the results for those categories where our models prove to be relevant.

29 Utility scores are available for ICD-10 codes based on EQ-5D (HODaR). These are derived from a sample of 15,113 subjects accounting for more than 37,000 ICD-10 observations (due to multiple diagnoses). Averaging utility scores across the ICD-10 codes corresponding to the cancer programme of care (note that not all ICD-10 codes corresponding to the cancer programme of care were represented in the HODaR sample) resulted in an average score of 0.689. The corresponding calculation for circulatory diseases is 0.669. Note that these are very rough estimates. To accurately calculate the cost of a QALY saved we would require utility scores for all of the programme budgeting ICD-10 codes together with the number of patients assigned to each of these codes. We do not have full information on these. We also note that the utility scores may be based on small samples (five or more subjects). The utility scores were made available by Dr Craig Currie, Director and Senior Lecturer in Health Outcomes Research, HODaR, Cardiff Medicentre, University Hospital of Wales.

6.3 Neurological programme of care

Table 4 shows the results for the neurological programme of care with deaths caused by epilepsy as the outcome indicator.[30] Although epilepsy accounts for less than 10 per cent of deaths attributable to the neurological care programme, it was the only mortality indicator available for this care programme at the time of writing.[31] Moreover, the other major causes of death in this category – motor neuron disease, Parkinson's disease, Alzheimer's disease, and multiple sclerosis – are not normally considered to be amenable to or avoidable with appropriate healthcare. Therefore, most expenditure in this PBC is likely to be directed towards caring for the patient rather than saving life.

Nevertheless, we have estimated outcome and expenditure models for the neurology programme with the mortality rate for epilepsy as the outcome indicator. Because epilepsy accounts for such a small proportion of all neurological deaths, and much expenditure will be directed towards 'caring' rather than life saving, it would not be surprising if our estimated marginal cost of a life year saved is large relative to that for other budgeting programmes where there is a better correspondence between the coverage of the expenditure and mortality data.

In the outcome equation with the epilepsy SMR as the dependent variable only the need term is significant. The Pesaran-Taylor test suggests no evidence of misspecification and tests indicate that the instruments are relevant and valid but that they may be weak. The model with the epilepsy SYLL rate as the dependent variable is poor in that neither the need nor the expenditure term is significant. For both outcomes (SMR and SYLL rate) Shea's partial R-squared is small and the F-statistic for the Cragg-Donald test does not exceed the Staiger and Stock criterion of being greater than ten – this indicates a potential problem with weak instruments and may account for these poor results.

30 Only 2SLS results are shown.

31 Of the 9,480 all-age deaths attributed to the neurological care programme in England in 2004 only 838 were due to epilepsy (NCHOD 2007 and ONS 2007).

Table 4: Results for neurological programme of care, 2006/07

N = 152	2SLS (1)		2SLS (2)	
	Neurological deaths	**Neurological expenditure**	**Neurological SYLL**	**Neurological expenditure**
Constant	1.852 (1.597)	-0.602 (0.875)	1.575 (1.520)	2.074 (1.665)
Need	1.738 (0.609)	1.064 (0.434)	0.913 (0.530)	1.195 (0.448)
Neurological expenditure	-0.744 (0.545)		0.003 (0.518)	
Total budget		0.532 (0.396)		0.747 (0.413)
All amenable deaths SMR		-0.523 (0.180)		
All deaths (SYLL)				-0.848 (0.272)
Test statistics:				
Sargan (χ^2_1)	1.97 (0.372)	6.94 (0.031)	2.52 (0.285)	4.94 (0.084)
Anderson (χ^2_2)	13.6 (0.003)	92.5 (0.000)	13.6 (0.003)	77.2 (0.000)
Cragg-Donald (F statistic)	4.82 (<0.05)	75.7 (<0.05)	4.82 (<0.05)	50.2 (<0.05)
Partial R^2	0.090	0.608	0.090	0.508
Reset:				
Pesaran-Taylor (χ^2_1)	2.90 (0.088)	0.40 (0.527)	0.11 (0.736)	0.94 (0.332)
Endogeneity (χ^2_1):				
Neurological expenditure	2.45 (0.117)		0.00 (0.932)	
All amenable deaths		8.79 (0.003)		
All deaths (SYLL)				13.21 (0.000)

Notes:

1. Parentheses show robust standard errors for parameter estimates and p-values for the test statistics.
2. The instrument set for epilepsy expenditure includes the proportion of households that are lone pensioner households, the proportion of the population providing unpaid care and the population weighted IMD based on local authority level 2007 scores.
3. The instrument sets for all amenable deaths (SMR) and all deaths (SYLL) include the proportion of households that are lone pensioner households, the proportion of the population providing unpaid care and the population weighted IMD based on local authority level 2007 scores.
4. Neurological deaths are proxied by the under-75 years direct SMR for epilepsy for 2004–06, and the neurological SYLL rate is proxied by the under-75 years epilepsy SYLL rate for 2004–06.
5. One PCT is omitted from the deaths equations because, with just one death from epilepsy in three years, it generates a very large residual.
6. Similar results are obtained if expenditure data is adjusted for PCT lead/host commissioning arrangements and for expenditure funded from PCT income.

In the cancer expenditure equation we employed the circulation death rate as a proxy for the other calls on a PCT's resources variable. In the circulation expenditure equation we employed the cancer death rate as a proxy for the other calls on a PCT's resources. However, when we employed both the cancer and circulation death rates as proxies for the other calls on resources in the neurological expenditure equation, we encountered co-linearity difficulties with the cancer and circulation death rate variables having opposite signs. Thus, for neurological expenditure (and for the expenditure equation for all of the other budgeting categories considered here) we have employed either the SMR from all causes amenable to healthcare for people aged under 75 years or the SYLL rate for all deaths of those aged under 75 as the proxy for other calls on resources.[32] Although these proxy measures will include some neurological deaths they will comprise a very small proportion of the total (for example, in the period 2002–04 neurological deaths accounted for less than 2 per cent of the 195,000 deaths from all causes amenable to healthcare in those aged under 75).

In both of the neurological expenditure equations two of the three regressors (need and the 'other calls on resources' term) have the anticipated effect on neurological expenditure and the test statistics reveal no evidence of misspecification. Although the total budget term is insignificant, re-estimation of the expenditure equations dropping the need term results in a highly significant total income term. Again, it appears that co-linearity between total budget and need makes it difficult to disentangle the need and income effect.

A condition-specific measure of need – the epilepsy prevalence rate – is available from data collected for the QOF. However, as was the case for the cancer and circulation problems categories, the use of this condition-specific measure of need offers little improvement over the more condition-specific measure of need.

The estimated coefficient (0.003) on expenditure in the SYLL rate outcome equation suggests that there is no beneficial impact of expenditure on epilepsy mortality. When estimated using expenditure data for 2005/06 and mortality data for the years 2002–04 we obtained a coefficient of -0.473. Although this was not statistically different from zero it did allow us to calculate the marginal cost of a life year saved associated with the neurology programme. We have been unable to detect a similar effect using data for 2006/07 and this may be due to changes to the construction of the neurology budgeting data for this year (expenditure per head increased by 35 per cent) and/or the weakness of the instruments.

6.4 Respiratory problems programme of care

Table 5 shows the results for the respiratory programme of care.[33] For the mortality outcome indicator we employ the sum of the under-75 years direct SMRs (or SYLL rates) for asthma, bronchitis, pneumonia and tuberculosis.[34] In 2004 these four causes accounted for about 52,000 of the 65,000 all-age deaths attributable to the respiratory problems care programme (NCHOD 2007 and ONS, VS3 Mortality by Cause, 2004 Registrations).

