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Further Evidence on the Link Between Health Care Spending and Health Outcomes in England

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Further evidence on the link between health care spending and health outcomes in England

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Executive summary

1. This report describes results from research funded by the Health Foundation under its Quest for Quality and Improved Performance (QQuIP) initiative.

2. It builds on our earlier report for the Health Foundation – *The link between health care spending and health outcomes: evidence from English programme budgeting data* – that took advantage of the availability of a major new dataset to examine the relationship between health care expenditure and mortality rates for two disease categories (cancer and circulation problems) across 300 English Primary Care Trusts.

3. Since 2003 each Primary Care Trust (PCT) in the English NHS has prepared data on expenditure on health care across 23 'programmes' of care, based on ICD10 disease categories. These programme budgeting data allocate exhaustively to disease categories all items of NHS expenditure, including expenditure on inpatient care, outpatient care, community care, primary care and pharmaceuticals. For 2005/06 the average size of the programmes varied considerably, with the three largest being mental health (£157 per head per year), circulation (£124) and cancer (£83).

4. The programme budgeting data offer immense opportunities for examining the link between health care expenditure and health outcomes across PCTs. There is a large international literature on this topic, but very little solid empirical evidence on the magnitude of the link. Indeed many authors claim that – at the margin – extra health care spending has little impact on health. The main reason for the lack of evidence is the difficulty of disentangling cause and effect. Areas with high health needs and poor outcomes tend to attract high levels of health care spending. For policy makers the issue is whether – *after adjusting for need* – extra spending gives rise to better health outcomes.

5. Our earlier study employed programme budgeting expenditure data for 2004/05 to model (a) outcomes as a function of need and expenditure and (b) expenditure as a function of need, total budget, and other calls on PCT expenditure. These relationships were estimated for two programmes of care: for cancer and for circulation problems. For both these programmes it proved possible to develop robust and well-specified statistical models in line with expectations. These demonstrated a strong positive link between expenditure and better health outcomes (lower mortality rate) in both disease categories, and that the link was stronger in circulation than in cancer.

6. In this study we update our earlier results for cancer and circulation problems using expenditure data for 2005/06 and, using this data set, we also apply our outcome and expenditure models to several other programmes of care. Satisfactory regression results are obtained for five further programmes (neurological, respiratory, gastro-intestinal, trauma, burns and injuries, and diabetes).

7. Using a measure of 'years of life lost' instead of a mortality rate as the measure of health outcome, it is also possible to estimate the expenditure required to 'save' one extra year of life in each disease category. We estimate that, on the basis of expenditure data for 2005/06, the marginal cost of a life year saved is:

   - £ 13,931 for cancer (£13,137 using 2004/05 expenditure data)
   - £ 8,426 for circulation problems (£ 7,979 using 2004/05 expenditure data)
   - £ 7,397 for respiratory problems
   - £ 18,999 for gastro-intestinal problems
   - £ 26,453 for diabetes.

8. It must be emphasized that these results have quite large confidence intervals, and should be treated with caution. Very importantly, they are not adjusted for quality of life. Moreover, for some categories the available mortality indicator only captures a proportion of all deaths

attributable to that category and this will tend to bias our cost estimates upwards. However, it is noteworthy that our cost estimates are not out of line with the threshold of £30,000 per quality adjusted life year often attributed to NICE for the acceptance of new therapies.

9. We also sought to develop models for three other programmes for which a relevant mortality indicator is available (infectious diseases, genito-urinary conditions, and neonate conditions). However, we were unable to obtain satisfactory results. This might be because for these budgeting categories death is a much less frequent and hence less relevant outcome measure. In addition, for genito-urinary conditions the death rate available reflects only a very small proportion of the conditions covered by the programme budgeting expenditure.

10. For some budgeting categories there is no relevant mortality indicator available and it was therefore impossible to estimate an outcome (death rate) equation. However, expenditure equations can still be estimated and satisfactory results for five further budgeting categories were obtained. 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.

11. Our results are useful from a number of perspectives. Scientifically, they confirm our previous findings that health care has an important impact on health across a range of conditions, suggesting that those results were robust across programmes of care and across years. From a policy perspective, these results can help set priorities by informing resource allocation across a larger number of programmes of care. They also add further evidence to help NICE decide whether its current QALY threshold is at the right level.

1. Introduction

A central issue in health policy concerns the extent to which additional health care expenditure yields patient benefits in the form of improved health outcomes. In a recent study we took advantage of the availability of a major new dataset to examine the relationship between health care expenditure and mortality rates for two disease categories (cancer and circulation problems) across 300 English Primary Care Trusts (Martin, Rice and Smith, 2007). This dataset presents expenditure on 23 broad programmes of care at the level of geographically defined local health authorities, 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 achieved, notably in the form of disease specific mortality rates.

Our model assumes that each Primary Care Trust (PCT) receives an annual financial lump sum budget from the national ministry and allocates its resources across the 23 programmes of care to maximize the health benefits associated with that expenditure. For each programme of care we modelled (a) expenditure as a function of the need for health care, competing calls on resources from other care programmes, and PCT income, and (b) outcomes as a function of expenditure and need. Employing programme budgeting data for financial year (FY) 2004/05 we found that, in the two programmes of care examined, such expenditure was positively associated with both income and need but negatively associated with other calls on resources, and that outcomes improved with expenditure but were adversely associated with need.

These results were encouraging. For both cancer and circulation problems it proved possible to develop robust and well-specified statistical models in line with expectations. These models demonstrated a strong positive link between more expenditure and better health outcomes (lower mortality rates). In addition, by using a measure of the 'years of life lost' rather than a mortality rate, we were also able to estimate the expenditure required to 'save' an additional year of life in each disease category. We estimated that the marginal cost of a life year saved was about £13,100 for cancer and about £8,000 for circulation problems.

Since our initial study, programme budgeting data for FY 2005/06 have been released. This study reports our findings from the application of our expenditure and outcome models to the cancer and circulation problems budgeting data for 2005/06, as well as the application of these models to four other programmes of care:

- 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 four other programmes of care for which a mortality indicator is available:

- infectious diseases (PBC 1)
- diabetes (PBC 4a)
- genito-urinary conditions (PBC 17)
- neonate conditions (PBC 19).

Apart from some limited success with diabetes, we were unable to develop satisfactory outcome equations for these other budgeting categories. This is probably because the available outcome indicator (the mortality rate) is less relevant to these care programmes than it is to the other budgeting categories where our models have enjoyed more success.

In addition, although we do not have an outcome (mortality) indicator for several categories of care we have nevertheless estimated expenditure functions and report these for five other categories:

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

The results for these budgeting categories are encouraging and demonstrate 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.

A further innovation of this study is that it draws on data collected from General Practices as part of the new Quality and Outcomes Framework (QOF). This is an evidence based quality framework within the new contract for General Medical Services introduced in the United Kingdom in April 2004. It consists of a series of indicators that represent the quality of primary care, in clinical and organizational areas, and also in additional services such as contraception and maternity services and patient experience. From these indicators it is possible to calculate prevalence rates – that is the percentage of the population registered with general practices within each PCT with a particular condition, such as cancer or circulation problems. We test these prevalence rates as indicators of the degree of programme specific need for particular care programmes.

As this report is closely related to our earlier study (Martin, Rice and Smith, 2007), it necessarily covers some of the same material, particularly the literature review and the theory underlying the outcome and expenditure equations to be estimated. The reader who is familiar with our earlier study should be able to skip these sections in this paper without any loss of continuity. However, some readers may not be familiar with our earlier study and we have therefore incorporated summary versions of some of the material presented previously so that this paper can if necessary be read without reference to our earlier work.

Section 2 provides a brief review of the literature on the relationship between health care spending and outcomes while section 3 provides some background information about programme budgeting as well as some descriptive statistics for the FY 2005/06 budgeting data. In section 4 a simple theoretical model of the budgetary problem faced by a PCT manager seeking to allocate limited funds between competing programmes of care is presented. Section 5 describes our estimation strategy. Well specified econometric models are developed in section 6 that estimate (a) the budgetary expenditure choices and (b) the health outcomes achieved by PCTs in six selected programmes of care. Consistent with our previous study, the model results show a strong positive impact of expenditure on health outcomes. In addition, the results from the outcome equation are used to construct a quantitative estimate of the marginal cost of a life year saved in five programmes of care. Section 7 presents outcome and expenditure results for four other programmes of care for which a mortality indicator is available (infectious diseases, diabetes, genito-urinary conditions, and neonate conditions), but where it proved impossible to derive a satisfactory outcome model. In section 8, we derive 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, the important policy implications of our estimates of the marginal cost of a life year saved are discussed in section 9.

2. Previous studies[1]

There is a considerable literature on the impact of health care and other related explanatory variables on some measure of health care outcome and this production function approach typically employs some form of regression analysis (Nolte and McKee, 2004). In an early cross-sectional study of 18 developed countries, Cochrane et al (1978) applied regression analysis to the statistical relationship between mortality rates on the one hand and per capita GNP and per capita consumption of inputs

[1] A very similar review of the literature was presented in our earlier report (Martin, Rice and Smith, 2007). It is repeated here for the benefit of those who are unfamiliar with our earlier study. The reader who is familiar with our earlier study should be able to skip this section without any loss of continuity.

such as health care provision on the other. They found that the indicators of health care were generally not associated with outcomes in the form of mortality rates. Thereafter, the failure to identify strong and consistent relationships between health care expenditure and health outcomes (after controlling for other factors) has become a consistent theme in the literature whilst, in contrast, socioeconomic factors are often found to be good determinants of health outcomes (Nolte and McKee, 2004, p58; 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 presence of simultaneous equation bias and the associated endogeneity problem, and the potential lag between expenditure and outcomes. To avoid the difficulties imposed by data heterogeneity inherent in international analyses, a study by Cremieux et al (1999) examined the relationship between expenditure and outcomes across ten Canadian provinces over the fifteen-year period 1978-1992. They found that lower health care spending was associated with a significant increase in infant mortality and a decrease in life expectancy.

Although challenging the received empirical wisdom, one shortcoming with the Cremieux et al (1999) study is that the estimated regression equation consists of a mixture of potentially endogenous variables (such as the number of physicians, health spending, alcohol and tobacco consumption, expenditure on meat and fat) and exogenous variables (such as income and population density). The authors' chosen estimation technique (GLS) does not allow for this endogeneity and consequently the coefficients on the endogenous variables may be biased (Gravelle and Backhouse, 1987, p428). Or's (2001) study of the determinants of variations in mortality rates across 21 OECD countries between 1970 and 1995 may suffer from the same weakness. She finds that the contribution of the number of doctors to reducing mortality in OECD countries is substantial but her estimation technique assumes that the number of doctors is exogenous to the health system.

Nixon and Ulmann (2006) have provided a detailed review of 16 studies that have examined the relationship between health care inputs and health outcomes, using macro-level data. They also undertook their own study using data for 15 EU countries over he period 1980-1995. They employed three health outcomes measures – life expectancy at birth for males and females, and the infant mortality rate – and a dozen or more 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 in-patient admission rate, alcohol and tobacco consumption, nutritional characteristics, and environmental pollution indicators. Nixon and Ulmann conclude that although health expenditure and the number of physicians have made a significant contribution to improvements in infant mortality, '...health care 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. 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 the archetypal centrally planned and publicly funded health system. Its revenue derives almost entirely from national taxation, and access to the system is generally free to the patient. Primary care is an important element of the system, and general practitioners act as gatekeepers to secondary care and pharmaceuticals. The system is organized

geographically, with the responsibility for the local administration of the NHS devolved to local health authorities known as Primary Care Trusts (PCTs). For the years relevant to this study, there were 303 PCTs with average populations of 160,000. PCTs are allocated fixed annual budgets by the national ministry, within which they are expected to meet expenditure on most aspects of health care, including inpatient, outpatient and community care, primary care and prescriptions.

3.1 The rationale behind the construction of programme budget data

Traditionally, PCTs have reported expenditure on the basis of inputs (for example, total expenditure on pay and non-pay items). However, NHS policy makers have for some time realized that this approach does not create clinically meaningful financial data or help in the design and evaluation of programmes of patient care. It therefore initiated a 'Programme Budgeting' project which has sought to create an accounting system that is more aligned with the distinct outputs and health outcomes of the health system. Since April 2003, in addition to its conventional accounting data, each PCT has prepared expenditure data disaggregated according to 23 programmes of health care. These programmes are defined by reference to the International Classification of Diseases (ICD) Version 10 codes at the four digit level, and most programme budget categories reflect ICD 10 chapter headings (e.g., cancer and tumours, circulation problems, renal problems, neonates, problems associated with the skin, vision, hearing, etc). In some cases, the 23 categories are broken down into further sub-areas to achieve a closer match with the various National Service Frameworks (NSFs): for example, the large mental health category is broken down into 'substance abuse', 'dementia', and 'other'.

Programme budgeting seeks to allocate all types of PCT expenditure to the various programme budget categories, including secondary care, community care and prescribing. However, the system acknowledges that a medical model of care may not always be appropriate, and two specific non-clinical groups - 'Healthy Individuals' and 'Social Care Needs' - have been created. These are intended to capture the costs of disease prevention programmes and the costs of services that support individuals with social rather than health care needs. In addition, it is in some cases not possible to assign activity by medical condition, preventative activity, or social care need, in which case expenditure is assigned to a category entitled 'Other'. The most important element of this programme is expenditure on general practitioner services. The use of this category ensures all expenditure can be assigned to a programme of care (DH, 2005a, p7).

The aim of the programme budget classifications is to identify the entire volume of health care resources assigned to broad areas of illness according to the primary diagnosis associated with an intervention. It serves a number of purposes, most notably to assist in the local planning of health care. But for this study its crucial merit is that it opens up the possibility of examining the statistical relationship between local programme spending and associated disease-specific outcomes.

3.2 Programme budget data for FY 2005/06: all England

Programme budgeting information was first collected for FY 2003/04, and here we report summary information for the third year of implementation, that is for FY 2005/06. The first column of Table 1 shows the national average NHS expenditure per person by programme budget category in 2005/06. Across England as a whole, NHS expenditure per person is £1,286. The single largest category is the 'other' category (programme budget category 23) with per capita expenditure of almost £168. 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 £145 per head.

There are two other categories with expenditure of over £100 per head: mental health (budget category 5) attracts an annual expenditure of £156 per person, and circulation (budget category 10) receives £123 per person. Next come seven programme budget categories – cancers and tumours (£83), gastro-intestinal problems (£81), trauma, burns and injuries (£76), musculo-skeletal problems (£74), respiratory problems (£69), genito-urinary problems (£67), and maternity and reproductive conditions (£60) – with an annual expenditure of between £60 and £83 per person. Three categories – learning disability (£45), neurological system (£41), and endocrine/metabolic (£37) – are allocated about £40 per person with the remaining ten categories spending between £6 (hearing) and £28 (eye/vision) per person.