In both of the outcome equations (see Table 5, columns 1 and 3), need and expenditure have the anticipated signs and are significant. The usual tests indicate that the instruments are relevant and valid, that expenditure is endogenous and that there is no evidence of misspecification. However, the instruments may be weakly associated with expenditure. Shea's R-squared is low and the Cragg-Donald F-statistic does not exceed Staiger and Stock's recommended criterion of ten. Stock and Yogo (2002) do

32 See Martin, Rice and Smith (2008a) for details of which deaths are deemed amenable to healthcare.

33 Only 2SLS results are shown.

34 In our previous study we did not have access to direct SMRs and therefore took weighted averages of the indirect SMRs for asthma, bronchitis and pneumonia; the weights reflected the number of deaths in each category.

not provide critical values for the expected ratio of 2SLS bias to OLS bias for two excluded instruments (as is the case here) and so we cannot assess the likely extent of bias related to OLS for these models. However, these results should be interpreted with caution.

Table 5: Results for respiratory programme of care, 2006/07

N = 152	**2SLS (1)**		**2SLS (2)**	
	Respiratory deaths	**Respiratory Expenditure**	**Respiratory SYLL**	**Respiratory expenditure**
Constant	-10.27 (5.898)	-0.142 (1.249)	-12.21 (6.563)	2.953 (2.334)
Need	8.008 (2.968)	1.714 (0.596)	9.158 (3.298)	1.741 (0.497)
Respiratory expenditure	-4.845 (2.146)		-5.568 (2.388)	
Total budget		0.780 (0.317)		1.044 (0.369)
All amenable deaths SMR		-0.802 (0.396)		
All deaths (SYLL)				-1.109 (0.454)
% lone pensioner h-holds		-0.497 (0.346)		-0.419 (0.251)
Test statistics:				
Sargan (χ^2_1)	0.32 (0.569)	2.27 (0.131)	0.32 (0.566)	0.25 (0.617)
Anderson (χ^2_2)	7.4 (0.024)	25.0 (0.000)	7.4 (0.024)	27.8 (0.000)
Cragg-Donald (F statistic)	3.82 (<0.05)	14.3 (<0.05)	3.82 (<0.05)	16.3 (<0.05)
Partial R^2	0.049	0.165	0.049	0.183
Reset:				
Pesaran-Taylor (χ^2_1)	1.46 (0.226)	0.27 (0.602)	2.52 (0.112)	0.11 (0.735)
Endogeneity (χ^2_1):				
Respiratory expenditure	71.67 (0.000)		73.20 (0.000)	
All amenable deaths		9.71 (0.001)		
All deaths (SYLL)				11.76 (0.000)

Notes:

1. Parentheses show robust standard errors for parameter estimates and p-values for the test statistics.
2. The instrument set for respiratory expenditure includes the proportion of the population providing unpaid care and the population weighted IMD based on local authority 2007 scores.
3. The instrument sets for all amenable deaths (SMR) and all deaths (SYLL) include the proportion of the population providing unpaid care and the population weighted IMD based on local authority level 2007 scores.

4. The negative coefficient on the lone pensioner households variable might reflect a selection effect. This variable is also significant and has a negative sign in the first stage regressions predicting the endogenous terms 'all amenable deaths' and 'all deaths SYLL'.
5. The deaths (under-75 years direct SMR) outcome indicator is the sum of individual asthma, bronchitis, pneumonia and tuberculosis SMRs while the under 75 years SYLL rate outcome indicator is the sum of the asthma, bronchitis, pneumonia and tuberculosis SYLL rates.
6. Similar results are obtained if expenditure data is adjusted for PCT lead/host commissioning arrangements and for expenditure funded from PCT income.

In both of the expenditure equations (see columns 2 and 4) need, total budget and the proxy for other calls on resources all have the anticipated effect on respiratory expenditure and are significant. The other regressor (the percentage of households that are lone pensioner households) is not significant but is shown as it was included when modelling expenditure for 2005/06. Again, the usual tests indicate that the instruments are relevant and valid, that the deaths term is endogenous and that there is no evidence of misspecification.

Two more condition-specific measures of need – the asthma prevalence rate and the chronic obstructive pulmonary disease (COPD) prevalence rate – are available from data collected for the QOF. We added these to the equations presented in Table 5 and estimated various models. However, the results generated by the use of these two condition-specific measures of need were at best no better than those available from the use of the more generic all-condition measure of need.

The results for the outcome model with the SYLL rate as the dependent variable (see column 3) can be used to calculate the marginal cost of one life year. A 1 per cent increase in respiratory expenditure per head – which was £64.70 in 2006/07 – leads to a 5.568 per cent reduction in YLL (all things being equal). Across the period 2004–06 the total life years lost to respiratory (asthma, bronchitis and other, pneumonia and TB) deaths in those aged under 75 was 321,263 or 107,087 per annum (324,735 life years were lost in the years 2002–04).[35] Across the English population of 50 million, this suggests the loss of 0.0021417 life years (0.78172 days) per person. Thus, a 1 per cent increase in expenditure per head (£0.647) is associated with a 5.568 per cent reduction in life years lost (0.0435261 days). This implies that one extra life year would cost £5,425 (£7,397 using expenditure data for 2005/06 and mortality data for 2002/04).

6.5 Gastro-intestinal programme of care

Table 6 shows the results for the gastro-intestinal programme of care.[36] We use the sum of the direct SMRs and the sum of the SYLL rates for deaths from liver disease and from an ulcer for those aged under 75 years as mortality outcome indicators.[37] In 2004 these two causes accounted for over 9,000 of the 25,000 all-age deaths attributable to the gastro-intestinal care programme (NCHOD 2007 and ONS 2007). As this is less than 40 per cent of the total number of deaths our estimates about the cost of a life year are likely to be too high.

In the outcome equations (see Table 6, columns 1 and 3), both need and expenditure have the anticipated signs and are significant. The usual tests indicate that the instruments are relevant and valid, that expenditure is endogenous and that there is no evidence of misspecification. In the expenditure equations (see columns 2 and 4) need, total budget and the proxy for other calls on resources all have

35 See the NCHOD website at www.nchod.nhs.uk/

36 Only 2SLS results are shown.

37 Previously when estimating the outcome equations we only had access to indirect SMRs which we calculated by taking a weighted average of the indirect SMRs for both causes of death (liver diseases and ulcers).

the anticipated effect on expenditure and, in five of the six cases, are statistically significant. Again, the usual tests indicate that the instruments are relevant and valid, that the all-amenable deaths term is endogenous and that there is little evidence of misspecification.

Table 6: Results for gastro-intestinal programme of care, 2006/07

N = 152	**2SLS (1)**		**2SLS (2)**	
	Gastro deaths	**Gastro expenditure**	**Gastro SYLL**	**Gastro expenditure**
Constant	-2.154 (1.046)	2.133 (1.762)	-0.954 (1.054)	8.378 (3.337)
Need	3.852 (0.551)	2.626 (0.851)	3.966 (0.557)	2.839 (0.758)
Gastro expenditure	-1.754 (0.396)		-1.544 (0.399)	
Total budget		0.538 (0.355)		1.058 (0.445)
All amenable deaths SMR		-1.386 (0.565)		
All deaths (SYLL)				-2.093 (0.663)
% lone pensioner h-holds		-0.838 (0.491)		-0.793 (0.384)
Test statistics:				
Sargan (χ^2_1)	3.46 (0.176)	9.52 (0.002)	5.01 (0.081)	1.98 (0.159)
Anderson (χ^2_2)	29.3 (0.000)	25.0 (0.000)	29.3 (0.000)	27.8 (0.000)
Cragg-Donald (F statistic)	11.7 (<0.05)	14.3 (<0.05)	11.7 (<0.05)	16.3 (<0.05)
Partial R^2	0.193	0.164	0.193	0.183
Reset:				
Pesaran-Taylor (χ^2_1)	0.22 (0.640)	0.01 (0.938)	1.01 (0.315)	0.13 (0.722)
Endogeneity (χ^2_1):				
Gastro expenditure	31.72 (0.000)		20.80 (0.000)	
All amenable deaths		14.72 (0.000)		
All deaths (SYLL)				24.65 (0.000)

Notes:

1. Parentheses show robust standard errors for parameter estimates and p-values for the test statistics.
2. The instrument set for gastro-intestinal expenditure includes the proportion of households that are lone pensioner households, the proportion of the population providing unpaid care and the population weighted IMD based on local authority level 2007 scores.
3. The instrument sets for all amenable deaths (SMR) and all deaths (SYLL) include the proportion of households that are lone pensioner households and the population weighted IMD based on local authority level 2007 scores.

4. The deaths (under 75 years direct SMR) outcome indicator is the sum of the direct SMRs for liver disease and for ulcers while the SYLL rate outcome indicator is the sum of the under 75 liver disease and ulcer SYLL rates.
5. Similar results are obtained if expenditure data is adjusted for PCT lead/host commissioning arrangements and for expenditure funded from PCT income.

The results from the gastro-intestinal outcome model with the SYLL rate as the dependent variable can be used to calculate the marginal cost of a single life year. The gastro-intestinal expenditure coefficient of -1.544 implies that a 1 per cent increase in expenditure gives rise to a 1.544 per cent reduction in life years lost. A 1 per cent increase in gastro-intestinal expenditure per head – which was £72.90 in 2006/07 – leads to a 1.544 per cent reduction in YLL (all things being equal). Across the period 2004–06, the total life years lost to gastro-intestinal deaths in those aged under 75 was 328,834 (or 109,611 life years per annum).[38] Across the English population of 50 million this suggests the loss of 0.0021922 life years (0.800153 days) per person. Thus, a 1 per cent increase in expenditure per head (£0.729) is associated with a 1.544 per cent reduction in life years lost (0.0123543 days) and implies that one extra life year would cost £21,538 (£19,000 using mortality data for 2002–04 and expenditure data for 2005/06).

6.6 Trauma and injuries programme of care

Table 7 shows the 2SLS results for the trauma and injuries programme of care. For the mortality outcome indicator we employ the sum of the direct SMRs for deaths from a fractured femur (ages 65–84) and from a skull fracture (ages under 75).[39] No SYLL rate data are available for these causes of death. In 2004 these two causes accounted for about one-quarter of the 10,500 deaths attributable to the trauma and injuries PBC (NCHOD 2007).

In the outcome equation (see Table 7, column 1) only the need term is significant with the anticipated sign. However, there is an indication that the instruments may be weakly associated with expenditure (for example, the Cragg-Donald F-statistic does not exceed Staiger and Stock's recommended level of ten) and this may account for the insignificance of the expenditure term. In both of the expenditure equations (see columns 2 and 4), need and the other calls on resources terms have the anticipated effect on expenditure and are statistically significant. Only the total budget term is insignificant and this becomes significant in both equations if the equation is re-estimated without the need term. The usual tests indicate that the instruments are relevant and valid, that the deaths term is endogenous and that there is no evidence of misspecification.

38 See the NCHOD website at www.nchod.nhs.uk/

39 Previously when estimating the outcome equations we only had access to indirect SMRs, which we calculated by taking a weighted average of the indirect SMRs for both causes of death (fractured femur and skull).

Table 7: Results for trauma and injuries programme of care, 2006/07

N = 152	**2SLS (2)**		**2SLS (3)**	
	Trauma deaths	**Trauma expenditure**	**Trauma SYLL**	**Trauma expenditure**
Constant	1.934 (1.493)	1.373 (1.104)		5.640 (2.299)
Need	1.444 (0.630)	1.906 (0.590)		2.081 (0.677)
Trauma expenditure	-0.120 (0.516)			
Total budget		0.222 (0.519)		0.580 (0.544)
All amenable deaths SMR		-0.916 (0.226)		
All deaths (SYLL)				-1.416 (0.371)
Test statistics:				
Sargan (χ^2_1)	0.271 (0.256)	1.84 (0.396)		0.51 (0.772)
Anderson (χ^2_2)	20.0 (0.000)	92.5 (0.000)		77.2 (0.000)
Cragg-Donald (F statistic)	7.46 (<0.05)	75.7 (<0.05)		50.2 (<0.05)
Partial R^2	0.132	0.608		0.508
Reset:				
Pesaran-Taylor (χ^2_1)	0.26 (0.609)	0.26 (0.611)		0.17 (0.680)
Endogeneity (χ^2_1):				
Trauma expenditure	0.816 (0.366)			
All amenable deaths		23.38 (0.000)		
All deaths (SYLL)				29.18 (0.000)

Notes:

1. Parentheses show robust standard errors for parameter estimates and p-values for the test statistics.
2. The instrument set for trauma expenditure includes the proportion of households that are lone pensioner households and the population weighted IMD based on local authority level 2007 scores.
3. The instrument sets for all amenable deaths (SMR) and all deaths (SYLL) include the proportion of households that are lone pensioner households, the proportion of the population providing unpaid care, and the population weighted IMD based on local authority level 2007 scores.
4. The deaths (direct SMR) outcome indicator is the sum of the fractured femur direct SMR (ages 65–84) and the skull fracture direct SMR (ages under 75). No SYLL based mortality rates are available for these deaths.
5. Similar results are obtained if expenditure data is adjusted for PCT lead/host commissioning arrangements and for expenditure funded from PCT income.

6.7 Diabetes programme of care

Table 8 shows the 2SLS outcome and expenditure equations for the diabetes programme of care. We found that the diabetes prevalence rate (based on data collected from general practices as part of the new QOF) performed better than the all-specialty need variable in the expenditure equations so the latter replaced the former in the two expenditure equations. However, the two other terms in the expenditure equations – PCT income and other calls on resources – are insignificant.

The need term is significant in both outcome equations and, although expenditure is significant in the SMR outcome equation, it is only significant at the 10 per cent level in the SYLL outcome equation. There is also evidence that the instruments are weak. This implies that caution should be exercised in using the coefficient on the diabetes expenditure variable (this is -1.648) to estimate the marginal cost of an additional life year saved in this budgeting category. Nevertheless, we can calculate that a 1 per cent increase in diabetes expenditure per head – which was £17.60 in 2006/07 – leads to a 1.648 per cent reduction in YLL (all things being equal). Across the period 2004–06, the total life years lost to diabetes deaths in those aged under 75 was 60,614 (or 20,205 life years per annum).[40] Across the English population of 50 million this suggests a loss of 0.0004041 life years (0.14750 days) per person. Thus, a 1 per cent increase in expenditure per head (£0.176) is associated with a 1.648 per cent reduction in life years lost (0.0024307 days) and implies that one extra life year would cost £26,429 (£26,453 using mortality data for 2002–04 and expenditure data for 2005/06).