Table 1 Expenditure by programme budget category, per person, all England, using cost adjusted expenditure by PCT, FY 2005-06

Programme budget Category	National net spend per head, £, 2005-06	PCT spend per head £, cost adjusted			
		Mean	Minimum	Maximum	CV
1 Infectious diseases	23.7	21.77	6.54	244.02	0.87
2 Cancers/tumours	82.8	84.37	37.20	139.54	0.21
3 Blood disorders	17.4	17.00	0.31	63.07	0.41
4 Endocrine/metabolic	37.0	37.56	15.17	191.69	0.31
4a Diabetes	16.8	17.26	1.41	44.23	0.30
4x Other	20.1	20.67	5.28	175.79	0.51
5 Mental health	156.9	154.35	34.22	360.54	0.29
5a Substance abuse	14.0	14.63	0.46	194.40	1.38
5b Dementia	16.3	16.61	0.24	70.67	0.80
5x Other	126.7	124.47	13.44	289.20	0.33
6 Learning disability	44.7	45.20	3.00	277.52	0.51
7 Neurological system	40.8	41.69	16.57	131.69	0.29
8 Eye and vision	28.0	28.84	12.22	57.72	0.27
9 Hearing	6.2	6.33	1.82	19.29	0.45
10 Circulation	123.6	125.59	64.82	192.52	0.19
11 Respiratory	69.2	70.43	5.56	145.10	0.25
12 Dental	23.3	24.62	1.91	92.60	0.68
13 Gastro-intestinal	80.9	82.39	39.27	132.54	0.22
14 Skin	26.6	26.97	12.58	52.95	0.25
15 Musculo-skeletal	74.2	75.72	33.75	177.99	0.25
16 Trauma/injuries	75.9	77.41	36.53	139.28	0.22
17 Genito-urinary	67.2	67.12	26.73	144.74	0.26
18 Maternity/repro	59.9	59.12	25.18	163.05	0.29
19 Neonate conditions	13.3	12.87	0.32	39.42	0.53
20 Poisoning	14.2	14.45	5.18	35.84	0.30
21 Healthy individuals	24.6	24.48	7.33	106.00	0.55
22 Social care needs	27.7	26.93	0.06	158.40	0.78
23 Other areas	168.1	168.45	78.42	378.89	0.18
23a GMS/PMS	145.5	145.89	12.39	264.73	0.14
Total expenditure	1286.2	1293.57	884.57	1871.32	0.13

NB Descriptive statistics across PCTs are unweighted and, 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. A per person spend of £1,286.2 and a population of 49,175,998 implies a total spend of £63.25 billion. Source: see the Department of Health's programme budgeting website at http://www.dh.gov.uk/PolicyAndGuidance/OrganisationPolicy/FinanceAndPlanning/ProgrammeBudgeting/fs/en

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 programme budget category. However, because input prices vary considerably across the country (for example, they are up to 30% higher in London and the south east of England than elsewhere), the raw expenditure data have been adjusted for the unavoidable geographical variation in costs by using a price index that reflects input costs in the local health economy (this is the Hospital and Community Health Services Market Forces Factor: see DH, 2005b).

For each programme budgeting category the unweighted average of the resulting 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. The final column shows the coefficient of variation. The variation in expenditure levels across PCTs in 2005/06 is considerable. For example, expenditure per head on cancers and tumours averages £84 across all PCTs but this varies between £37 and over £139 per head. Similarly, expenditure per head on circulation problems averages £126 across all PCTs but this varies between £65 and over £192 per head. Although there is considerable variation within these two particular programme budget categories, this variation is small relative to that in other programmes of care. Programme budget categories such as infectious diseases and blood disorders have much larger coefficients of variation, indicating substantially more variation than that in the cancer and circulation categories.

Moreover, comparing the expenditure statistics for FY 2005/06 with comparable ones for FY 2004/05 (see Table A1 in Appendix A) reveals little evidence of convergence in expenditure rates across PCTs: compared with 2004/05, in 2005/06 the coefficient of variation increases in 8 and decreases in 10 programmes of care for which expenditure data is available.

Some of the within programme variation in (cost adjusted) per capita expenditure observed in Table 1 will reflect different levels of the need for health care. Some areas will have a relatively large proportion of elderly residents and some will be operating in relatively deprived locations. It is to be expected that PCTs operating with relatively elderly populations and/or in more deprived locations will spend more per head than their counterparts with relatively young and/or affluent populations. The DH recognises this by adjusting per capita budgetary allocations to PCTs according to a complex 'needs' formula, derived from an econometric analysis of the link between health care expenditure and socio-economic factors at a small area level within England (DH, 2005b).

To purge expenditure levels of the impact of demographic and deprivation factors (hereafter summarised as the need for health care) as well as local variation in input prices, the expenditure per head data in Table 2 has been calculated using the Department of Health's unified weighted population for each PCT: that is, each PCT's raw population adjusted for its need for health care which incorporates age, HCHS, prescribing, GMS, HIV/AIDS and MFF adjustments and as is used for resource allocation purposes (DH, 2005b).

A comparison of Table 1 and Table 2 reveals that for most of the programme budget categories the coefficient of variation falls when per capita expenditure is calculated using the cost *and* need adjusted population rather than the cost adjusted population alone. However, this decline in the variation across PCTs is relatively small and there are still substantial differences in expenditure per head across the country even after allowing for differences in local cost and need. For example, for cancer and tumours the minimum and maximum spend per head is £37 and £139 using the cost adjusted expenditure data (from Table 1) but £38 and £145 using the cost and need adjusted population data (see Table 2). Similarly, expenditure per head in the circulation problems category varies between £65 and £192 using cost adjusted expenditure data (from Table 1) but lies between £74 and £171 using cost and need adjusted population data (see Table 2). Such variation in expenditure levels raises the issue of whether those PCTs that spend more in a particular programme of care achieve a better outcome.

3.3 Conclusion

The Department of Health's programme budgeting project has allocated all PCT expenditure to one of 23 mutually exclusive categories of illness according to the primary diagnosis associated with an intervention. This data set opens up the possibility of examining the statistical relationship between local programme spending and associated disease-specific outcomes.

Table 2 Expenditure by programme budget category, per person, all England, using cost and need adjusted expenditure data by PCT, FY 2005-06

Programme budget Category	PCT spend per head £, cost & need adjusted			
	Mean	Minimum	Maximum	CV
1 Infectious diseases	21.71	8.62	280.75	0.92
2 Cancers/tumours	84.60	38.42	145.23	0.20
3 Blood disorders	16.96	0.34	49.16	0.36
4 Endocrine/metabolic	37.63	13.70	165.96	0.26
4a Diabetes	17.23	1.90	39.50	0.26
4x Other	20.77	6.01	152.19	0.45
5 Mental health	153.40	29.63	325.30	0.26
5a Substance abuse	14.36	0.36	173.60	1.34
5b Dementia	16.86	0.22	82.48	0.82
5x Other	123.56	11.97	279.80	0.29
6 Learning disability	45.80	3.03	365.95	0.60
7 Neurological system	41.78	18.57	110.86	0.27
8 Eye and vision	28.80	13.41	52.90	0.23
9 Hearing	6.30	1.63	21.43	0.42
10 Circulation	125.10	73.88	170.83	0.14
11 Respiratory	69.82	5.80	115.26	0.17
12 Dental	23.87	2.28	94.60	0.62
13 Gastro-intestinal	81.95	47.97	118.34	0.16
14 Skin	26.93	14.09	55.73	0.21
15 Musculo-skeletal	75.73	34.85	150.59	0.21
16 Trauma	77.30	38.29	128.14	0.19
17 Genito-urinary	66.88	27.61	124.70	0.22
18 Maternity/reproductive	59.16	22.70	168.38	0.26
19 Neonate conditions	12.82	0.34	37.32	0.48
20 Poisoning	14.38	4.17	32.10	0.26
21 Healthy individuals	24.48	8.51	109.65	0.54
22 Social care needs	27.52	0.06	190.29	0.84
23 Other areas	170.10	83.57	346.62	0.20
23a GMS/PMS	147.32	14.11	264.78	0.17
All categories	1292.93	1056.19	1887.38	0.07

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

Expenditure is not spread evenly across the 23 categories but varies from just over £6 per person on hearing to just under £157 per person on mental health. There is also considerable geographical variation in expenditure levels within a given budgeting category (having controlled for local variations in input prices) and this variation is only slightly reduced by controlling for local differences in the need for health care. Clearly, for each disease category expenditure per head varies considerably geographically and this variation – holding constant input prices and the need for health care – offers the opportunity to examine whether PCTs that spend more on health care achieve a better outcome and, if so, at what cost.

The remainder of this report outlines a model of expenditure and outcomes, and estimates the strength of these relationships for various programme budgeting categories. The next section

presents a theoretical model of PCT expenditure allocation across the 23 programme budgeting categories. This is followed by details of our estimation strategy in section 5 with empirical results in sections 6, 7 and 8.

4. Theoretical model[2]

We assume that each PCT i receives an annual financial lump sum budget y_i from the national ministry, 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 in this case). 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.

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 $\boldsymbol{n_{ij}}$) and broader local environmental factors $\boldsymbol{z_{ij}}$ 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 in nature. 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 constraint and the health production functions for each programme of care:

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

It can of course quite plausibly be argued 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 the last pound spent in each programme of care is the same. This can be represented diagrammatically, as in Figure 1, which considers the trade-off between just two programmes of care. The top left hand quadrant indicates the health production function for programme 1, whilst the bottom right hand quadrant indicates the health production function for programme 2, albeit in transposed form. The bottom left hand quadrant indicates the budget constraint – the expenditure choice must lie on the budget line. This means that for each feasible pair of expenditure choices (points on the budget constraint line – a pair of health outcomes in the two programmes emerges, which is traced out as the production possibility frontier in the top right quadrant. The PCT will choose the point on this frontier that maximizes welfare. In this example, we have indicated a simple health maximizing approach (the maximum health summing across the two programmes), leading to optimal health outcomes (H_1^*, H_2^*) and expenditure (X_1^*, X_2^*).

[2] This model was first presented in our earlier report (Martin, Rice and Smith, 2007). It is repeated here for the benefit of those who are unfamiliar with our earlier study. The reader who is familiar with our earlier study should be able to skip this section without any loss of continuity.

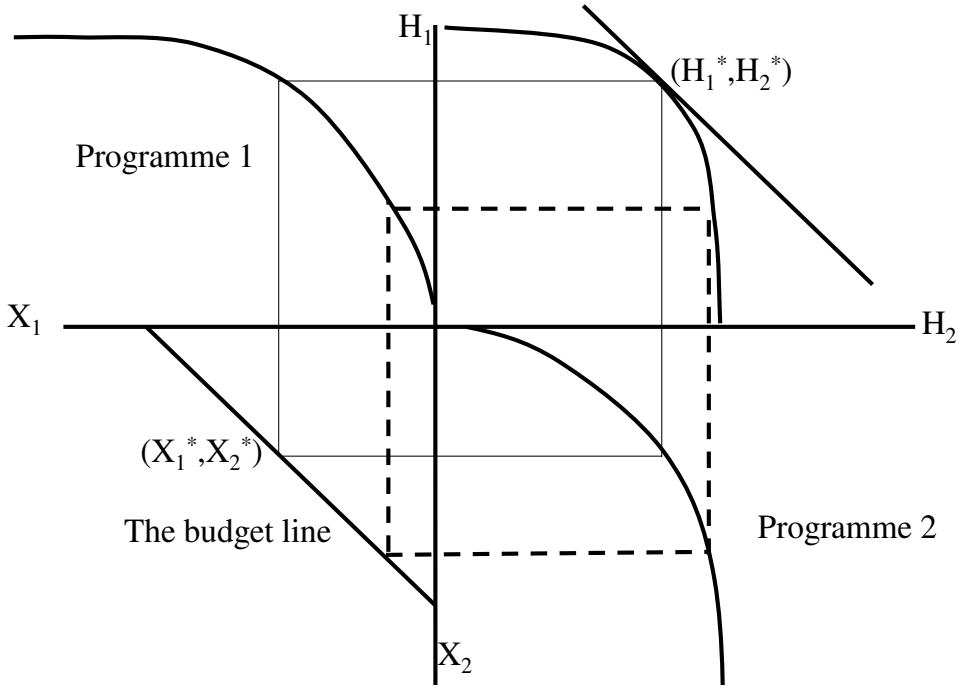

Figure 1 Optimal trade-off between two programmes of care

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 health care 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 ($y_i$). Thus

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

Thus, for each programme of care there exists an expenditure equation (3) explaining expenditure choice of PCTs and a health outcome equation (1) that models the associated health outcomes achieved. The next section describes how we estimate these equations empirically for each programmes of care.

5. Estimation strategy

The theoretical model suggests the 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, requiring variables to identify expenditure, need, environmental factors and health outcomes in each of the 23 programmes of care.

At the time of writing health outcome indicators were available for only ten disease categories. Moreover, we do not have convincing data on all the environmental factors likely to affect the production of health care. 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. We therefore proxy health care need in each programme using the 'needs' component of the resource allocation formula. The needs element of the Department of Health formula was specifically designed to adjust PCT allocations for local health care needs and accordingly, ceteris paribus, we would expect a positive relationship between expenditure x_{il} and need n_{il} 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 develop models using two alternative measures of health outcome: the disease-specific standardized mortality ratio for those aged under 75, and a measure of the avoidable years of life lost (YLL) to the disease. The latter variable is calculated by summing over ages 1 to 74 years the number of deaths at each age 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 is the second health outcome variable employed in this study (Lakhani et al., 2006, p379).

The expenditure equation to be estimated also requires a proxy for need across the other programmes of care. In our previous study – where we were modelling only two 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. As these are both programmes that attract considerable expenditure it is not implausible that expenditure in one of the programmes will impact upon expenditure in the other and, in this study, we have persevered with this approach when updating our cancer and circulation results for 2005/06.

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, co-linearity difficulties were encountered 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 leads to difficulties in interpreting the signs of the estimated coefficients. Therefore, for the other eight expenditure equations presented below we have employed either (a) the death rate from all causes amenable to health care for the under 75 year olds or (b) the SYLL rate for all deaths of those aged under 75 as the proxy for other calls on resources.

Although these proxy measures will include some 'own specialty' deaths, these will comprise a small proportion of the total. As Table 3 shows, in 2004 cancer and circulation problems accounted for over two-thirds of all deaths for those under 75 years of age and the third largest category – respiratory problems – accounted for less than one in ten of all deaths. We therefore feel that the 'all causes' mortality indices are reasonable proxies for demands on the PCT budget from other specialities.

Our estimation strategy is as follows. First we estimate equations (4) and (5) for each programme using OLS. 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.[3] 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 model. We test for endogeneity using the appropriate statistical procedure (Durbin, 1954). Under the null hypothesis of exogeneity, OLS will yield consistent parameter estimates.

[3]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 health care is exogenous as it will reflect factors, such as living conditions and lifestyle (both past and present), that our 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 an output 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, inter alia, expenditure on other care programmes. This distinction between exogenous and endogenous variables is important because it affects whether OLS or more sophisticated estimation methods should be employed. If all regressors are exogenous then OLS can be applied but the presence of an endogenous regressor requires a different estimator such as two-stage least squares. Throughout, we test for the presence of endogenous regressors and report the outcome of these statistical tests.