This figure for diabetes is slightly larger than what we found for the marginal cost of one additional life year for cancer (£15,387), circulation problems (£9,974), respiratory problems (£5,425) and gastro-intestinal problems (£21,538). This is probably because much of the expenditure in the diabetes programme – like that in the neurology programme – is on the management of the condition and is not directly for life-saving purposes.

40 See the NCHOD website at www.nchod.nhs.uk/

Table 8: Results for diabetes programme of care, 2006/07

N = 152	2SLS (1)		2SLS (2)	
	Diabetes deaths	**Diabetes expenditure**	**Diabetes SYLL**	**Diabetes expenditure**
Constant	-11.45 (4.958)	-2.631 (1.139)	-7.80 (4.453)	-3.131 (1.834)
Need	4.096 (1.120)		3.411 (1.033)	
Diabetes expenditure	-2.146 (1.059)		-1.648 (0.942)	
Total budget		0.280 (0.295)		0.214 (0.383)
All amenable deaths SMR		0.190 (0.193)		
All deaths (SYLL)				0.243 (0.286)
% lone pensioner h-holds	-1.95 (0.540)		-1.252 (0.508)	
Diabetes prevalence rate		0.732 (0.174)		0.755 (0.170)
Test statistics:				
Sargan (χ^2_1)	0.37 (0.541)	0.87 (0.646)	0.12 (0.719)	1.03 (0.595)
Anderson (χ^2_2)	4.11 (0.127)	94.7 (0.000)	4.11 (0.127)	78.8 (0.000)
Cragg-Donald (F statistic)	2.04 (0.133)	80.6 (<0.05)	2.04 (0.133)	52.4 (<0.05)
Partial R^2	0.027	0.623	0.027	0.518
Reset:				
Pesaran-Taylor (χ^2_1)	20.54 (0.000)	0.01 (0.912)	3.74 (0.053)	0.00 (0.944)
Endogeneity (χ^2_1):				
Diabetes expenditure	21.62 (0.000)		8.25 (0.004)	
All amenable deaths		0.98 (0.320)		
All deaths (SYLL)				0.50 (0.476)

Notes:

1. Parentheses show robust standard errors for parameter estimates and p-values for the test statistics.
2. The instrument set for diabetes expenditure includes the proportion of households that are lone pensioner households, the proportion of the population providing unpaid care and the population weighted IMD based on local authority level 2007 scores.
3. The instrument sets for all amenable deaths (SMR) and all deaths (SYLL) include the proportion of households that are lone pensioner households, the proportion of the population providing unpaid care, the population weighted IMD based on local authority level 2007 scores, and the all-specialty needs index (not included as a regressor in the second-stage equations).

4. The diabetes death measure is the under-75 years direct SMR for 2004–06 and the SYLL rate is for those aged under 75 over the same three-year period. The expenditure and outcome data have identical ICD-10 coverage.
5. Similar results are obtained if expenditure data is adjusted for PCT lead/host commissioning arrangements and for expenditure funded from PCT income.

In addition to the programmes of care discussed above, we also estimated outcome and expenditure equations for three other programmes – infectious diseases, genito-urinary problems and neonate conditions – for which a relevant mortality indicator is available. However, we met with less success for these other budgeting categories. This is perhaps not surprising as the specialty coverage of the outcome measure – the mortality rate from chronic renal failure (ICD-10 code N18) – is considerably smaller than that of the expenditure data (which relates to ICD-10 codes A50-A64, N00-N99, Q500-Q649, R30-R39, R86-R87) and renal failure accounts for less than one-fifth of all deaths that fall within the genito-urinary programme. In addition, there are relatively few deaths from this condition: over the three year period from 2002–04 there were on average 1,406 deaths per year which is less than 5 deaths per PCT per annum. Similar issues with small numbers also arise with the infectious diseases and neonate conditions categories.

7 Empirical results: programmes without a mortality indicator but generating a satisfactory expenditure equation

For some budgeting categories no relevant mortality indicator is available; thus, it is impossible to estimate an outcome (death rate) equation. However, we can still estimate expenditure equations and we present these below for the five budgeting categories for which we could obtain plausible results.[41] These results illustrate the applicability of our expenditure model to programmes of care even when the absence of a mortality measure precludes the application of our outcome model.[42]

7.1 Vision programme of care

Table 9 (columns 1 and 2) show expenditure equations for the vision programme of care. In both equations the need and other calls on resources terms are significant and have the correct sign. The coefficient on PCT income is positive but insignificant, although if the need term is dropped then the coefficient on PCT income increases and becomes significant. The Sargan test suggests that there might be some misspecification in one of the equations, but generally the diagnostic statistics do not reveal any problems.

7.2 Endocrine, nutritional and metabolic programme of care

Table 9 (columns 3 and 4) also shows expenditure equations for the endocrine, nutritional and metabolic programme of care. In both equations the diabetes prevalence rate (replacing the all-condition need term) and the total income terms are significant and have the correct sign. The coefficient on other calls on resources term is negative but insignificant. The diagnostic statistics do not reveal any problems with the equations.

41 Only 2SLS results are shown.

42 We were unable to obtain a plausible expenditure equation for the six other budgeting categories – blood disorders, learning disability, hearing problems, dental problems, skin problems and maternity – without a mortality indicator.

Table 9: Expenditure equations for vision problems and endocrine/metabolic problems, 2006/07

N = 152	**Vision expenditure (PBC 8)**		**Endocrine/metabolic expenditure (PBC 4)**	
	2SLS	**2SLS**	**2SLS**	**2SLS**
Constant	0.673 (1.220)	5.383 (2.402)	-1.873 (0.833)	-1.483 (1.322)
Need	1.769 (0.546)	1.989 (0.586)		
Total budget	0.556 (0.465)	0.940 (0.514)	0.885 (0.185)	0.943 (0.247)
All amenable deaths (SMR)	-0.948 (0.254)		-0.085 (0.135)	
All deaths (SYLL)		-1.514 (0.394)		-0.137 (0.200)
Diabetes prevalence rate			0.391 (0.123)	0.382 (0.120)
Test statistics:				
Sargan (χ^2_1)	7.13 (0.007)	4.59 (0.032)	0.29 (0.024)	0.21 (0.647)
Anderson (χ^2_2)	92.2 (0.000)	76.0 (0.000)	92.3 (0.000)	78.1 (0.000)
Cragg-Donald	113.4 (<0.05)	73.5 (0.05)	113.9 (<0.05)	77.7 (<0.05)
Partial R^2	0.606	0.500	0.607	0.514
Reset:				
Pesaran-Taylor (χ^2_1)	0.05 (0.824)	0.01 (0.920)	0.22 (0.638)	0.18 (0.671)
Endogeneity (χ^2_1):				
All amenable deaths (SMR)	9.44 (0.002)		7.65 (0.005)	
All deaths (SYLL)		12.60 (0.000)		5.26 (0.021)

Notes:

1. Parentheses show robust standard errors for parameter estimates and p-values for the test statistics.
2. The instrument sets for the all-amenable deaths and all deaths variables include the proportion of households that are lone pensioner households and the population weighted IMD based on local authority level 2007 scores.
3. Similar results are obtained if expenditure data is adjusted for PCT lead/host commissioning arrangements and for expenditure funded from PCT income.

7.3 Mental health programme of care

Table 10 (columns 1 and 2) shows expenditure equations for the mental health programme of care. These are for all mental health expenditure including dementia. The three usual regressors – (mental health) need, total budget and the proxies for other calls on resources – have the anticipated effect on expenditure in both equations and all six are statistically significant.[43] The percentage of all households that are lone pensioner has a significant negative impact on expenditure. This might reflect a selection effect or indicate the presence of unmet need. The diagnostic statistics detect no issues with these equations. A second condition-specific measure of mental health need – the mental illness prevalence rate – is available from data collected for the QOF. However, the use of this need indicator as a regressor led to no overall improvement in the results.

7.4 Musculo-skeletal programme of care

Table 10 (columns 3 and 4) also shows expenditure equations for the musculo-skeletal programme of care. Two of the three regressors – need and the proxies for other calls on resources – have the anticipated effect on expenditure and are statistically significant. The proxies for the other calls on resources variables are endogenous and there is no evidence of misspecification. Although the PCT income term is insignificant, re-estimation of both expenditure equations without the need term generates positive and significant coefficients on PCT income.

43 Rather than employ the all-specialty measure of need we use the index of mental health need as constructed by the DH for allocating resources to hospital and community health services.

Table 10: Expenditure equations for mental health and musculo-skeletal expenditure, 2006/07

N = 150 (mental health) N = 152 (musculo-skeletal)	Mental health expenditure (PBC 5)		Musculo-skeletal expenditure (PBC 15)	
	2SLS	2SLS	2SLS	2SLS
Constant	9.729 (3.117)	33.44 (13.872)	1.741 (1.448)	6.418 (2.857)
Need	2.125 (0.500)	3.120 (1.135)	2.110 (0.760)	2.338 (0.862)
Total budget	2.072 (0.418)	4.135 (1.366)	-0.009 (0.583)	0.359 (0.581)
All amenable deaths (SMR)	-2.958 (0.093)		-0.952 (0.289)	
All deaths (SYLL)		-6.157 (2.314)		-1.511 (0.455)
% lone pensioner h-holds	-0.940 (0.273)	-0.701 (0.483)		
Test statistics:				
Sargan (χ^2_1)	0.20 (0.654)	1.97 (0.159)	4.85 (0.027)	2.71 (0.099)
Anderson (χ^2_2)	26.2 (0.000)	7.1 (0.028)	91.7 (0.000)	75.4 (0.000)
Cragg-Donald	15.2 (<0.05)	3.5 (<0.05)	112.9 (<0.05)	72.8 (<0.05)
Partial R^2	0.175	0.047	0.607	0.499
Reset:				
Pesaran-Taylor (χ^2_1)	2.09 (0.148)	6.13 (0.013)	0.09 (0.760)	0.18 (0.675)
Endogeneity (χ^2_1):				
All amenable deaths (SMR)	38.11 (0.000)		13.36 (0.000)	
All deaths (SYLL)		38.83 (0.000)		17.09 (0.000)

Notes:

1. Parentheses show robust standard errors for parameter estimates and p-values for the test statistics.
2. The instrument sets for the all-amenable deaths and all-deaths variables include the proportion of households that are lone pensioner households and the population weighted IMD based on local authority level 2007 scores.
3. The mental health need variable has been constructed by taking weighted averages of the same variable for the old 303 PCTs and combining these to form the same indicator for the new 152 PCTs. Unfortunately, boundary changes mean that we cannot calculate this variable for two new PCTs.
4. Similar results are obtained if expenditure data is adjusted for PCT lead/host commissioning arrangements and for expenditure funded from PCT income.

7.5 Poisoning programme of care

We also successfully estimated expenditure equations for the poisoning programme of care (not shown here). As we have found for other programmes, the need and the other calls on resources terms are significant and have the anticipated signs. The coefficient on the income term is positive but not significant, although re-estimation without the need term results in a significant coefficient on PCT income. The diagnostic statistics reveal no obvious problems with these results.

8 Conclusions

In 2006 the number of English PCTs was reduced from 303 to 152. In the same year, several changes were made to the methods used to construct the programme budgeting data. In addition, mortality data for the three-year period from 2004 to 2006 have recently been released. We have used these new data sets to re-estimate our health outcome and expenditure models. Despite the substantial changes to the way in which the data are constructed, this study has shown that our earlier results still apply.

In particular, we have shown that healthcare expenditure has a demonstrably positive effect on outcomes in five of the care programmes we investigated (that is, for cancer, circulation problems, respiratory problems, gastro-intestinal problems and diabetes). Our lack of success with five other categories – neurology, trauma and injuries, infectious diseases, genito-urinary problems and neonatal care – probably reflects the fact that our outcome indicator (death) is not a common outcome for these categories and/or that the specialty coverage of the mortality data fails to match closely enough the coverage of the budgeting data. No outcome indicator was available for another five categories, although we obtained plausible expenditure results in line with our model's expectations.

Our estimates confirm the findings presented in an earlier study (Martin, Rice and Smith 2008b), which employed budgeting expenditure data for 2005/06 and mortality data for the period 2002–04 for 303 PCTs. In this study we have used budgeting data for 2006/07 and mortality data for the period 2004–06. Our estimates confirm that the marginal cost of a life year saved is quite low and that this finding is not confined to cancer and circulation problems. Using expenditure data for 2006/07, we estimate that the marginal cost of a life year saved is:

- £15,387 for cancer (£13,931 for 2005/06)
- £9,974 for circulation problems (£8,426 for 2005/06)
- £5,425 for respiratory problems (£7,397 for 2005/06)
- £21,538 for gastro-intestinal problems (£18,999 for 2005/06)
- £26,429 for diabetes (£26,453 for 2005/06).

These figures provide evidence that expenditure on the various disease categories yields quite consistent benefits in terms of life years saved. Furthermore, it is quite likely that the variations we observe between the costs in the different programmes can be explained by two factors. The first is interventions, such as cancer palliative care, that yield benefits that cannot be measured to any great extent in increased life expectancy. The second is differences in the extent to which the specialty coverage of the mortality data corresponds to the coverage of the budgeting data.

The dramatic change in inference that arises when moving from the misspecified OLS models to the well-specified 2SLS models illustrates why proper econometric modelling is needed if the nature of the relationship between expenditure and outcome is to be investigated correctly. The models and methods described here are rather complex and will be unfamiliar to many commentators, but they are essential if incorrect inferences are to be avoided. In particular, they suggest a far more marked influence of healthcare spending on health outcomes than is often indicated by more conventional analysis.

Nevertheless, we recognise that this study has a number of limitations. It uses limited health outcomes data (in the form of mortality rates). For the purposes of this study we were able to use only data made publicly available by the DH, and we hope that in time a greater range of outcome and epidemiological

data will be made available. We did have access to a number of additional condition-specific needs variables, which previously have not been available, but in general these did not perform any better than the more generic all-specialty need variable.

We have modelled outcome data for the period 2004–06 along with expenditure data for the financial year 2006/07. In practice, health outcomes are the results of years of expenditure by local PCTs and, conversely, current expenditure is expected to yield outcome benefits beyond the current year. Implicitly, our analysis assumes that PCTs have reached some sort of equilibrium in the expenditure choices they make and the outcomes they secure. This is probably not an unreasonable assumption, given the relatively slow pace at which both types of variable change. But a longer time series of data would enable us to model the effects with more confidence. Unfortunately, changes to the methods used to construct the budgeting data for 2006/07 have introduced a discontinuity into the data for this year.