Table 3 Cause of death, by programme budgeting category, under 75 years, England 2004

Programme Budget Category		Death Count, aged under 75		
		Underlying Cause	Secondary Cause	Total
1	Infectious diseases	1,021	0	1,021
2	Cancers and tumours	63,696	0	63,696
3	Disorders of blood	378	0	378
4	Endocrine, nutritional, metabolic problems	2,351	0	2,351
5	Mental health disorders	2,433	0	2,433
6	Learning disability	213	0	213
7	Neurological problems	4,476	1	4,477
8	Problems of vision	5	0	5
9	Problems of hearing	15	0	15
10	Problems of circulation	48,475	0	48,475
11	Problems of the respiratory system	14,346	21	14,367
12	Dental problems	4	0	4
13	Problems of the gastro-intestinal system	10,592	1	10,593
14	Problems of the skin	351	129	480
15	Problems of the musculo-skeletal system	1,104	1	1,105
16	Problems due to trauma and injuries	0	5,809	5,809
17	Problems of genito-urinary system	1,637	0	1,637
18	Maternity and reproductive health	45	0	45
19	Conditions of neonates	341	0	341
19	Neonatal deaths	2,117	0	2,117
20	Poisoning and adverse effects	118	4,550	4,668
21	NSF Prevention programme	237	0	237
23	Other	147	0	147
U	Unclassified, without secondary cause	865	0	865
U	Unclassified, with secondary cause	10,512		
	Total	165,479	10,512	165,479

Note: The 'unclassified' category largely comprises deaths due to an external cause (such as transport accidents, falls, accidental poisoning, and self-harm.

Source: Figures compiled by NCHOD from Annual Mortality Extract from ONS (NCHOD, 2007).

If there is evidence of endogeneity of expenditure and health outcomes we implement two-stage least squares. 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 instruments should be good predictors of the endogenous variable but should not belong directly in the equation of interest.[4]

[4] We have a number of potential instruments available, mostly derived from 2001 Population Census, and these are described in Table A4 in appendix A. These indicators reflect factors, such as socio-economic deprivation and the availability of informal care in the community, that might indirectly impact upon mortality rates and/or health care expenditure levels. From this set of indicators we attempt to 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. These are, firstly, that they have face validity, that is, that they are plausible determinants of the endogenous variable being instrumented, and secondly, that the instruments are 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 ward level IMD 2000 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 one of these variables was not a valid instrument. A discussion of the choice of instruments for each pair of expenditure and outcome equations together with the first stage regression results for the models presented in section 5 can be found in Appendix B.

Should the instrument set be relevant and valid, two-stage least squares will produce consistent estimates of the parameters of the reduced form models. We subject the instrument sets to tests for validity using the Sargan (1958) test of overidentifying restrictions. In addition to the Sargan test, we test for instrument relevance using the Anderson (1984) likelihood-ratio test while the Cragg-Donald statistic provides a test for weak instruments (see Cragg-Donald, 1993 and Stock and Yogo, 2002).[5] 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).

6. Empirical results I: programmes generating satisfactory outcome and expenditure equations

In our earlier study we presented outcome and expenditure equations using expenditure data for 2004/05 for two programme budgeting categories: for cancer and for circulation problems (Martin, Rice and Smith, 2007). With the release of budgeting data for 2005/06, we can validate our models for cancer and circulation problems using this new data. Moreover, these are just two of the 23 available programme budgeting categories and an obvious extension of our earlier work is to apply our expenditure and outcome models to the other 21 categories. However, the only reliable outcome measures relate to condition-specific mortality and so we can apply our outcome model only to those programme budgeting categories where a suitable mortality indicator is available. 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 over the three-year period 2002-04 190,000 people aged under 75 died from cancer and 155,000 aged under 75 died from circulation problems), and for these conditions the coverage of the specialty-specific mortality rate data corresponds very closely to the coverage of the budgeting data.

However, for most of the remaining budgeting categories death is a much less frequent and hence 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 of conditions 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 modeling these other care programmes and less satisfactory results than those obtained for cancer and for circulation problems. However, and as the following results demonstrate, even where mortality is not perhaps the most appropriate outcome measure, it is still possible to obtain plausible results that are consistent with our model's predictions.[6] In particular, for the six care programmes – cancer, circulation problems, neurological problems, respiratory problems, gastro-intestinal problems, and trauma and injury – whose detailed results are presented below we find:

- that own specialty need and expenditure have the anticipated positive and negative effects respectively on own specialty deaths; and
- that own specialty need and PCT income boost own specialty expenditure while other calls on resources reduce own specialty expenditure.

We also find that the results for cancer and circulation problems using expenditure data for 2005/06 are very similar to those employing expenditure data for 2004/05 presented in our earlier report. Furthermore, from the results for five of the six care programmes we can estimate the marginal cost of a life year saved. For four of the care programmes this varies between £7,397 for respiratory problems and £18,999 for gastro-intestinal problems with the fifth care programme (neurological problems) generating a much higher marginal cost of a life year saved.[7] It is not possible to estimate the marginal cost of a life year saved in the sixth programme (trauma) as there are no years of life lost data available for this category. Detailed modeling results for each of these six budgeting categories follow.

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[5] In the Anderson test the null hypothesis assumes that the equation is underidentified and the Cragg-Donald statistic is based on the null that the instruments are weak.

[6] See Table A2 in Appendix A for details of the mortality rates available for use in conjunction with each care programme.

[7] The estimated marginal cost of a life year saved for neurological problems (£191,401) is not meaningful because the mortality indicator available (epilepsy deaths) captures less than 10 per cent of all deaths in this category and much expenditure will be directed towards 'caring' rather than life saving.

6.1 Cancer programme of care

We first present results for the cancer programme of care. These are provided in Table 4. Columns under (1) present ordinary least squares (OLS) results using standardized mortality rates (SMRs) as the measure of health outcome.[8] Columns under (2) present two-stage least squares using SMRs as the measure of health outcome while columns under (3) present two-stage least squares estimates using the standardized years of life lost (SYLL) rate as the outcome measure.[9] All variables have been log transformed and accordingly parameter estimates can be interpreted as elasticities.[10]

OLS results are presented as a starting point but 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 the effect is very small (the coefficient is -0.053) and is not significant at the 1% level. With regard to the expenditure equation, other calls on expenditure – as proxied here by the circulation death rate – has the anticipated negative effect on cancer expenditure. The estimated coefficient (-0.445) suggests that a 10% increase in other calls on expenditure results in a 4.45% reduction in cancer expenditure. We further observe a large and positive relationship between total PCT budget and expenditure on cancer services and this indicates that a 10% increase in budget leads to a 9.9% increase in cancer expenditure. This suggests that increases in income are distributed across programme budgets approximately in equal proportion to existing allocations. This would appear rational and provides additional face validity to the model specifications. Both the death and expenditure equations are very similar to those obtained using expenditure data for 2004/05 (Martin, Rice and Smith, 2007).

The second set of results present two-stage least squares estimates under (2).[11] These allow for the possibility that some of the explanatory variables may be endogenous. These 2SLS estimates 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 models this influence as well as the more obvious influence of expenditure on outcome. The 2SLS results under (2) indicate that a 10% increase in cancer programme expenditure results in approximately a 5% reduction in adverse health outcomes, observed through cancer deaths.

Substituting the SYLL (standardized years of life lost) rate for the standardized mortality rate (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 1% increase in cancer expenditure per head – which was £82.8 in 2005/6 – gives rise, ceteris paribus, to a 0.393% reduction in years of life lost. Across 2002-04, total life years lost to cancer deaths in those aged under 75 was 2,268,541. This averaged 756,180 life years per annum which, across the English population of roughly 50 million, averages out at 0.015 life years (5.52 days) per person. Thus a 1% increase in expenditure per head (£0.828) is associated with a 0.393% reduction in life years lost (0.0217 days) and implies that one life year would cost £13,931.[12]

[8] These SMRs are for those aged under 75 years.

[9] This SYLL rate is calculated on the basis of a 75 year life expectancy and relates to all deaths (and not just those deaths deemed amenable to health care).

[10] The number of observations in the regression equations is 295 not 303. There are 8 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.

[11] Details of the first stage regressions for the two-stage results presented in this section under (2) can be found in Appendix B.

[12] In some programmes a PCT may hold budgets and commission services for one or more neighbouring PCTs. Budgeting data is now available which adjusts expenditure data for such lead/host arrangements. The data suggest that a similar set of about 15 to 20 PCTs tend to adopt this role for many budgeting categories but the expenditure adjustments are generally very small. For example, in cancer only seven PCTs have an adjusted expenditure figure which is less than 95% of their net expenditure and another nine PCTs have an adjusted spend figure which is more than 105% of their net spend. However, there are some unexpected data values in this data set -- for example, over 98% of Dudley South PCT net expenditure on cancer is for patients in other PCTs and this PCT's expenditure net of host/lead arrangements on blood disorders is negative – and the total of host adjusted expenditure is more than £1billion more than the unadjusted total. Nevertheless, re-estimation of the results in Table 4 omitting Dudley South PCT has no material effect on the results and the coefficient on the cancer expenditure term in the cancer SYLL equation (-0.403) is almost identical to the coefficient (-0.393) reported in Table 4.

Table 4 Results for cancer programme of care, 2005-06

N = 295	OLS (1)		2SLS (2)		2SLS (3)	
	Cancer deaths	Cancer expenditure	Cancer deaths	Cancer expenditure	Cancer SYLL	Cancer expenditure
Constant	4.669 (0.062)	-0.711 (0.301)	3.546 (0.292)	-0.024 (0.509)	4.100 (0.248)	-0.019 (0.516)
Need	0.699 (0.034)	0.427 (0.206)	0.988 (0.096)	0.652 (0.233)	0.904 (0.083)	0.703 (0.248)
Cancer expenditure	-0.053 (0.024)		-0.504 (0.118)		-0.393 (0.100)	
Total Budget		0.988 (0.193)		0.935 (0.190)		0.968 (0.190)
Circulation deaths SMR		-0.445 (0.063)		-0.593 (0.109)		
Circulation SYLL						-0.576 (0.107)
Test statistics:						
Sargan (χ^2_1)			0.403 (0.525)	0.032 (0.858)	1.164 (0.280)	0.602 (0.437)
Anderson (χ^2_2)			42.01 (0.000)	213.5 (0.000)	42.01 (0.000)	176.5 (0.000)
Cragg-Donald			22.27 (<0.05)	154.0 (<0.05)	22.27 (<0.05)	118.8 (<0.05)
Partial R^2			0.132	0.515	0.132	0.450
Reset:						
F(3,289)	11.25 (0.000)					
F(3,288)		1.55 (0.200)				
Pesaran-Taylor (χ^2_1)			0.02 (0.883)	2.82 (0.093)	0.04 (0.837)	2.98 (0.084)
Endogeneity (χ^2_1):						
Cancer expenditure			55.15 (0.000)		35.63 (0.000)	
Circulation deaths				4.842 (0.027)		
Circulation SYLL						7.830 (0.005)

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 include the proportion of households that are lone pensioner household and the proportion of the population providing unpaid care.

There is clear evidence that the OLS deaths model is misspecified ($F(3,289) = 11.25;\ p = 0.000$), and it should therefore be rejected in favour of the 2SLS model which shows no evidence of misspecification (Pesaran-Taylor statistic=0.02; p=0.883). Although the OLS expenditure model is not misspecified, neither is the 2SLS model and there is evidence that the Circulation deaths term is endogenous. Further support for the 2SLS models 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. These tests indicate that the instrument set is both valid and relevant.

The measure of the need for cancer care employed here is not a condition-specific measure 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 outcome equation it is statistically insignificant but the need term remains significant. Alternatively, if the need variable is dropped and the prevalence rate is added the latter is now significant but the equation seriously fails the Sargan test (indicating an invalid instrument set). If the prevalence rate is added to the expenditure equation both it and need become insignificant, and if the need term is dropped the prevalence rate remains insignificant. Overall, the cancer prevalence term appears to offer little improvement over the use of the more general need for health care variable.

6.2 Circulation programme of care

Analogous results for circulatory diseases are shown in Table 5. In general, the estimated coefficients exhibit the same qualitative characteristics as for cancer and 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 -1.282 on circulatory expenditure in the 2SLS deaths models implies that circulatory deaths are more responsive to increases in expenditure than are cancer deaths and that a 10% increase in expenditure is associated with a 12.82% reduction in the circulation death rate.

The results for circulation problems are similar to those obtained previously using expenditure data for 2004/05 (Martin, Rice and Smith, 2007). As before an additional 'needs' variable, in the form of the percentage of the population in a 'white' ethnic group, was included in the expenditure models. On this occasion, however, there was some evidence that one of the instruments – the proportion of the population providing unpaid care – should be included as an additional regressor in the circulatory expenditure equation and, when this adjustment is made, the equation now shows no evidence of instrument misspecification.[13] [14] The positive sign on this regressor implies that either 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.

Although both the 2SLS circulation death equations show no evidence of misspecification (Pesaran-Taylor test), and the cancer deaths term is clearly endogenous, and the instruments are relevant (Anderson and Cragg-Donald tests), there is some evidence from the Sargan test that the instrument set is not wholly satisfactory (p-values of 0.003 in the SMR equation and 0.037 in the SYLL equation) but this is a rather borderline result.

[13] 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.

[14] This unpaid carers variable was statistically significant when the errors from the initial 2SLS regression were regressed on the instrument set. One implication of this is that the unpaid carers variable belongs in the 2SLS regression as a regressor and is not a valid instrument.

The results from the years of life lost 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 (-1.369) implies that a 1% increase in expenditure gives rise to a 1.369% reduction in life years lost. Across 2002-04, total life years lost to all circulation deaths in those aged under 75 was 1,607,171. This averaged 535,724 life years per annum which, across an English population of 50 million, averages out at 0.0107144 life years (3.910756 days) per person. Thus a 1% increase in expenditure per head (£1.236) is associated with a 1.369% reduction in life years lost (0.0535382 days) and implies that one life year would cost £8,427. This estimate is slightly larger than the comparable figure using 2004/05 expenditure data (£7,979).[15]

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 Quality and Outcomes Framework (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, those on the stroke and transient ischaemic attack register, and those on the hypertension register divided by the total patient list size).

If the circulation problems prevalence rate is added to the outcome equation it is statistically insignificant but need remains significant and the result is very similar to that presented in Table 5 (the coefficient on expenditure is -1.549; the Sargan statistic is 9.9 with a p-value of 0.0196; and the reset test statistic equals 2.38 with a p-value of 0.1231). Alternatively, a very poor result is obtained if the need variable is dropped and the prevalence rate is added. If the prevalence rate is added to the expenditure equation it is insignificant, and if the need term is dropped the prevalence rate becomes significant but the Sargan test indicates that the instrument set is not a valid one. 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.[16]

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 how they might be adjusted to yield quality-adjusted life years (QALYs), we have applied the utility scores made available by the HODaR project (HODaR, University Hospital of Wales) using the UK EQ-5D scoring algorithm. Quality of life scores are available for by ICD10 codes and can be assigned to the programme budget categories used here. We have therefore simply assigned scores to each of the ICD10 categories with the programme budgeting areas of cancer and circulatory diseases where these match with the HODaR categories, and averaged the scores across the categories.[17] Using this method, for cancer expenditure cost of a QALY is £20,219, whilst for circulatory diseases the corresponding figure is £12,596. We emphasize that these results are at best indicative and cannot offer an accurate calculation of a quality-adjusted life year saved, but they do suggest that the cost of a QALY from these programmes of care may be lower than many commentators have assumed.

[15] Re-estimation of the results in Table 5 using expenditure data adjusted for host/lead commissioner arrangements and omitting one PCT (Dudley South) whose reported spend data looks unusual has no material effect on the results and the coefficient on the CHD expenditure term in the CHD SYLL equation (-1.310) is very similar to the coefficient (-1.369) reported in Table 5.

[16] A second condition specific need indicator – the circulatory morbidity index from the Hospital and Community Health Services resource allocation formula – was also used in addition to and as a replacement for the generic need indicator. Again, no great improvement was forthcoming: the inclusion of both variables generated insignificant coefficients and when the generic need index was dropped the morbidity index became significant but the Sargan test suggested that the instrument set was invalid.

[17] Utility scores are available for ICD10 codes based on EQ-5D (HODaR). These are derived from a sample of 15,113 subjects accounting for more than 37,000 ICD10 observations (due to multiple diagnoses). Averaging utility scores across the ICD10 codes corresponding to the cancer programme of care (note that not all ICD10 codes corresponding to the cancer programme of care were represented in the HODaR sample) resulted in an average score of .689. The corresponding calculation for circulatory diseases is .669. Note that these are very rough estimates. To accurately calculate the cost of a quality-adjusted life year saved we would require utility scores for all of the programme budgeting ICD10 codes together with the number of patients assigned to each of these codes. We do not have full information on these. It is also noted 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.

Table 5 Results for circulation programme of care, 2005-06

N = 295	OLS (1)		2SLS (2)		2SLS (3)	
	CHD deaths	CHD expenditure	CHD deaths	CHD expenditure	CHD SYLL	CHD expenditure
Constant	3.749 (0.134)	-0.040 (0.461)	1.878 (0.314)	2.098 (0.733)	1.848 (0.323)	3.440 (1.110)
Need	1.589 (0.073)	0.241 (0.166)	2.383 (0.155)	0.693 (0.205)	2.628 (0.162)	0.884 (0.261)
CHD expenditure	-0.386 (0.063)		-1.282 (0.151)		-1.369 (0.155)	
Total Budget		0.766 (0.138)		0.705 (0.142)		0.681 (0.160)
Cancer deaths SMR		-0.192 (0.103)		-0.706 (0.173)		
Cancer SYLL						-0.953 (0.248)
% white ethnic group		0.124 (0.059)		0.180 (0.058)		0.197 (0.066)
% pop unpaid carers		0.568 (0.104)		0.415 (0.118)		0.363 (0.136)
Test statistics:						
Sargan (χ^2_1)			13.904 (0.003)	3.353 (0.067)	8.486 (0.037)	2.397 (0.121)
Anderson (χ^2_2)			109.8 (0.000)	82.64 (0.000)	109.8 (0.000)	44.70 (0.000)
Cragg-Donald			32.61 (<0.05)	46.56 (<0.05)	32.61 (<0.05)	23.56 (<0.05)
Partial R^2			0.311	0.244	0.311	0.140
Reset:						
F(3,289)	2.64 (0.049)					
F(3,286)		0.86 (0.461)				
Pesaran-Taylor (χ^2_1)			0.70 (0.403)	0.44 (0.508)	0.16 (0.686)	0.28 (0.594)
Endogeneity (χ^2_1):						
CHD expenditure			118.4 (0.000)		114.3 (0.000)	
Cancer deaths				11.653 (0.000)		
Cancer SYLL						13.844 (0.000)

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 based on ward level IMD 2000 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 index of multiple deprivation based on ward level IMD 2000 scores.
4. The term 'CHD' is used as a shorthand for 'circulation problems'.

Table 6 Results for neurological programme of care, 2005-06

N = 295	OLS (1)		2SLS (2)		2SLS (3)	
	Neurological deaths	Neurological expenditure	Neurological deaths	Neurological expenditure	Neurological SYLL	Neurological expenditure
Constant	3.793 (0.326)	-1.369 (0.484)	1.789 (1.251)	-0.643 (0.585)	-0.017 (1.647)	2.065 (1.130)
Need	1.243 (0.183)	0.296 (0.235)	1.662 (0.324)	0.497 (0.254)	1.352 (0.418)	0.773 (0.297)
Neurological expenditure	-0.231 (0.100)		-0.855 (0.389)		-0.473 (0.511)	
Total Budget		1.116 (0.224)		1.072 (0.227)		1.111 (0.243)
All amenable deaths SMR		-0.440 (0.099)		-0.588 (0.118)		
All deaths (SYLL)						-0.898 (0.182)
Test statistics:						
Sargan (χ^2_1)			1.379 (0.501)	1.708 (0.425)	0.092 (0.955)	0.711 (0.700)
Anderson (χ^2_2)			23.52 (0.000)	230.7 (0.000)	23.43 (0.000)	176.3 (0.000)
Cragg-Donald			8.03 (<0.05)	114.2 (<0.05)	7.99 (<0.05)	78.7 (<0.05)
Partial R^2			0.076	0.542	0.076	0.449
Reset:						
F(3,289)	0.38 (0.764)					
F(3,288)		2.15 (0.094)				
Pesaran-Taylor (χ^2_1)			0.36 (0.549)	0.05 (0.823)	1.16 (0.280)	0.02 (0.888)
Endogeneity (χ^2_1):						
Neurological expenditure			3.04 (0.080)		0.349 (0.554)	
All amenable deaths				2.570 (0.108)		
All deaths (SYLL)						12.250 (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 index of multiple deprivation based on ward level IMD 2000 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 index of multiple deprivation based on ward level IMD 2000 scores.
4. Neurological deaths are proxied by the all age indirect epilepsy SMR for 2002-04, and the neurological SYLL rate is proxied by the under 75 years epilepsy SYLL rate for 2002-04.

Cancer and circulation problems comprise just two of the 23 programme budgeting categories and an obvious extension of our earlier work is to apply our expenditure and outcome models to the other 21 categories. However, the only outcome measures we have are mortality rates and so we can apply our outcome model to those programme budgeting categories only where a suitable mortality rate is available. Relevant mortality rates are available for several programme budgeting categories and satisfactory regression results were obtained for four other programmes of care:

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

These are presented below. However, we were unable to obtain satisfactory outcome and expenditure results for:

- infectious diseases (PBC 1)
- diabetes (PBC 4a)
- genito-urinary conditions (PBC 17)
- neonate conditions (PBC 19)

Our lack of success with these four categories might reflect the fact that death is not a conventional outcome for these categories and/or that the specialty coverage of the mortality data (for details of this see Table A2) fails to corresponds closely enough with the coverage of the budgeting data.

6.3 Neurological programme of care

Results for the neurological programme of care with deaths caused by epilepsy as the outcome indicator are shown in Table 6. 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.[18] 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 health care and so most expenditure in this programme budgeting category is likely to be directed towards caring for the patient rather than saving life.

Nevertheless, out of curiosity we have estimated outcome and expenditure models for the neurology programme with the mortality rate for epilepsy as the outcome indicator. However, 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 very large relative to that found for other budgeting programmes where there is a better correspondence between the coverage of the expenditure and mortality data.

In the OLS deaths equation both need and expenditure are significant and have the anticipated signs. The reset test suggests no evidence of misspecification. The equivalent 2SLS result is similar to its OLS counterpart and tests indicate that the instruments are relevant and valid. However, it is not clear that expenditure is in fact endogenous. The 2SLS model with the SYLL rate as the dependent variable is similar to its SMR counterpart except that the expenditure term is now statistically insignificant.

In the cancer expenditure equation we employed the circulation death rate as a proxy for the other calls on the PCT's resources variable, and in the circulation expenditure equation we employed the cancer death rate as a proxy for the other calls on the PCT's resources variable. However, when we employed both the cancer and circulation death rates as proxies for the other calls on resources variables in the neurological expenditure equation, co-linearity difficulties were encountered with the

[18] 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).

cancer and circulation death rate variables having opposite signs. Thus for neurological expenditure (and indeed for the expenditure equation for all of the other budgeting categories considered here) we have employed either (a) the SMR from all causes amenable to health care for the under 75 year olds or (b) the SYLL rate for all deaths of those aged under 75 as the proxy for other calls on resources.[19] Although these proxy measures will include some neurological deaths they will comprise a very small proportion of the total (for example, in 2002-04 neurological deaths accounted for less than 2% of the 195,000 deaths from all causes amenable to health care in those aged under 75).

In the OLS expenditure equation need, total budget, and all deaths amenable to health care have the anticipated effect on neurological expenditure. Of these three variables only need is statistically insignificant and this might be because we only have a measure of all condition need for health care rather than a neurological condition specific measure. The reset test suggests no evidence of misspecification. The 2SLS versions of the expenditure equation are qualitatively similar to the OLS counterpart, with the coefficient on the need variable increasing so that, in the expenditure equation with other calls on resources proxied by the SYLL rate for all deaths, it is now statistically significant.

A condition-specific measure of need – the epilepsy prevalence rate – is available from data collected for the Quality and Outcomes Framework (QOF). However, as was the case for the cancer and circulation problems categories, this more condition-specific measure of need offers little improvement over the more generic all condition measure of need. In addition, the employment of another condition specific measure of need – the nervous system morbidity index from the HCHS resource allocation formula – performed no better than the more generic measure of need.

Using the results in Table 6 to estimate the marginal cost of a life year is complicated by the fact that the estimated coefficient (-0.473) on epilepsy expenditure in the 2SLS version of the SYLL rate deaths equation is not significantly different from zero and that, according to the relevant test, epilepsy expenditure is not endogenous. This implies that it would not be inappropriate to use the estimated coefficient on the same variable in the OLS version of the SYLL deaths equation but this is much smaller than its 2SLS counterpart (it is -0.231) and consequently would more than double the estimated cost of a life year saved presented in the following paragraph.

A 1% increase in neurological expenditure per head – which was £40.8 in 2005/06 - gives rise to a 0.473% reduction in life years lost to neurological problems. Across 2002-04, 67,600 life years were lost to epilepsy deaths in those aged under 75 or 22,553 life years per annum. Across an English population of 50 million, this suggests 0.00045106 life years (0.164637 days) per person. Thus a 1% increase in expenditure per head (£0.408) is associated with a 0.473% reduction in life years lost (0.0007787325 days) and this implies that one extra life year would cost £191,234.[20] This is a much larger figure than that estimated for other care programmes and, as we have noted above, probably reflects the fact that epilepsy deaths account for only a small proportion of all deaths attributable to neurological causes and that much expenditure in this budgeting category will be directed towards 'caring' rather than life saving. Of course, similar caveats will apply to our estimates of the marginal cost of a life year in other programmes but these issues are likely to be less severe elsewhere as there is a better correspondence between the specialty coverage of the available mortality indicator and the coverage of the programme budgeting data.

[19] See Table A3 in Appendix A for details of which deaths are deemed amenable to health care.

[20] Re-estimation of the results in Table 6 using expenditure data adjusted for host/lead commissioner arrangements and omitting one PCT (Dudley South) whose reported spend data looks unusual has no material effect on the results and the coefficient on the neurological expenditure term in the neurological SYLL equation (-0.496) is very similar to the coefficient (-0.473) reported in Table 6.

6.4 Respiratory problems programme of care

Results for the respiratory programme of care are shown in Table 7. For the mortality outcome indicator we employ a weighted average of the SMRs for asthma, for bronchitis, and for pneumonia with weights determined by the number of deaths attributed to each cause in 2004.[21] For the SYLL rate outcome indicator we sum the SYLL rate for each of these three causes of death. In 2004 these three causes accounted for almost 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 the OLS deaths equation both need and expenditure have the anticipated signs although expenditure is not significant. The reset test suggests misspecification. The equivalent 2SLS result is similar to its OLS counterpart but the coefficients are much larger and both are now significant.[22] The usual tests indicate that the instruments are relevant and valid, that expenditure is endogenous, and that there is no evidence of misspecification. The 2SLS result with the SYLL rate as the dependent variable is qualitatively similar to its SMR counterpart.

In the OLS expenditure equation need, total budget, and all deaths amenable to health care have the anticipated effect on respiratory expenditure. Of these three variables only the all amenable deaths term is statistically insignificant. In the comparable 2SLS result with the all amenable deaths term as the proxy for other calls on resources, all three variables are significant as is an additional variable (the percentage of households that are lone pensioner households).[23] This might be indicative of an unmet needs effect or of a selection effect. Again, the usual tests indicate that the instruments are relevant and valid, that the all amenable deaths term is endogenous, and that there is no evidence of misspecification. The 2SLS result with the SYLL rate as the proxy for other calls on resources is very similar to its SMR counterpart.

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 Quality and Outcomes Framework (QOF). 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. For example, if the asthma and COPD prevalence rates are added to the 2SLS deaths equation, both variables are statistically insignificant and expenditure is no longer significant. If the all condition need variable is also dropped, the asthma prevalence rate now has a negative significant sign, the COPD rate is insignificant, and expenditure now has a significant positive impact on deaths!

The results from the respiratory expenditure model with the SYLL rate as the dependent variable can be used in the usual way to calculate the marginal cost of one life year. The respiratory expenditure coefficient of -4.321 implies that a 1% increase in expenditure gives rise to a 4.321% reduction in life years lost. A 1% increase in respiratory expenditure per head – which was £69.2 in 2005/06 – gives rise *ceteris paribus* to a 4.321% reduction in years of life lost. Across 2002-04, total life years lost to respiratory (asthma, bronchitis and other, and pneumonia) deaths in those aged under 75 was 324,735 (or 108,245 life years per annum). Across the English population of 50 million, this suggests the loss of 0.0021649 life years (0.79 days) per person. Thus a 1% increase in expenditure per head (£0.692) is associated with a 4.321% reduction in life years lost (0.034136 days) and implies that one extra life year would cost £7,397.[24]

[21] More precisely, the respiratory SMR = ((1160/51700)*asthma SMR) + ((21662/51700)*bronchitis et al SMR) + ((28878/51700)*pneumonia SMR). See Table A2 for more details.

[22] To obtain this satisfactory result we dropped the proportion of households that are lone pensioner households from the instrument set (the Sargan test suggested that this was an invalid instrument).

[23] The Sargan test suggested that this was an invalid instrument and when this variable was added to the second stage regression it was statistically significant.

[24] Re-estimation of the results in Table 7 using expenditure data adjusted for host/lead commissioner arrangements and omitting one PCT (Dudley South) whose reported spend data looks unusual has no material effect on the results. The coefficient on the respiratory expenditure term in the respiratory SYLL equation (-3.759) is similar to the coefficient (-4.321) reported in Table 7 and the use of the former coefficient in the calculation of the cost of a life year saved would increase the estimated cost from £7,397 to £8,502.