Nevertheless, we believe that programme budgeting is a major initiative that offers immense potential for researchers and policy-makers. For the first time it brings together clinical data, in the form of health outcomes, and expenditure data. Therefore, it has the potential to engage clinicians in value-for-money issues where more conventional budgetary approaches fail. It also offers the potential for better clinical engagement in budgetary choices and better-informed purchasing decisions by PCTs.

This paper offers a glimpse of this potential. The results can help the Treasury and national politicians make more informed decisions about whether healthcare expenditure offers value for money. They can help the DH and local purchasers make better informed decisions about where their limited budgets are best spent. And they can also inform the decisions of the National Institute for Health and Clinical Excellence (NICE) about whether its current threshold for accepting new technologies is set at an appropriate level.

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Appendix A: National net expenditure per head of population by programme budget category and sub-category, 2004/05–2006/07

Table A1 reports national net expenditure per head of population by programme budget category and sub-category for the three-year period 2004/05–2006/07.

Table A1: National net expenditure per head of population by programme budget category and sub-category, 2004/05–2006/07

	Programme budget category	National expenditure per head of population, England, £					
		Net	Net, adj	Net	Net, adj	Net	Net, adj
		2004/05	2004/05	2005/06	2005/06	2006/07	2006/07
1	**Infectious diseases**	20.1	20.2	23.7	23.6	21.4	20.9
1a	HIV and AIDS					7.4	7.4
1x	Infectious diseases (other)					14.0	13.5
2	**Cancers and tumours**	75.1	75.5	82.8	83.2	80.9	81.7
2a	Cancer, head and neck					2.8	2.8
2b	Cancer, upper GI					4.0	4.1
2c	Cancer, lower GI					6.4	6.5
2d	Cancer, lung					3.9	3.9
2e	Cancer, skin					1.9	1.9
2f	Cancer, breast					7.3	7.4
2g	Cancer, gynaecological					2.9	3.0
2h	Cancer, urological					7.7	7.8
2i	Cancer, haematological					8.4	8.4
2x	Cancers and tumours (other)					35.5	36.0
3	**Disorders of blood**	16.9	17.0	17.4	17.5	16.5	16.6
4	**Endocrine, nutritional and metabolic**	31.7	31.9	37.0	37.3	36.4	36.7
4a	Diabetes	13.5	13.6	16.8	17.0	17.6	17.8
4b	Endocrine, nutritional and metabolic					6.9	6.9
4x	Other endocrine, nutritional, metabolic	18.2	18.2	20.1	20.3	11.9	12.0

5	**Mental health disorders**	145.3	146.8	156.9	159.0	163.9	166.5
5a	Substance misuse	11.9	12.3	14.0	14.4	13.1	13.8
5b	Organic mental disorders	16.1	15.9	16.3	16.4	14.0	14.2
5c	Psychotic disorders					23.7	23.8
5d	Child and adolescent mental health					12.0	12.1
5x	Other mental health disorders	117.3	118.6	126.7	128.2	101.1	102.5
6	**Problems of learning disability**	42.0	43.4	44.7	46.5	46.2	48.4
7	**Neurological**	34.9	35.1	40.8	41.1	54.7	55.3
7a	Chronic pain					19.2	19.3
7x	Neurological (Other)					35.5	36.0
8	**Problems of vision**	27.5	27.6	28.0	28.2	26.8	27.0
9	**Problems of hearing**	6.3	6.3	6.2	6.3	6.1	6.2
10	**Problems of circulation**	122.0	122.4	123.6	124.3	121.1	122.1
10a	Coronary heart disease					38.6	38.9
10b	Cerebrovascular disease					15.9	16.1
10c	Problems of rhythm					7.2	7.2
10x	Problems of circulation (other)					59.4	59.9
11	**Problems of the respiratory system**	62.5	62.7	69.2	69.6	64.7	65.1
11a	Obstructive airways disease					10.6	10.6
11b	Asthma					14.0	14.0
11x	Problems of the respiratory system, other					40.1	40.4
12	**Dental problems**	13.3	13.6	23.3	24.9	44.3	51.9
13	**Problems of gastro intestinal system**	73.0	73.2	80.9	81.3	72.9	73.3
13a	Upper GI					19.8	19.9
13b	Lower GI					20.3	20.5
13c	Hepatobiliary					11.2	11.3
13x	Problems of the gastro intestinal system					21.5	21.7
14	**Problems of the skin**	24.8	16.1	26.6	26.8	28.1	28.3
14a	Burns					1.1	1.1

14x	**Problems of the skin**					27.0	27.2
15	**Problems of musculo skeletal system**	71.2	71.7	74.2	74.7	65.5	66.2
16	**Problems due to trauma and injuries**	71.9	72.1	75.9	76.4	56.8	57.3
17	**Problems of genito-urinary system**	62.1	62.4	67.2	67.4	68.5	69.0
17a	Genital tract problems					19.2	19.3
17b	Renal problems					21.4	21.5
17c	STD					4.2	4.3
17x	Problems of genito-urinary system, other					23.6	23.8
18	**Maternity and reproductive health**	54.7	55.0	59.9	60.4	57.2	57.6
19	**Conditions of neonates**	13.9	13.9	13.3	13.4	13.1	13.2
20	**Adverse effects and poisoning**	12.3	12.3	14.2	14.3	14.5	14.6
20a	Unintended consequences of treatment					10.5	10.5
20b	Poisoning					2.1	2.1
20c	Violence					0.5	0.5
20x	Poisoning and adverse effects					1.4	1.4
21	**Healthy individuals**	21.7	22.8	24.6	26.2	25.2	26.8
21a	NSF prevention programme					2.2	2.3
21b	NSF mental health prevention					0.2	0.2
21x	Healthy individuals (other)					22.8	24.4
22	**Social care needs**	25.1	30.9	27.7	33.6	23.2	30.3
23	**Other**	154.7	157.8	168.1	171.8	206.6	209.7
23a	GMS/PMS	126.9	127.4	145.5	146.1	140.6	141.4
23b	Training (WDCs)	0.0	-0.2	0.4	0.5	0.5	0.6
23x	Miscellaneous	27.8	30.4	22.2	25.2	65.5	67.7
	Total	1183.1	1190.8	1286.2	1307.8	1314.5	1344.5

Note:

The two differences between the net and net-adjusted expenditure figures are that the latter incorporate adjustments for PCT lead/host commissioning arrangements and expenditure funded from charges levied by PCTs. We use the net expenditure data when estimating the regression models (although similar results are obtained with the net-adjusted data). We have used the net data in both previous studies, although in Martin, Rice and Smith (2008b) it was noted that the use of the net-adjusted expenditure data generated very similar results to those obtained using the net data.

Table A2 reports correlation coefficients between expenditure (cost-adjusted) per head (2006-07) and various socioeconomic indicators for four PBCs. Table A3 reports correlation coefficients between SMRs for three PBCs and various socioeconomic indicators.