Table 7 Results for respiratory programme of care, 2005-06

N = 295	OLS (1)		2SLS (2)		2SLS (3)	
	Respiratory deaths	Respiratory expenditure	Respiratory deaths	Respiratory Expenditure	Respiratory SYLL	Respiratory expenditure
Constant	4.545 (0.089)	-2.570 (0.338)	-1.162 (1.689)	1.517 (1.213)	-8.447 (3.087)	4.367 (1.756)
Need	0.800 (0.072)	0.629 (0.188)	3.295 (0.757)	2.396 (0.516)	6.916 (1.382)	2.226 (0.436)
Respiratory expenditure	-0.021 (0.033)		-2.152 (0.632)		-4.321 (1.156)	
Total Budget		0.850 (0.199)		0.780 (0.219)		0.849 (0.223)
All amenable deaths SMR		-0.088 (0.099)		-1.293 (0.357)		
All deaths (SYLL)						-1.366 (0.327)
%lone pensioner h-holds		-0.052 (0.120)		-0.949 (0.286)		-0.612 (0.164)
Test statistics:						
Sargan (χ^2_1)			0.141 (0.707)	1.840 (0.174)	0.031 (0.860)	0.002 (0.965)
Anderson (χ^2_2)			7.979 (0.0185)	33.789 (0.000)	7.979 (0.0185)	54.27 (0.000)
Cragg-Donald			3.99 (<0.05)	17.54 (<0.05)	3.99 (<0.05)	29.19 (<0.05)
Partial R^2			0.026	0.108	0.026	0.168
Reset: F(3,289)	10.38 (0.000)					
F(3,287)		0.58 (0.628)				
Pesaran-Taylor (χ^2_1)			0.00 (0.946)	0.99 (0.319)	0.41 (0.521)	0.58 (0.445)
Endogeneity (χ^2_1):						
Respiratory expenditure			55.78 (0.000)		84.43 (0.000)	
All amenable deaths				10.83 (0.000)		
All deaths (SYLL)						9.298 (0.002)

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 index of multiple deprivation based on ward level IMD 2000 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 index of multiple deprivation based on ward level IMD 2000 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 (all age SMR) outcome indicator is a weighted average of the asthma, bronchitis, and pneumonia SMRs (with weights reflecting the number of deaths in each category) while the SYLL rate outcome indicator is the sum of the asthma, bronchitis, and pneumonia SYLL rates.

6.5 Gastro-intestinal programme of care

Results for the gastro-intestinal programme of care are shown in Table 8. For the mortality rate outcome indicator we employ a weighted average of the SMRs for liver disease and for ulcer deaths with weights determined by the number of deaths attributed to each cause in 2004.[25] For the SYLL rate outcome indicator we sum the SYLL rate for each of these two causes of death. 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 cost estimates are likely to be over-estimates.

In the OLS deaths equation both need and expenditure have the anticipated signs and are significant. The equivalent 2SLS result is similar to its OLS counterpart but the coefficients are much larger. The usual tests indicate that the instruments are relevant and valid, that expenditure is endogenous, and that there is no evidence of misspecification. The 2SLS result with the SYLL rate as the dependent variable is very similar to its SMR counterpart except that the coefficients are larger still.

In the OLS expenditure equation need, total budget, and all deaths amenable to health care all have the anticipated effect on expenditure and are statistically significant. In the comparable 2SLS result all three variables are 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 no evidence of misspecification. The 2SLS result with the all deaths SYLL rate as the proxy for other calls on resources is similar to its SMR counterpart.

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 -2.018 implies that a 1% increase in expenditure gives rise to a 2.018% reduction in life years lost. A 1% increase in gastro-intestinal expenditure per head – which was £80.9 in 2005/06 – gives rise *ceteris paribus* to a 2.018% reduction in years of life lost. Across 2002-04, total life years lost to respiratory deaths in those aged under 75 was 316,506 (or 105,502 life years per annum). Across the English population of 50 million, this suggests 0.00211 life years (0.77 days) per person. Thus a 1% increase in expenditure per head (£0.809) is associated with a 2.018% reduction in life years lost (0.0155 days) and implies that one extra life year would cost £19,000. However, this is likely to be an over-estimate because liver disease and ulcers accounted for less than 40 per cent of deaths attributable to the gastro-intestinal care programme.[26]

6.6 Trauma, burns and injuries programme of care

Results for the trauma, burns and injuries programme of care are shown in Table 9. For the mortality rate outcome indicator we employ a weighted average of the SMRs for deaths from a fractured femur and from a skull fracture with weights determined by the number of deaths attributed to each cause in 2004.[27] No SYLL rate data is 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 programme budgeting category (NCHOD, 2007).

[25] More precisely, the gastro-intestinal SMR = ((5438/8754)*liver disease SMR) + ((3316/8574)*ulcers SMR). See Table A2 for more details.

[26] Re-estimation of the results in Table 8 using expenditure data adjusted for host/lead commissioner arrangements and omitting one PCT (Dudley South) whose reported spend data looks unusual has no material effect on the results. The coefficient on the gastro-intestinal expenditure term in the gastro-intestinal SYLL equation (-1.847) is similar to the coefficient (-2.018) reported in Table 8 and the use of the former coefficient in the calculation of the cost of a life year saved would increase the estimated cost from £7,397 to £8,502.

[27] More precisely, the trauma, burns and injuries SMR = ((2517/7814)*fractured femur SMR) + ((5297/7814)*skull fracture SMR). See Table A2 for more details. These are deaths where the primary cause is 'unclassified' according to the programme budgeting project (that is, there is an external cause for the death) but the secondary cause is recorded as a fractured femur or a fractured skull.

Table 8 Results for gastro-intestinal programme of care, 2005-06

N = 295	OLS (1)		2SLS (2)		2SLS (3)	
	Gastro deaths	Gastro expenditure	Gastro deaths	Gastro expenditure	Gastro SYLL	Gastro expenditure
Constant	3.982 (0.200)	-1.438 (0.329)	1.043 (0.604)	-0.815 (0.488)	-2.051 (0.915)	1.240 (0.929)
Need	1.418 (0.114)	0.710 (0.155)	2.621 (0.276)	0.882 (0.186)	4.254 (0.411)	1.115 (0.230)
Gastro expenditure	-0.235 (0.079)		-1.404 (0.240)		-2.018 (0.364)	
Total Budget		0.790 (0.153)		0.752 (0.152)		0.772 (0.166)
All amenable deaths SMR		-0.264 (0.066)		-0.391 (0.098)		
All deaths (SYLL)						-0.639 (0.148)
Test statistics:						
Sargan (χ^2_1)			3.531 (0.171)	4.760 (0.0291)	2.406 (0.300)	2.577 (0.108)
Anderson (χ^2_2)			56.09 (0.0000)	230.0 (0.000)	56.09 (0.0000)	158.8 (0.000)
Cragg-Donald			20.2 (<0.05)	171.3 (<0.05)	20.2 (<0.05)	103.4 (<0.05)
Partial R^2			0.173	0.541	0.173	0.416
Reset:						
F(3,289)	2.67 (0.0478)					
F(3,288)		1.51 (0.213)				
Pesaran-Taylor (χ^2_1)			3.14 (0.076)	0.02 (0.901)	2.47 (0.115)	1.17 (0.279)
Endogeneity (χ^2_1):						
Gastro expenditure			42.57 (0.000)		41.92 (0.000)	
All amenable deaths				4.396 (0.036)		
All deaths (SYLL)						8.089 (0.004)

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 index of multiple deprivation based on ward level IMD 2000 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 index of multiple deprivation based on ward level IMD 2000 scores.
4. The deaths (all age SMR) outcome indicator is a weighted average of the liver disease and ulcer SMRs with weights reflecting the number of deaths in each category while the SYLL rate outcome indicator is the sum of the liver disease and ulcer SYLL rates.

Table 9 Results for trauma, burns and injuries programme of care, 2005-06

N = 295	OLS (1)		2SLS (2)		2SLS (3)	
	Trauma deaths	Trauma expenditure	Trauma deaths	Trauma expenditure	Trauma SYLL	Trauma expenditure
Constant	0.509 (0.509)	-1.101 (0.354)	0.689 (1.461)	-0.092 (0.564)		1.796 (1.086)
Need	1.171 (0.240)	0.650 (0.161)	1.588 (0.444)	0.929 (0.199)		1.063 (0.245)
Trauma expenditure	-0.362 (0.153)		-1.331 (0.469)			
Total Budget		0.750 (0.156)		0.689 (0.156)		0.741 (0.160)
All amenable deaths SMR		-0.345 (0.072)		-0.552 (0.115)		
All deaths (SYLL)						-0.738 (0.175)
% pop unpaid carers			1.163 (0.392)			
Test statistics:						
Sargan (χ^2_1)			1.656 (0.198)	3.639 (0.1621)		8.290 (0.0158)
Anderson (χ^2_2)			35.15 (0.0000)	230.7 (0.000)		176.3 (0.000)
Cragg-Donald			18.3 (<0.05)	114.2 (<0.05)		78.7 (<0.05)
Partial R^2			0.112	0.542		0.449
Reset: F(3,289)	2.77 (0.0422)					
F(3,288)		0.77 (0.5096)				
Pesaran-Taylor (χ^2_1)			0.65 (0.420)	0.30 (0.581)		0.49 (0.483)
Endogeneity (χ^2_1):						
Trauma expenditure			4.421 (0.035)			
All amenable deaths				8.153 (0.004)		
All deaths (SYLL)						10.73 (0.001)

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 index of multiple deprivation based on ward level IMD 2000 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 index of multiple deprivation based on ward level IMD 2000 scores.
4. Similar results are available without the population weighted index of multiple deprivation based on ward level IMD 2000 scores in the instrument set.
5. The deaths (SMR) outcome indicator is a weighted average of the fractured femur and skull fracture SMRs with weights reflecting the number of deaths in each category. No SYLL based mortality rates are available for these deaths.

In the OLS deaths equation both need and expenditure have the anticipated signs and are significant. The equivalent 2SLS result is similar to its OLS counterpart but the coefficients are much larger. In addition it was necessary to add the proportion of the population providing unpaid care as an additional regressor. Initially this variable was included in the instrument set but the Sargan test revealed that this variable was not a valid instrument. It has a significant positive sign in the outcome equation and the implication is that, ceteris paribus, areas with more unpaid carers have higher mortality rates from fractures. This might be because the availability of care allows the elderly to continue to live in their own home and that they are more likely to fall and die from a fall at home than they are in alternative accommodation (such as a residential home or sheltered housing). The usual statistical tests indicate that the remaining instruments are relevant and valid, that expenditure is endogenous, and that there is no evidence of misspecification. There is no expenditure equation with the SYLL rate as the dependent variable as no SYLL rate is available and so no estimate of the marginal cost of an extra life year can be made.

In the OLS expenditure equation need, total budget, and deaths amenable to health care all have the anticipated effect on expenditure and are statistically significant. In the comparable 2SLS result all three variables are also 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 no evidence of misspecification. The 2SLS result with the all deaths SYLL rate as the proxy for other calls on resources is similar to its SMR counterpart.

7. Empirical results II: programmes generating less satisfactory outcome and expenditure models

In addition to the six programmes of care discussed in section 6, we also estimated outcome and expenditure equations for the four other programmes for which a relevant mortality indicator is available. Generally, we met with less success for these budgeting categories although we were able to obtain plausible results for one or two equations. To illustrate the difficulties encountered, below we present some of the 2SLS results obtained for these budgeting categories.

7.1 Infectious diseases programme of care

2SLS results for the infectious diseases programme of care are shown in Table 10. The HIV/AIDS weighted population is included as an additional needs variable in both the outcome and expenditure equations.[28] The two outcome equations are disappointing: in both the all age SMR and the under 75 SYLL rate equations, expenditure on infectious diseases has the 'wrong' sign and is significant (and the HIV/AIDS population has the 'wrong' sign but is not significant). The two expenditure equations are more plausible. Expenditure on infectious diseases is positively related to PCT total income, and the HIV/AIDS population has a positive impact on expenditure. The usual need variable is also significant but has a negative sign and the other deaths variable also has the 'wrong' sign.

We can suggest two reasons why we have found it difficult to identify plausible expenditure and outcome models for this budgeting category. Most importantly, there are relatively few deaths in this category: in 2004 just over 1,000 people aged under 75 died from an infectious disease (see Table 3) and this averages about 4 deaths per PCT per year. Second, deaths in this category may comprise causes that are positively associated with age and deprivation as well as those (such as for HIV/AIDS) where this association is less clear cut, making the identification of the usual expenditure and outcome relationships more difficult.

[28] This variable incorporates elements for the treatment, care, and prevention of the spread of HIV/AIDS and is employed by the Department of Health in its resource allocation formula. This factor is one (very small) component in the all condition needs index so that any induced co-linearity between the HIV/AIDS specific variable and the all condition needs index will be negligible.

Table 10 Results for infectious diseases programme of care, 2005-06

N = 295	2SLS (1)		2SLS (2)	
	Infectious deaths	Infectious expenditure	Infectious SYLL	Infectious Expenditure
Constant	11.312 (3.462)	-9.943 (1.053)	9.160 (5.154)	-14.07 (2.234)
Need	-0.573 (0.565)	-1.194 (0.452)	-0.169 (0.843)	-1.741 (0.611)
Infectious expenditure	1.278 (0.533)		1.655 (0.785)	
Total Budget		1.778 (0.419)		1.779 (0.443)
All amenable deaths SMR		0.679 (0.220)		
All deaths (SYLL)				1.219 (0.365)
HIV/AIDS population	-0.154 (0.124)	0.202 (0.029)	-0.077 (0.188)	0.190 (0.029)
Test statistics:				
Sargan (χ^2_1)	3.164 (0.205)	3.475 (0.176)	0.378 (0.827)	0.568 (0.752)
Anderson (χ^2_2)	10.342 (0.015)	183.0 (0.000)	10.342 (0.015)	124.1 (0.000)
Cragg-Donald	3.4 (<0.05)	82.5 (<0.05)	3.4 (<0.05)	50.2 (<0.05)
Partial R^2	0.034	0.462	0.173	0.343
Reset:				
F(3,289)				
F(3,288)				
Pesaran-Taylor (χ^2_1)	13.63 (0.000)	6.01 (0.014)	7.28 (0.007)	1.89 (0.169)
Endogeneity (χ^2_1):				
Infectious expenditure	16.56 (0.000)		9.93 (0.001)	
All amenable deaths		16.96 (0.000)		
All deaths (SYLL)				25.79 (0.000)

Notes:
1. Parentheses show robust standard errors for parameter estimates and p-values for the test statistics.
2. The instrument set for infectious expenditure includes 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 ward level IMD 2000 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 index of multiple deprivation based on ward level IMD 2000 scores.
4. The infectious deaths (all age SMR and under 75 years SYLL rate) outcome indicators have an identical ICD 10 coverage to the programme budgeting expenditure data.
5. Re-estimation of these results using expenditure data adjusted for host/lead commissioner arrangements and omitting one PCT (Dudley South) whose reported spend data looks unusual has no material effect on the results.