Table A2: Correlation between expenditure (cost-adjusted) per head (2006/07) and various socioeconomic indicators, for four programme budgeting categories, across all PCTs

	Expenditure (cost adjusted) per head on:			
Socioeconomic indicator	**cancers/ tumours**	**mental health**	**CHD problems**	**gastro-intestinal problems**
Proportion of residents in white ethnic group	0.352	-0.415	0.375	0.308
Proportion of working age population with long-term illness	0.591	0.422	0.655	0.703
Proportion of population providing some unpaid care	0.541	-0.271	0.671	0.608
Proportion of population providing <20 hours week unpaid care	0.207	-0.580	0.331	0.223
Proportion of population providing 20-49 hours week unpaid care	0.547	0.269	0.623	0.667
Proportion of population providing >50 hours week unpaid care	0.661	0.141	0.732	0.733
Proportion of households that are one pensioner households	0.547	-0.093	0.582	0.426
Proportion of households that are one parent households	0.265	0.620	0.224	0.322
Proportion of population aged 16-74 that are permanently sick	0.609	0.416	0.667	0.726
Proportion of population aged 16-74 are long-term unemployed	0.265	0.671	0.190	0.277
Population weighted average of local authority IMD2007 scores	0.366	0.661	0.311	0.402

Sources: data are from Population Census 2001. Thanks are due to Linda Williams at the Office for National Statistics for supplying the relevant Key Statistics data based upon the new October 2006 PCT boundaries. Details about the construction of the socioeconomic indicators can be found in Table A4.

Table A3: Correlation between SMRs for three programme budgeting categories and various socioeconomic indicators, across all PCTs

Socioeconomic indicator	Direct Standardised Mortality Rate for:		
	cancers/ tumours	CHD problems	gastro-intestinal problems
Proportion of residents in white ethnic group	-0.018	-0.396	-0.238
Proportion of working age population with long-term illness	0.798	0.769	0.654
Proportion of population providing some unpaid care	0.240	0.048	0.067
Proportion of population providing <20 hours week unpaid care	-0.296	-0.488	-0.358
Proportion of population providing 20-49 hours week unpaid care	0.681	0.667	0.536
Proportion of population providing >50 hours week unpaid care	0.683	0.544	0.451
Proportion of households that are one pensioner households	0.101	-0.146	0.076
Proportion of households that are one parent households	0.755	0.845	0.657
Proportion of population aged 16-74 that are permanently sick	0.810	0.742	0.665
Proportion of population aged 16-74 are long-term unemployed	0.671	0.726	0.588
Population weighted average of local authority IMD2007 scores	0.771	0.878	0.727

Sources: data are from Population Census 2001 and NCHOD. Thanks are due to Linda Williams at the Office for National Statistics for supplying the relevant Key Statistics data based upon the new October 2006 PCT boundaries. The gastro-intestinal mortality indicator is the sum of the direct SMRs for people aged under 75 years for liver disease and ulcers. Details about the construction of the socioeconomic indicators can be found in Table A4.

Table A4: Socioeconomic indicators available as potential instruments in the 2SLS estimation

Indicator name	Short description	Long description with relevant Census Key Statistic table and cell numbers
WHITEEG	Residents in white ethnic group	Population in white ethnic group divided by total population (KS006002+KS006003+KS006004)/KS006001
PCWALLTI	Population of working age with illness	Proportion of population of working age with limiting long term illness divided by population aged 16-74 (KS008003/KS09A001)
POPPUCAR	Unpaid care providers in population	Proportion of population providing unpaid care (KS008007/KS008001)
POPPUCA1	Unpaid care (<20 hrs week) in population	Proportion of population providing unpaid care of 1–19 hours a week (KS008008/KS008001)
POPPUCA2	Unpaid care (20-49 hrs) in population	Proportion of population providing unpaid care for 20–49 hours per week (KS008009/KS008001)
POPPUCA3	Unpaid care (>50 hrs week) in population	Proportion of population providing unpaid care for over 50 hours week (KS008010/KS008001)
LONEPENH	Lone pensioner households	Proportion of households that are one pensioner households (KS020002/KS020001)
LONEPARH	Lone parent households	Proportion of households that are lone parent households with dependent children (KS020011/KS020001)
PERMSICK	Permanently sick of those aged 16-74	Proportion of population aged 16–74 that are permanently sick (KS09A010/KS09A001)
PC74LTUN	Long-term unemployed of those aged 16–74	Proportion of those aged 16–74 that are long-term unemployed (KS09A015/KS09A001)
IMD2007	Index of Multiple Deprivation	Population weighted average of local authority IMD 2007 scores

Note:

A further dozen potential instruments were available but not used because we had found little use for them in our previous studies (see Martin, Rice and Smith 2008a; 2008b).

Appendix B: Instruments employed in the 2SLS estimation of outcome and expenditure models (presented in section 6)

Table B1 reports the first-stage regressions with robust standard errors for the outcome and expenditure models presented in section 6.

1 Cancer programme of care

The instrument set for the cancer programme of care includes the proportion of households that are lone pensioner households and the proportion of the population providing unpaid care. These instruments have intuitive appeal. The first stage regressions of cancer expenditure on the instruments and the need for healthcare (as an exogenous regressor in the 2SLS model) reveals a positive and significant coefficient on lone pensioners and a negative but non-significant coefficient on the proportion of unpaid carers. The proportion of lone pensioners is likely to reflect an additional adjustment for healthcare need specific to an elderly and needy population. Unpaid care is a substitute for the provision of healthcare services and accordingly one may expect a negative relationship with expenditure.

For the cancer expenditure model the first stage regression of the instrument set (including need and total budget) on circulatory deaths results in a negative coefficient on both instruments excluded from the second-stage regression. A greater proportion of unpaid carers reflects an increased level of care (and perhaps increased compliance with care programmes and drug regimes) resulting in a decrease in circulatory deaths. Conditional on need and the total PCT budget, the negative coefficient on the proportion of lone pensioners may be indicative of areas with increased networks of social support, or reflect a selection effect in the sense that areas with a low under 75 death rate may as a result have an older age structure.

2 Circulation problems programme of care

The two instruments used for cancer were also employed to predict circulation expenditure but were augmented with the population weighted IMD for 2000. The relevance of this variable is theoretically plausible as circulatory disease is more related to disadvantage than is cancer. In addition, we also employed the proportion of residents in the white ethnic group as an additional instrument for expenditure as it is employed as a regressor in the second-stage expenditure equation.

Increased expenditure on circulatory disease in the first stage regression is associated with a greater proportion of pensioners living alone and a greater proportion of unpaid carers. The latter may reflect an increased awareness and compliance with medical intervention, particularly preventative measures, brought about by carers. Increased expenditure is also associated with less deprivation and this might reflect some unmet need.

With regard to the endogenous cancer SMR in the CHD expenditure equation, we found that both the proportion of pensioners living alone and unpaid carers were negatively associated with the under-75 years cancer death rate, while deprivation was positively associated with the cancer death rates.

3 Neurological problems programme of care

Both neurological equations include three instruments that are excluded as regressors from the second stage of estimation. Of these three variables only the IMD is significantly associated with expenditure and this is a negative relationship and might reflect some unmet need. As a predictor of the under-75 SMR for deaths from conditions amenable to healthcare, the negative coefficient on the proportion of lone pensioners may be indicative of areas with increased networks of social support, or reflect a selection effect, in the sense that areas with a low under-75 death rate may as a result have an older age structure.

4 Respiratory problems programme of care

The IMD is negatively associated with expenditure on respiratory problems but this is only significant at the 10 per cent level and may reflect some unmet need. The regressors employed to predict the under-75 SMR for deaths from conditions amenable to healthcare are the same as those for neurological problems (the negative coefficient on the proportion of lone pensioners may again be indicative of areas with increased networks of social support or reflect a selection effect in the sense that areas with a low under-75 death rate may, as a result, have an older age structure).

5 Gastro-intestinal problems programme of care

Increased expenditure on gastro-intestinal problems in the first stage regression is positively associated with the proportion unpaid carers. This may reflect an increased awareness and compliance with medical intervention, particularly preventative measures, brought about by carers. The regressors employed to predict the under-75 SMR for deaths from conditions amenable to healthcare are similar to those for both neurological problems and for respiratory problems, and the results are qualitatively the same.

6 Trauma, burns and injuries programme of care

Increased expenditure on trauma, burns and injuries in the first stage regression is positively associated with the proportion of pensioners living alone. This may reflect longer stays in hospital and an increased need for community care. The regressors employed to predict the under-75 SMR for deaths from conditions amenable to healthcare are similar to those for neurological, respiratory and gastro-intestinal problems, and the results are qualitatively the same.

7 Diabetes programme of care

Increased expenditure on diabetes in the first stage regression is positively associated with need but negatively associated with the proportion of pensioners living alone (the latter may reflect a selection effect). The regressors employed to predict the under-75 SMR for deaths from conditions amenable to healthcare are lone pensioners (negatively) and unpaid carers, PCT income and the IMD2007 (positively).

Table B1: First-stage regressions with robust standard errors for outcome and expenditure models presented in section 6

Programme	**Regressors**					
Budget						
Category	**Need**	**Lone_ pension**	**Unpaid_ carers**	**White_ ethnic**	**PCT budget**	**IMD2000**
Cancer						
Expenditure	0.405**	0.592**	-0.013			
Circulation SMR	1.753**	-0.740**	-0.248**		-0.156	
Circulation						
Expenditure	1.172**	0.229**	0.374**	-0.006		-0.151**
Cancer SMR	0.659**	-0.334**	-0.142*	0.238**	0.027	0.061*
Neurological						
Expenditure	1.308**	0.287	-0.067			-0.217*
Amenable SMR	0.774**	-0.518**	-0.051		-0.090	0.191**
Respiratory						
Expenditure	1.569**		0.121			-0.131*
Amenable SMR	0.774**	-0.518**	-0.051		-0.090	0.191**
Gastro-intestinal						
Expenditure	0.970**	0.044	0.574**			-0.047
Amenable SMR	0.709**	-0.526**			-0.077	0.203**
Trauma, burns						
Expenditure	0.727*	0.561**	-0.148			-0.016
Amenable SMR	0.774**	-0.518**	-0.051		-0.090	0.191**
Diabetes						
Expenditure	1.724**	-0.606*	0.064			-0.240
Amenable SMR	0.075	-0.505**	0.242*		0.412**	0.306**

Notes:

1. *=significant at 5 per cent level and **=significant at 1 per cent level
2. The ‘need’ term in the amenable SMR equation for diabetes is the diabetes prevalence rate.

Descriptive statistics for the socioeconomic and mortality variables employed in the regression analysis

Table C1 reports descriptive statistics for various socioeconomic and mortality variables employed in the regression analysis (these are all for variables in absolute form). The 'need for healthcare' index averages about 1 across all PCTs but varies substantially: some PCTs have a needs index 30 per cent below the national average and others have a need for healthcare 40 per cent above the national average. On average, lone pensioner households comprise 14 per cent of all households and lone parent households account for 7 per cent of all households. The 'white ethnic' group accounts for 89 per cent of the population and 10 per cent of the population are unpaid carers. Twelve per cent of the working age population (aged 16–74) has a limiting long-term illness and 6 per cent is permanently sick. On average, 1 per cent of the population is long-term unemployed.

The mortality data employed in this study were released by NCHOD in December 2007 and relate to deaths over the three-year period 2004–2006. The directly (age) standardised annual mortality rate (SMR) for those aged under 75 years and dying from cancer averages 120 deaths per 100,000 population across all PCTs, but this varies between 76 deaths and 165 deaths per 100,000 population. Similarly, the direct SMR for those aged under 75 years and dying from circulation problems averages 90 deaths per 100,000 population annually, and this varies between 55 and 142 deaths per 100,000 population. The direct SMR for those aged under 75 years and dying from all causes averages 326 deaths per 100,000 population while the same SMR from all causes deemed amenable to healthcare is 118 deaths per 100,000 population.

In addition to the SMRs, we also employ a measure of the avoidable YLL. This is calculated by summing the number of deaths at each age over ages 1 to 74 years multiplied by the number of years of life remaining up to age 75 years. The crude YLL rate is simply the number of years of life lost divided by the resident population aged under 75 years. Like conventional mortality rates, YLL can be age standardised to eliminate the effects of differences in population age structures between areas, and this (age) standardised YLL (SYLL) rate is what we use in this study (Lakhani et al 2006, p 379). As Table 1 shows, on average 158 years of life were lost annually to cancer per 10,000 population over the three-year period 2004–2006. For circulation problems, 108 years of life were lost each year per 10,000 population. For all causes of death 483 years of life were lost annually and 153 years of life per 10,000 population were lost annually for deaths from causes considered amenable to healthcare. Table 1 also presents descriptive statistics for other causes of death.

Table C1: Descriptive statistics for socioeconomic and mortality variables employed in the regression analysis

Variable	Mean	Std. Dev.	Min	Max
Need	1.03	0.14	0.72	1.40
Lone pensioners	0.14	0.02	0.10	0.19
Lone parents	0.07	0.02	0.04	0.12
White ethnic group	0.89	0.13	0.39	0.99
Unpaid carers	0.10	0.01	0.07	0.12
Working age with LLTI	0.12	0.03	0.07	0.18
Permanently sick	0.06	0.02	0.02	0.12
Long-term unemployed	0.01	0.01	0.00	0.03
IMD2007	23.63	9.07	8.06	46.97
Cancer SMR	120.80	14.76	76.71	165.98
Cancer SYLL rate	158.36	18.30	103.55	218.82
Circulation SMR	90.19	19.41	55.59	142.35
Circulation SYLL rate	108.56	25.21	65.20	177.80
All causes SMR	326.69	56.31	211.71	495.66
Amenable causes SMR	118.45	23.32	69.18	186.24
All causes SYLL rate	483.39	83.87	318.09	742.49
Amenable causes SYLL rate	153.28	30.97	88.32	249.26
Epilepsy SMR	1.65	0.61	0.19	3.93
Epilepsy SYLL rate	5.25	2.13	0.54	13.09
Asthma SMR	1.60	0.61	0.62	4.04
Bronchitis SMR	13.72	4.87	5.94	27.29

Pneumonia SMR	7.59	2.59	2.47	16.10
TB SMR	0.42	0.46	0.00	2.64
Asthma SYLL rate	2.39	1.26	0.13	6.34
Bronchitis SYLL rate	11.99	4.80	3.74	26.12
Pneumonia SYLL rate	9.70	3.72	3.61	21.89
TB SYLL rate	0.85	1.07	0.00	5.21
Liver disease SMR	10.99	4.14	4.83	32.77
Ulcer SMR	2.08	0.93	0.24	8.29
Liver disease SYLL rate	22.94	9.91	8.22	74.96
Ulcer SYLL rate	2.66	1.45	0.06	11.56
Femur fracture SMR	10.06	6.60	0.00	30.63
Skull fracture SMR	1.94	0.78	0.42	4.36
Diabetes SMR	3.48	1.47	1.31	11.20
Diabetes SYLL rate	4.52	2.07	1.27	15.29