7.2 Diabetes programme of care

2SLS results for the diabetes programme of care are shown in Table 11. We found that the diabetes prevalence rate (based on data collected from General Practices as part of the new Quality and Outcomes Framework (QOF)) performed better than the all specialty need variable so the latter was dropped in favour of the former. The index of multiple deprivation was also useful as an additional regressor in one of the expenditure equations.[29]

The first outcome equation (with the diabetes SMR rate as the outcome measure) is relatively uninformative with all three regressors being insignificant. The second outcome equation (with the SYLL rate as the outcome measure) is more promising as expenditure has the anticipated negative effect on the mortality rate and both the prevalence rate and the index of multiple deprivation are positively associated with the death rate. There is some evidence of mis-specification (the Sargan

[29]For example, if the all condition need variable is used instead of the diabetes prevalence rate in the years of life lost outcome equation, neither expenditure nor need have a significant impact on the years of life lost.

Table 11 Results for diabetes programme of care, 2005-06

N = 290	2SLS (1)		2SLS (2)	
	Diabetes deaths	Diabetes expenditure	Diabetes SYLL	Diabetes expenditure
Constant	5.243 (0.947)	-2.995 (1.076)	-3.133 (2.611)	-2.699 (1.412)
Need				
Diabetes expenditure	-0.053 (0.251)		-1.427 (0.759)	
Total budget		0.652 (0.266)		0.696 (0.291)
All amenable deaths SMR		0.053 (0.159)		
All deaths (SYLL)				0.002 (0.189)
Diabetes prevalence rate	0.234 (0.176)	0.448 (0.133)	0.923 (0.412)	0.467 (0.127)
IMD2000	-0.027 (0.050)		0.595 (0.123)	
Test statistics:				
Sargan (χ^2_1)	0.732 (0.392)	8.032 (0.045)	0.377 (0.539)	8.18 (0.042)
Anderson (χ^2_2)	11.991 (0.002)	326.8 (0.000)	10.587 (0.005)	325.0 (0.000)
Cragg-Donald	6.02 (<0.05)	147.3 (<0.05)	5.30 (<0.05)	145.9 (<0.05)
Partial R^2	0.041	0.674	0.035	0.672
Reset:				
F(3,289)				
F(3,288)				
Pesaran-Taylor (χ^2_1)	0.07 (0.785)	0.00 (0.962)	12.30 (0.001)	0.02 (0.900)
Endogeneity (χ^2_1):				
Diabetes expenditure	0.23 (0.630)		7.16 (0.007)	
All amenable deaths		0.07 (0.786)		
All deaths (SYLL)				0.09 (0.760)

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 index of multiple deprivation based on ward level IMD 2000 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 index of multiple deprivation based on ward level IMD 2000 scores, and the all specialty needs index (not included as a regressor in the second-stage equations).
4. The diabetes death measure is the all age SMR for 2002-04 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. The sample size for the diabetes deaths equation is 284.

statistic=12.3, p=0.0005) but the coefficient on the diabetes expenditure variable (-1.427) can be employed to estimate the marginal cost of an additional life year saved in this budgeting category. A 1% increase in expenditure would cost £0.168 per person and this would generate a 1.427% reduction in life years lost. The total number of life years lost to diabetes for those aged under 75 in England over the three year period from 2002 to 2004 totaled 66,757 life years. Assuming an English population of 50 million the increased expenditure would therefore save (0.01427*66,757)/(3*50,000,000) life years which generates a marginal cost of £26,453 for one additional life year.[30] This figure is slightly larger than that found for the marginal cost of one additional life year for cancer (£13,931), for circulation problems (£8,426), for respiratory problems (£7,397), and for gastro-intestinal problems (£18,999). 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.

[30] Re-estimation of the results in Table 11 using expenditure data adjusted for host/lead commissioner arrangements and omitting one PCT (Dudley South) whose reported spend data looks unusual has no material effect on the results. The coefficient on the diabetes expenditure term in the diabetes SYLL equation (-1.384) is similar to the coefficient (-1.427) reported in Table 11.

The two expenditure equations are reasonably satisfactory: in both cases the PCT income term and the diabetes prevalence rate are both significant and are positively associated with expenditure. Although positive the 'other calls on resources term' is insignificant in both equations and there is no evidence of mis-specification.

The endogeneity test suggests that the 'other calls on PCT resources' term is not endogenous but OLS estimation of the two expenditure equations generated results that are no better than those presented in Table 11.

Table 12 Results for genito-urinary programme of care, 2005-06

N = 295	2SLS (1)		2SLS (2)	
	Genito-urinary deaths	Genito-urinary expenditure	Genito-urinary SYLL	Genito-urinary expenditure
Constant	1.920 (1.460)	-3.935 (0.584)	1.502 (3.507)	-5.493 (1.153)
Need	1.569 (0.477)	-0.162 (0.247)	0.471 (1.260)	-0.381 (0.290)
Genito-urinary expenditure	-0.146 (0.508)		2.127 (1.309)	
Total budget		1.111 (0.217)		1.115 (0.216)
All amenable deaths SMR		0.192 (0.119)		
All deaths (SYLL)				0.401 (0.185)
% lone pensioner h-holds	-1.141 (0.185)		-1.961 (0.547)	
Test statistics:				
Sargan (χ^2_1)	3.459 (0.062)	7.767 (0.020)	0.228 (0.633)	5.213 (0.073)
Anderson (χ^2_2)	14.858 (0.000)	230.75 (0.000)	14.881 (0.000)	176.32 (0.000)
Cragg-Donald	7.49 (<0.05)	114.2 (<0.05)	7.51 (<0.05)	78.7 (<0.05)
Partial R^2	0.049	0.542	0.054	0.449
Reset:				
F(3,289)				
F(3,288)				
Pesaran-Taylor (χ^2_1)	0.02 (0.901)	5.39 (0.020)	0.96 (0.327)	4.07 (0.043)
Endogeneity (χ^2_1):				
Genito-urinary expenditure	0.15 (0.691)		3.042 (0.081)	
All amenable deaths		0.011 (0.914)		
All deaths (SYLL)				4.95 (0.026)

Notes:
1. Parentheses show robust standard errors for parameter estimates and p-values for the test statistics.
2. The instrument set for genito-urinary expenditure the proportion of the population providing unpaid care and the population weighted index of multiple deprivation based on ward level IMD 2000 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 index of multiple deprivation based on ward level IMD 2000 scores.
4. The genito-urinary death measure is the all age SMR for 2002-04 for chronic renal failure and the SYLL rate is for those aged under 75 over the same three year period (again for chronic renal failure). The expenditure (A50-A64, N00-N99, Q500-Q649, R30-R39, R86-R87) and outcome (N18) data have very different ICD 10 coverage.
5. The sample size for the SYLL outcome equation is 267 because the SYLL rate for 28 PCTs is zero and the logarithm of zero is undefined. The smallest (defined) value of the logged SYLL rate is -2.3. If we replace the 28 undefined values with, say, -5.0, there is no material improvement in the result. In particular, the coefficient on expenditure is still positive and insignificant.
6. Re-estimation of these results using expenditure data adjusted for host/lead commissioner arrangements and omitting one PCT (Dudley South) whose reported spend data looks unusual has no material effect on the results.

7.3 Genito-urinary programme of care

2SLS results for the genito-urinary programme of care are shown in Table 12. These are poor with 'incorrect' signs on coefficients in both the expenditure and outcome equations. This lack of success is perhaps not particularly 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 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 2002-04, there were on average 1,406 deaths per year which is less than 5 deaths per PCT per annum.

Table 13 Results for neonate programme of care, 2005-06

N = 294	2SLS (1: neonate expenditure)		2SLS (2: neonate and maternity spend)	
	Neonate deaths	Neonate expenditure	Neonate Deaths	Neonate and maternity expenditure
Constant	1.626 (0.497)	-13.94 (2.573)	0.228 (1.355)	-10.39 (0.988)
Need		-2.172 (0.804)		-1.507 (0.304)
Neonate expenditure	-0.235 (0.127)		-1.500 (0.947)	
Total budget		1.348 (0.668)		0.887 (0.252)
All amenable deaths SMR		1.888 (0.523)		1.557 (0.200)
All deaths (SYLL)				
Low birth weight	0.917 (0.236)	0.154 (0.416)	1.256 (0.405)	-0.213 (0.171)
Lone parent households	0.548 (0.125)		1.096 (0.453)	
Test statistics:				
Sargan (χ^2_1)	5.75 (0.124)	4.103 (0.128)	3.298 (0.347)	0.04 (0.978)
Anderson (χ^2_2)	22.49 (0.000)	134.51 (0.000)	4.931 (0.294)	134.5 (0.000)
Cragg-Donald	5.70 (<0.05)	55.5 (<0.05)	1.21 (>0.05)	55.5 (<0.05)
Partial R^2	0.073	0.367	0.016	0.367
Reset:				
F(3,289)				
F(3,288)				
Pesaran-Taylor (χ^2_1)	1.31 (0.252)	0.25 (0.619)	0.40 (0.526)	0.04 (0.843)
Endogeneity (χ^2_1):				
Neonate expenditure	3.88 (0.048)		4.412 (0.035)	
All amenable deaths		3.854 (0.049)		
All deaths (SYLL)				26.02 (0.000)

Notes:
1. Parentheses show robust standard errors for parameter estimates and p-values for the test statistics.
2. The instrument set for neonate expenditure includes the proportion of those aged 16-74 without any qualifications, the proportion of those aged 16-74 that are long-term unemployed, the proportion of households that are rented from the local authority/housing association, and all condition needs index.
3. The instrument sets for all amenable deaths (SMR) includes 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 ward level IMD 2000 scores.
4. The neonate outcome measure is the infant mortality rate per 1,000 live births, aged under 28 days, over the three year period 2003-05.
5. Re-estimation of these results using expenditure data adjusted for host/lead commissioner arrangements and omitting one PCT (Dudley South) whose reported spend data looks unusual has no material effect on the results.

7.4 Neonate programme of care

2SLS results for the neonate programme of care are shown in the first two columns of Table 13. The outcome measure is the infant (aged under 28 days) mortality rate per 1,000 live births. The outcome equation generated more satisfactory results when the all condition need variable was replaced with the proportion of households that are lone parent households with dependent children. The estimated equation is plausible with positive and significant coefficients on the low birth weight and lone parent

household regressors (the former is a specialty specific needs measure drawn from the Department of Health's resource allocation formula).[31]

The negative coefficient on expenditure is significant at the 10% level. The expenditure equation, however, is less satisfactory. There are significant positive coefficients on PCT income and low birth weight but a negative coefficient on need and a positive coefficient on the 'other calls on resources' variable.[32]

As there might be some difficulty separating maternity and neonate expenditure, we also estimated outcome and expenditure equations replacing neonate expenditure with neonate and maternity expenditure combined. These are shown in the final two columns of Table 13. The outcome equation is reasonable and similar to that obtained with neonate expenditure alone but the neonate and maternity expenditure combined equation is poor with several 'incorrect' signs on the estimated coefficients.

In the absence of further data, we are unable to offer a persuasive explanation for why the expenditure models associated with perinatal care are weak. They indicate that the forces that drive budgetary choices in other specialties – population needs and competition from other specialties – do not appear to apply in maternity and neonatal services. This finding merits further analysis by those with more detailed data and expertise in this specialty.

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

For some budgeting categories no relevant mortality indicator is available and thus it is impossible to estimate an outcome (death rate) equation. However, expenditure equations can still be estimated and these are presented below for the five budgeting categories for which plausible results are obtainable.[33] 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.

8.1 Endocrine/metabolic programme of care

OLS and comparable 2SLS expenditure equations for the endocrine/metabolic programme of care (PBC 4) are shown in Table 14.[34] In the OLS expenditure equations only need and total budget have the anticipated effect on expenditure and are statistically significant. The impact of the proxy for other calls on PCT resources is negative as expected but is statistically insignificant. The 2SLS results are similar but tests indicate that the other calls on resources variable is not endogenous and this, combined with the acceptable reset test for the OLS models suggests that these should be preferred to their 2SLS counterparts.

Two condition-specific measures of need – the diabetes prevalence rate and the hypothyroidism prevalence rate – are available from data collected for the Quality and Outcomes Framework (QOF). If these are included as regressors as well as the all condition need indicator only the diabetes prevalence rate is significant. Dropping the insignificant need and hypothyroidism prevalence rate generates results which are qualitatively similar to those in Table 14 but the coefficients are larger and standard errors smaller.

[31] We also employed an alternative outcome measure – the infant (aged under 365 days) mortality rate per 1,000 live births – but this did not generate better results than the under 28 day mortality rate.

[32] Thinking that there might be colinearity problems with the inclusion of both the need and low birth weight variables, we re-estimated the equation without the need variable but not one of three remaining regressors was significant and with the 'correct' sign.

[33] 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. The 2SLS version of the standard expenditure equation for each of these budgeting categories is shown in Appendix C.

[34] This programme includes diabetes. Results for diabetes alone can be found in section 7.2.

Table 14 Results for endocrine/metabolic expenditure function, 2005-06

N = 295	Endocrine/metabolic expenditure (PBC 4)		Endocrine/metabolic expenditure (PBC 4)	
	OLS	OLS	2SLS	2SLS
Constant	-3.394 (0.426)	-2.434 (0.669)	-3.243 (0.767)	-2.770 (1.480)
Need	0.387 (0.196)	0.569 (0.215)	0.429 (0.277)	0.505 (0.339)
Total Budget	0.447 (0.171)	0.424 (0.171)	0.438 (0.177)	0.433 (0.174)
All amenable deaths (SMR)	-0.004 (0.086)		-0.035 (0.155)	
All deaths (SYLL)		-0.157 (0.106)		-0.103 (0.237)
Test statistics:				
Sargan (χ^2_1)			5.051 (0.024)	4.839 (0.027)
Anderson (χ^2_2)			230.0 (0.000)	158.8 (0.000)
Cragg-Donald			171.3 (<0.05)	103.4 (<0.05)
Partial R^2			0.541	0.416
Reset: F(3,288)	0.68 (0.566)	0.77 (0.514)		
Pesaran-Taylor (χ^2_1)			0.87 (0.351)	2.75 (0.097)
Endogeneity (χ^2_1):				
All amenable deaths (SMR)			0.152 (0.695)	
All deaths (SYLL)				0.155 (0.693)

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 index of multiple deprivation based on ward level IMD 2000 scores.
3. Re-estimation of these results using expenditure data adjusted for host/lead commissioner arrangements and omitting one PCT (Dudley South) whose reported spend data looks unusual has no material effect on the results.

Table 15 Results for eye and vision expenditure, 2005-06

N = 295	Eye and vision expenditure (PBC 8)		Eye and vision expenditure (PBC 8)	
	OLS	OLS	2SLS	2SLS
Constant	-2.083 (0.561)	-1.914 (0.944)	-1.691 (0.745)	-0.003 (1.457)
Need	1.144 (0.257)	1.048 (0.287)	1.252 (0.298)	1.414 (0.363)
Total Budget	0.011 (0.238)	0.062 (0.242)	-0.012 (0.241)	0.015 (0.245)
All amenable deaths (SMR)	-0.310 (0.113)		-0.390 (0.150)	
All deaths (SYLL)		-0.271 (0.150)		-0.578 (0.233)
Test statistics:				
Sargan (χ^2_1)			0.571 (0.449)	1.140 (0.028)
Anderson (χ^2_2)			230.0 (0.000)	158.8 (0.000)
Cragg-Donald			171.3 (<0.05)	103.4 (<0.05)
Partial R^2			0.541	0.416
Reset: F(3,288)	1.15 (0.330)	1.00 (0.392)		
Pesaran-Taylor (χ^2_1)			0.26 (0.608)	0.39 (0.530)
Endogeneity (χ^2_1):				
All amenable deaths (SMR)			0.676 (0.410)	
All deaths (SYLL)				3.219 (0.072)

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 index of multiple deprivation based on ward level IMD 2000 scores.

8.2 Eye/vision programme of care

OLS and comparable 2SLS expenditure equations for the eye/vision programme of care are shown in Table 15. In the OLS expenditure equations both need and one of the proxies for other calls on resources have the anticipated effect on expenditure and are statistically significant. The coefficient on the total budget variable is very small and is not statistically different from zero. Similar results occur if expenditure is adjusted for lead/host commissioner arrangements but now the coefficient on the total budget term increases to about 0.50 but remains statistically insignificant. This is plausible, as eye/vision net expenditure increased by 1.8% in 2005/06 while total all programme net expenditure increased by 8.7% so the income elasticity for expenditure in this category may well be small.

8.3 Musculo-skeletal programme of care

OLS and comparable 2SLS expenditure equations for the musculo-skeletal programme of care are shown in Table 16. In the OLS expenditure equations 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 2SLS results are qualitatively similar to their OLS counterparts and, as the proxies for the other calls on resources variables are endogenous, the 2SLS results are to be preferred to their OLS counterparts.[35]

Table 16 Results for musculo-skeletal expenditure, 2005-06

N = 295	Musculo-skeletal expenditure (PBC 15)		Musculo-skeletal expenditure (PBC 15)	
	OLS	OLS	2SLS	2SLS
Constant	-0.884 (0.463)	-0.006 (0.760)	0.312 (0.672)	3.492 (1.354)
Need	0.903 (0.240)	0.916 (0.256)	1.233 (0.272)	1.586 (0.349)
Total Budget	0.363 (0.234)	0.408 (0.245)	0.290 (0.227)	0.323 (0.251)
All amenable deaths (SMR)	-0.375 (0.093)		-0.620 (0.137)	
All deaths (SYLL)		-0.436 (0.121)		-0.999 (0.217)
Test statistics:				
Sargan (χ^2_1)			3.929 (0.0475)	1.738 (0.187)
Anderson (χ^2_2)			230.0 (0.000)	158.8 (0.000)
Cragg-Donald			171.3 (<0.05)	103.4 (<0.05)
Partial R^2			0.541	0.416
Reset:				
F(3,288)	1.03 (0.380)	1.14 (0.333)		
Pesaran-Taylor (χ^2_1)			0.18 (0.6734)	0.11 (0.739)
Endogeneity (χ^2_1):				
All amenable deaths (SMR)			8.549 (0.003)	
All deaths (SYLL)				14.625 (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 index of multiple deprivation based on ward level IMD 2000 scores.

The 2SLS results can be improved through the use of a condition-specific measure of the need for musculo-skeletal health care. This is the musculo-skeletal morbidity index from the HCHS resource allocation formula and the replacement of the generic all condition need index with this condition-specific indicator increases the size of all three coefficients so that now the total budget term is

[35] Similar results are generated if expenditure is adjusted for lead/host commissioner arrangements but now the total budget term is statistically significant.

significant with a coefficient of 0.461 and a robust standard error of 0.175 (the coefficient on the musculo-skeletal morbidity term is 1.900 (with a robust standard error of 0.372) and the coefficient on the all amenable deaths term is -0.726 (with a robust standard error of 0.142)).

8.4 Poisoning programme of care

OLS and comparable 2SLS expenditure equations for the poisoning programme of care are shown in Table 17. In the OLS expenditure equations all three regressors – need, total budget, and the proxies for other calls on resources – have the anticipated effect on expenditure and are statistically significant. The 2SLS results are qualitatively similar to their OLS counterparts. The usual tests indicate that the instrument is both relevant and valid, that there is no evidence of misspecification, and that the proxies for other calls on resources are indeed endogenous.

Table 17 Results for poisoning expenditure, 2005-06

N = 295	Poisoning expenditure (PBC 20)		Poisoning expenditure (PBC 20)	
	OLS	OLS	2SLS	2SLS
Constant	-2.278 (0.504)	-1.310 (0.897)	-1.229 (0.648)	1.372 (1.346)
Need	0.775 (0.229)	0.774 (0.259)	1.065 (0.272)	1.288 (0.351)
Total Budget	0.707 (0.228)	0.764 (0.242)	0.644 (0.228)	0.699 (0.254)
All amenable deaths (SMR)	-0.451 (0.104)		-0.666 (0.132)	
All deaths (SYLL)		-0.511 (0.145)		-0.942 (0.215)
Test statistics:				
Sargan (χ^2_1)			0.065 (0.9680)	1.775 (0.411)
Anderson (χ^2_2)			230.0 (0.000)	176.3 (0.000)
Cragg-Donald			114.2 (<0.05)	78.7 (<0.05)
Partial R^2			0.541	0.449
Reset: F(3,288)	0.37 (0.773)	0.39 (0.762)		
Pesaran-Taylor (χ^2_1)			0.01 (0.9134)	0.12 (0.728)
Endogeneity (χ^2_1):				
All amenable deaths (SMR)			4.153 (0.041)	
All deaths (SYLL)				6.208 (0.012)

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, the proportion of the population that provide unpaid care, and the population weighted index of multiple deprivation based on ward level IMD 2000 scores.
3. Re-estimation of these results using expenditure data adjusted for host/lead commissioner arrangements and omitting one PCT (Dudley South) whose reported spend data looks unusual has no material effect on the results.

8.5 Mental health programme of care

OLS and comparable 2SLS expenditure equations for the mental health programme of care are shown in Table 18. These are for all mental health expenditure excluding that on dementia (the dementia element accounts for only 11% of expenditure and the inclusion of this element generates marginally poorer results). In the OLS expenditure equations all three regressors – mental health need, total budget, and the proxies for other calls on resources – have the anticipated effect on expenditure and five of the six are statistically significant.[36] The 2SLS results are qualitatively similar to their OLS counterparts but the Sargan test indicates that the instrument set is of marginal validity.

[36] Rather than employ the all specialty measure of need, we use the index of mental health need as constructed by the Department of Health for its HCHS resource allocation purposes

Otherwise, there is no evidence of misspecification and the proxies for other calls on resources appear to be endogenous. A second condition-specific measure of mental health need – the mental health prevalence rate – is available from data collected for the Quality and Outcomes Framework (QOF). However, the use of this need indicator as a regressor led to no improvement in the results.[37]

Table 18 Results for mental health expenditure excluding dementia, 2005-06

N = 288	Mental health expenditure excluding dementia (PBC 5a and 5x)		Mental health expenditure excluding dementia (PBC 5a and 5x)	
	OLS	OLS	2SLS	2SLS
Constant	-0.455 (0.877)	0.141 (1.295)	8.526 (2.648)	6.845 (3.528)
Mental health need	0.714 (0.194)	0.649 (0.162)	2.277 (0.475)	1.340 (0.388)
Total Budget	0.844 (0.168)	0.947 (0.167)	0.647 (0.212)	1.128 (0.191)
All amenable deaths (SMR)	-0.368 (0.178)		-2.216 (0.545)	
All deaths (SYLL)		-0.387 (0.210)		-1.478 (0.573)
Test statistics:				
Sargan (χ^2_1)			7.729 (0.0210)	19.627 (0.0001)
Anderson (χ^2_2)			36.6 (0.000)	40.0 (0.000)
Cragg-Donald			12.7 (<0.05)	14.0 (<0.05)
Partial R^2			0.119	0.129
Reset: F(3,285)	0.17 (0.919)	0.11 (0.952)		
Pesaran-Taylor (χ^2_1)			0.17 (0.6832	0.07 (0.791)
Endogeneity (χ^2_1):				
All amenable deaths (SMR)			14.59 (0.000)	
All deaths (SYLL)				4.582 (0.032)

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, the proportion of the population that provide unpaid care, and the population weighted index of multiple deprivation based on ward level IMD 2000 scores.
3. The results presented are for all mental health expenditure excluding that on dementia (the latter accounts for about 11% of all mental health expenditure) although similar models are obtainable for all mental health expenditure.
4. Re-estimation of these results using expenditure data adjusted for host/lead commissioner arrangements and omitting one PCT (Dudley South) whose reported spend data looks unusual has no material effect on the results.

We did estimate a mental health outcome equation with the suicide rate as the dependent variable (just over 3,000 deaths in 2004 in England were attributed to intentional self-harm). However, the results were poor with expenditure and the need for mental health care having the 'wrong' signs. This result probably reflects the low number of suicides relative to the very high prevalence of mental health problems, and suggests that the suicide rate is not an adequate summary outcome measure for this programme of care.

9 Conclusions

This study has shown that health care expenditure has a demonstrably positive effect on outcomes in seven of the care programmes investigated– cancer, circulation problems, neurological problems, respiratory problems, gastro-intestinal problems, trauma and injuries problems, and diabetes. Our lack of success with three other categories – infectious diseases, genito-urinary problems, and neonatal care – might reflect the fact that our outcome indicator (death) is not a conventional outcome

[37] For example, the coefficient on the prevalence rate is positive and significant when added to the 2SLS outcome equations but the other coefficients are little changed and remain significant.

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 yet we obtained plausible expenditure results in line with our model's expectations.

Our estimates confirm and extend the findings presented in our earlier report (Martin, Rice and Smith, 2007). Using budgeting expenditure data for 2004/05, our earlier study estimated that the marginal cost of a 'life year' saved appeared quite low, at approximately £8,000 for circulatory disease and £13,100 for cancer. Although these estimates were not adjusted for quality of life, and they were associated with quite large confidence intervals, they compared quite favourably with the sum of £30,000 for a quality-adjusted life year commonly attribute to NICE as the threshold for accepting new therapeutic technologies.

In this study we have used budgeting data for 2005/06. Our estimates again suggest that the marginal cost of a 'life year' saved is quite low and this finding is not confined to cancer and circulation problems. We estimate that the marginal cost of a life year saved is:

- £ 13,931 for cancer
- £ 8,426 for circulation problems
- £ 7,397 for respiratory problems
- £ 18,999 for gastro-intestinal problems
- £ 26,453 for diabetes.

We also calculated a very large figure (£191,000) for the cost of a life year saved in neurological problems. However, this should not be taken as a reliable figure as it probably reflects the fact that the mortality indicator available to us (for epilepsy) captures fewer than 10 per cent of the deaths in the neurology care programme and that much expenditure in this programme will be directed towards 'caring' rather than increased life expectancy.

Apart from the neurological programme, the marginal cost of a life year saved figures provide evidence that expenditure on the various disease catagories yields quite consistent benefits in terms of life years saved. This is reassuring, as it implies that PCTs are tending to allocate resources consistently across programmes, in line with expected benefits. Furthermore, it is quite likely that the variations we observe between the costs in the different programmes can be explained by: (a) interventions, such as cancer palliative care, that yield benefits that cannot be measured to any great extent in increased life expectancy; and (b) differences in the extent to which the specialty coverage of the mortality data corresponds to the coverage of the budgeting data..

The models offer evidence of a strong substitution effect between expenditure on programmes of care. Other things being equal, expenditure on a specific programme is depressed in the face of higher need in other programme areas. This confirms that PCTs may be acting appropriately by directing their budget rationally to the programme areas that will yield greatest health benefit for their locality.

The dramatic change in inference that arises from moving from the misspecified OLS models to the well-specified 2SLS models illustrates why proper econometric modelling is needed if nature of the relationship between expenditure and outcome is to be investigated correctly. The models and methods described here are of necessity 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 health care spending on health outcomes than is often indicated by more conventional analysis.

We nevertheless recognize that this study, like its predecessor, 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 Department of Health, and we would hope that in time a greater range of outcome and epidemiological data will be made available. Nevertheless, for this study we did have available a number of condition specific needs variables which were not available to our earlier study but, overall, these did not in general perform any better than the more generic all specialty need variable.

Furthermore, we have modeled outcome data for 2002-04 along with expenditure data for FY 2005/06. 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 may enable us to model the effects with more confidence.

The English programme budgeting project is a major new data development. However, it is still under development, and there remain unresolved issues. Some health system expenditure is difficult to assign to programmes, most notably in primary care. Furthermore, accounting practice is variable, and we would recommend that programme budgeting accounts should be properly audited.

We nevertheless believe that programme budgeting is a major initiative that should be actively and vigorously promoted by the Department of Health. Most importantly, it brings together for the first time clinical data (in the form of health outcomes) and expenditure data. It therefore has the potential for engaging clinicians in value-for-money issues where more conventional budgetary approaches fail, thereby offering the potential for better clinical engagement in budgetary choices and better-informed purchasing decisions by PCTs.

Furthermore, programme budgeting permits researchers to model links between health care expenditure and health outcomes in a much more secure manner than hitherto. This report has offered a glimpse of its potential in this respect. The results can help the Treasury and national politicians make more informed decisions on whether health care expenditure offers value for money. They can help the Department of Health and local purchasers make better informed decisions about where their limited budgets are best spent. And they can also inform the decisions of NICE on whether their current threshold for accepting new technologies is set at an appropriate level.

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APPENDIX A: Data considerations

Table A1 Expenditure by programme budget category, per person, all England, 2004-05 and descriptive statistics for cost adjusted expenditure by PCT

Programme budget category	National net spend per head, £, 2004-05	PCT spend per head £, 2004-5, cost adjusted			
		Mean	Minimum	Maximum	CV (see below)
1 Infectious diseases	20.1	18.6	8.9	137.6	0.68
2 Cancers/tumours	75.1	75.8	39.1	133.4	0.21
3 Blood disorders	16.9	16.4	3.8	58.1	0.46
4 Endocrine/metabolic	31.7	31.7	12.4	51.5	0.18
Diabetes	13.5	13.4	0.0	33.3	0.34
Other	18.2	18.2	0.0	40.9	0.30
5 Mental health	145.3	142.9	51.2	323.3	0.28
Substance abuse	11.9	12.2	-2.0	146.8	1.37
Dementia	16.1	16.3	0.0	158.3	1.28
Other	117.3	114.3	0.0	247.8	0.34
6 Learning disability	42.0	42.5	4.7	163.3	0.46
7 Neurological system	34.9	35.5	18.6	70.6	0.24
8 Eye and vision	27.5	28.2	4.5	65.7	0.30
9 Hearing	6.3	6.3	1.7	32.7	0.47
10 Circulation (CHD)	122.0	124.1	64.0	186.3	0.19
11 Respiratory	62.5	63.7	30.3	147.6	0.25
12 Dental	13.3	13.4	0.0	96.4	0.80
13 Gastro Intestinal	73.0	74.4	34.4	132.3	0.22
14 Skin	24.8	24.9	13.2	49.7	0.27
15 Musculo Skeletal	71.2	72.3	19.1	157.6	0.23
16 Trauma/injuries	71.9	72.7	35.2	209.1	0.26
17 Genito/urinary	62.1	61.6	30.8	151.3	0.27
18 Maternity/repro	54.7	53.8	25.1	151.3	0.31
19 Neonate conditions	13.9	13.8	0.3	53.2	0.53
20 Poisoning	12.3	12.5	4.2	24.5	0.28
21 Healthy individuals	21.7	21.5	4.2	90.1	0.51
22 Social care needs	25.1	24.5	-80.4	140.1	0.85
23 Other areas	154.7	156.8	98.2	574.2	0.29
GMS/PMS*	126.9	128.8	90.8	237.4	0.14
Total expenditure	1183.1	1188.1	820.2	1705.9	0.13

NB Descriptive statistics across PCTs are unweighted for population size and, for any given PCT, its expenditure per head figures reflect 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. *The GMS/PMS figures exclude three PCTs for whom the reported expenditure figures are either zero or implausibly low.

Table A2 Mortality measures employed alongside expenditure data for 2005/06

The National Centre for Health Outcomes Development reports mortality rates by PCT for all causes and selected individual causes averaged over the three-year period 2002-04 for various age groups. For further details see the NCHOD website (http://www.nchod.nhs.uk/), Compendium Indicators, Archived Compendia, data release date September 2006. Unfortunately, during the course of this study NCHOD removed this data set from its website but a copy is available on application to NCHOD. Listed below are details of the mortality rates used in conjunction with each programme budgeting category in this study.

Programme budgeting category (ICD 10 coverage)	Mortality rates available (ICD 10 coverage)
PBC 1 Infectious diseases (A00-B99 excluding A500-A599 (syphilis etc))	Infectious diseases (A00-B99) (1,656 deaths, 2004, under 75 years) 1 Indirect SMR, all ages, 2002-04 2 Standardised YLL rate, under 75 years, 2002-04
PBC 2 Cancers and tumours (C00-C97, D00-D50)	All cancers (C00-C97) (190,751 deaths under 75 years 2002-04) 1 Direct SMR, under 75 years, 2002-04 2 Standardised YLL rate, under 75 years, 2002-04
PBC 3 Blood disorders (D500-D899)	No mortality rate available
PBC 4 Endocrine, nutritional and metabolic problems (a) 'diabetes' E100-E149 (b) 'other' E000-E899 excluding E100-E149	Diabetes (E10-E14) (17,007 deaths, all ages, 2002-04) 1 Indirect SMR, all ages, 2002-04 2 Standardised YLL rate, under 75 years, 2002-04
PBC 5 Mental health (F001-F999 excluding F700-F899 (learning disability)) 2 Standardised YLL rate, under 75 years, 2002-04	1 Intentional self-harm (X60-X84) (9,255 all age deaths, 2002-04) 1 Direct SMR, all ages, 2002-04 2 Intentional self-harm, injury undetermined (X60-X84, Y10-Y34) (13,420 all age deaths, 2002-04) 1 Direct SMR, all ages, 2002-04 2 Standardised YLL rate, under 75 years, 2002-04

Programme budgeting category (ICD 10 coverage)	Mortality rates available (ICD 10 coverage)
PBC 6 Learning disability (F700-F739, F780-F849, F88-F90, Q90, Q91)	No outcome indicator
PBC 7 Neurological system (G000-G999, Q000-Q079, R200-R999)	Epilepsy (G40-G41) (2,819 deaths, all ages, 2002-04) 1 Indirect SMR, all ages, 2002-04 2 Standardised YLL rate, under 75 years, 2002-04
PBC 8 Eye and vision problems (H000-H599, Q100-Q159)	No mortality rate available
PBC 9 Hearing problems (H600-H999, Q160-Q179)	No mortality rate available
PBC10 Circulation problems (I00-I99, Q20-Q28)	Circulatory diseases (I00-I99) (154,905 deaths < 75 years 2002-04) 1 Direct SMR, under 75 years, 2002-04 2 Standardised YLL rate, under 75 years, 2002-04
PBC11 Respiratory problems (A150-A169, A190-A199, J000-J989, Q300-Q349, R000-R099)	Asthma (J45-J46) (1,160 all age deaths in 2004) 1 Indirect SMR, all ages, 2002-04 2 Standardised YLL rate, under 75 years, 2002-04 Bronchitis, emphysema, other (J40-J44) (21,662 all age deaths in 2004) 1 Indirect SMR, all ages, 2002-04 2 Standardised YLL rate, under 75 years, 2002-04 Pneumonia (J12-J18) (28,878 all age deaths in 2004) 1 Indirect SMR, all ages, 2002-04 2 Standardised YLL rate, under 75 years, 2002-04

Programme budgeting category (ICD 10 coverage)	Mortality rates available (ICD 10 coverage)
PBC12 Dental problems (K000-K099)	No mortality rate available
PBC13 Gastro-intestinal problems (I840-I859, K091-K929, Q380-Q459, R100-R198)	Liver disease (K70, K73-K74) (5,438 all age (1+) deaths in 2004) 1 Indirect SMR, all ages, 2002-04 2 Standardised YLL rate, under 75 years, 2002-04 Ulcers (K25-K27) (3,316 all age (1+) deaths in 2004) 1 Indirect SMR, all ages, 2002-04 2 Standardised YLL rate, under 75 years, 2002-04
PBC14 Skin problems (L000-L999, Q351-Q379, Q800-Q859)	No mortality rate available
PBC15 Musculo-skeletal problems (M00-M99, Q18, Q650-Q799)	No mortality rate available
PBC16 Trauma, burns and injuries (S000-S999, T000-T357, T79)	Fracture of thighbone (S72) (2,517 deaths aged 65-84 in 2002-04) 1 Direct SMR, aged 65-84 years, 2002-04 2 No SYLL available Skull, cranial injury (S02, S06, T90) (2,813 deaths < 75, 2002-04) 1 Direct SMR, under 75 years, 2002-04 2 No SYLL available

Programme budgeting category (ICD 10 coverage)	Mortality rates available (ICD 10 coverage)
PBC17 Genito-urinary problems (A50-A64, N00-N99, Q500-Q649, R30-R39, R86-R87)	Mortality from chronic renal failure (N18) (4,217 deaths, all ages, 2002-04) 1 Indirect SMR, all ages, 2002-04 2 Standardised YLL rate, under 75 years, 2002-04
PBC18 Maternity and reproductive problems (N96-N98, O000-O999, Z300-Z391)	No mortality rate available
PBC19 Neonate conditions (P000-P299, P350-P399, P500-P619, P700-P839, P900-P969)	1 Infant mortality rate per 1,000 live births, aged under 1 year, 2003-05 2 Infant mortality rate per 1,000 live births, aged under 28 days, 2003-05
PBC20 Poisoning (Q86, R78, R82, T360-T888)	No mortality rate available
PBC21 Healthy individuals	No mortality rate available
PBC22 Social care needs	No mortality rate available
PBC23 Other areas	No mortality rate available

Table A3 Deaths considered amenable to health care

Deaths considered amenable to health care are defined as those from the following causes for the specific age groups stated. See http://www.nchod.nhs.uk/ for further details.

Intestinal infections (ICD-10 A00-A09, ICD-9 001-009), ages 0-14 years;

Tuberculosis (ICD-10 A15-A19, B90; ICD-9 010-018, 137), ages 0-74 years;
Other infectious diseases (diptheria, tetanus, poliomyelitis) (ICD-10 A36, A35, A80; ICD-9 032, 037, 045), ages 0-74 years;
Whooping cough (ICD-10 A37, ICD-9 033), ages 0-14 years;
Septicaemia (ICD-10 A40-A41, ICD-9 038), ages 0-74 years;
Measles (ICD-10 B05, ICD-9 055), ages 1-14 years;
Malignant neoplasm of colon and rectum (ICD-10 C18-C21, ICD-9 153-154), ages 0-74 years;
Malignant neoplasm of skin (ICD-10 C44, ICD-9 173), ages 0-74 years;
Malignant neoplasm of female breast (ICD-10 C50, ICD-9 174), ages 0-74 years;
Malignant neoplasm of cervix uteri (ICD-10 C53, ICD-9 180), ages 0-74 years;
Malignant neoplasm of unspecified part of the uterus (ICD-10 C54-C55, ICD-9 179, 182), ages 0-44 years;
Malignant neoplasm of testis (ICD-10 C62, ICD-9 186), 0-74 years;
Hodgkin's disease (ICD-10 C81, ICD-9 201), ages 0-74 years;
Leukaemia (ICD-10 C91-C95, ICD-9 204-208), ages 0-44 years;
Diseases of the thyroid (ICD-10 E00-E07, ICD-9 240-246), ages 0-74 years;
Diabetes mellitus (ICD-10 E10-E14, ICD-9 250), ages 0-49 years;
Epilepsy (ICD-10 G40-G41, ICD-9 345), 0-74 years;
Chronic rheumatic heart disease (ICD-10 I05-I09, ICD-9 393-398), ages 0-74 years;
Hypertensive disease (ICD-10 I10-I13, I15 ; ICD-9 401-405), ages 0-74 years;
Ischaemic heart disease (ICD-10 I20-I25, ICD-9 410-414), ages 0-74 years;
Cerebrovascular disease (ICD-10 I60-I69, ICD-9 430-438), ages 0-74 years;
All respiratory diseases (excl. pneumonia, influenza and asthma) (ICD-10 J00-J09, J20-J44, J47-J99; ICD-9 460-479, 488-492, 494-519), ages 1-14 years;
Influenza (ICD-10 J10-J11, ICD-9 487), ages 0-74 years;
Pneumonia (ICD-10 J12-J18, ICD-9 480-486), ages 0-74 years;
Asthma (ICD-10 J45-J46, ICD-9 493), ages 0-44 years;
Peptic ulcer (ICD-10 K25-K27, ICD-9 531-533), ages 0-74 years;
Appendicitis (ICD-10 K35-K38, ICD-9 540-543), ages 0-74 years;
Abdominal hernia (ICD-10 K40-K46, ICD-9 550-553), ages 0-74 years;
Cholelithiasis & cholecystitis (ICD-10 K80-K81, ICD-9 574-575.1), ages 0-74 years;
Nephritis and nephrosis (ICD-10 N00-N07, N17-N19, N25-N27; ICD-9 580-589), ages 0-74 years;
Benign prostatic hyperplasia (ICD-10 N40, ICD-9 600), ages 0-74 years;
Maternal deaths (ICD-10 O00-O99, ICD-9 630-676), ages 0-74 years;
Congenital cardiovascular anomalies (ICD-10 Q20-Q28, ICD-9 745-747), ages 0-74 years;
Perinatal deaths (all causes excl. stillbirths), ages 0-6 days;
Misadventures to patients during surgical and medical care (ICD-10 Y60-Y69, Y83-Y84; ICD-9 E870-E876, E878-E879), ages 0-74 years.

Table A4 Socio-economic indicators available as potential instruments in the 2SLS estimation.

Indicator name	Short description	Long description
BORNEXEU	Residents born outside the European Union	Residents born outside the European Union divided by all residents (census cell definition: KS005008/KS005001)
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 (KS008007/KS008001)
NQUAL174	Proportion aged 16-74 with no qualifications	Proportion of population aged 16-74 with no qualifications (KS013002/KS013001
FTSTUDEN	Proportion aged 16-74 full-time students	Proportion of population aged 16-74 that are full-time students ((KS013008+KS013009)/KS013001)
HHNOCAR	Households without a car	Proportion of households without a car (KS017002/KS017001)
OWNOCC	Owner occupied households	Proportion of households that are owner occupied (KS018002+KS018003+KS018004)/KS018001)
LAHARENT	Rented social housing	Proportion of households that are rented from LA or HA ((KS018005+KS018006)/KS018001)
PRIVRENT	Rented private housing	Proportion of households that are rented from private landlords (KS018007/KS018001)
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)
WORKAGRI	Employed in agriculture	Proportion of those aged 16-74 in employment that are working agriculture (KS11A002/KS11A001)
PROFOCCU	People in professional occupations	Proportion of those aged 16-74 in managerial and professional occupations ((KS14A002+KS14A003+KS14A004)/KS14A001)
POPWIMD	Index of multiple deprivation	Population weighted index of multiple deprivation based on ward level IMD 2000 scores
LISI2002	Exemptions from prescription charges	Low income supplement index (LISI). A measure of deprivation based on claims for exemption from prescription charges on grounds of low income. December 2001 to November 2002.
UNIFIED NEED	All NHS services needs index	This incorporates age, HCHS, prescribing, GMS, and HIV/AIDS adjustments. See DH (2005b) for details.

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

1 Cancer programme of care

The instrument set for the cancer programme of care (see Table C1) 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 health care (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 health care need specific to an elderly and needy population. Unpaid care is a substitute for the provision of health care 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 index of multiple deprivation (IMD 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 index of multiple deprivation 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 health care, 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% level and may reflect some unmet need. The regressors employed to predict the under 75 SMR for deaths from conditions amenable to health care 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 health care 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 health care are similar to those for neurological , respiratory, and gastro-intestinal problems, and the results are qualitatively the same.

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

Programme Budget Category	Regressors: Need	Lone_pension	Unpaid_carers	White_ethnic	PCTbudget	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**

Note: *=significant at 5% level and **=significant at 1% level

Appendix C Expenditure equations (2SLS) for programmes without a mortality indicator and generating unsatisfactory expenditure equations

Programme Budget - Category	Regressors: Constant	Need	PCT budget	All cause SMR	Sargan test	Reset test
Blood disorders						
Expenditure	-8.008**	-0.843	1.185**	0.739**	6.9 (0.031)	4.48 (0.034)
Learning disability						
Expenditure	-2.232	0.189	0.461	-0.225	0.02 (0.990)	0.04 (0.849)
Hearing problems						
Expenditure	-4.183**	1.270**	0.047	-0.200	7.32 (0.025)	0.30 (0.584)
Dental problems						
Expenditure	-2.861	0.994	2.170**	-0.340	13.40 (0.001)	0.22 (0.636)
Skin problems						
Expenditure	-4.006**	0.223	0.768**	0.036	6.32 (0.042)	8.99 (0.002)
Maternity						
Expenditure	-9.08**	-1.14**	0.599*	1.259**	1.59 (0.449)	0.05 (0.829)

Notes:
1. For regressors: *=significant at 5% level and **=significant at 1% level with robust standard errors
2. Parentheses show p-values for the instrument validity (Sargan) and equation mis-specidifcation (reset) test statistics.
3. The instrument set for the endogenous all cause SMR variable includes the proportion of households that are lone pensioner households, the proportion of the population that provide unpaid care, and the population weighted index of multiple deprivation based on ward level IMD 2000 scores.
4. The addition of a low birth weight variable to the maternity expenditure equation has little impact on the result.
5. Re-estimation of these results using expenditure data adjusted for host/lead commissioner arrangements and omitting one PCT (Dudley South) whose reported spend data looks unusual has no material effect on the results.