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THE UNIVERSITY of York

# The Link Between Health Care Spending and Health Outcomes for the New English Primary Care Trusts

## CHE Research Paper 42

# The link between health care spending and health outcomes for the new English Primary Care Trusts

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## ABSTRACT

English programme budgeting data have yielded major new insights into the link between health care spending and health outcomes. This paper updates two recent studies that have used programme budgeting data for 295 Primary Care Trusts (PCTs) in England to examine the link between spending and outcomes for several programmes of care. We use the same economic model employed in the two previous studies. It focuses on a decision maker who must allocate a fixed budget across programmes of care so as to maximize social welfare given a health production function for each programme. Two equations – a health outcome equation and an expenditure equation – are estimated for each programme (data permitting). The two previous studies employed expenditure data for 2004/05 and 2005/06 for 295 health authorities and found that in several care programmes – cancer, circulation problems, respiratory problems, gastro-intestinal problems, trauma burns and injury, and diabetes – expenditure had the anticipated negative effect on the mortality rate. Each health outcome equation was used to estimate the marginal cost of a life year saved. In 2006/07 the number of PCTs in England was reduced to 152, largely through a series of mergers. In addition, several changes were made to the methods employed to construct the programme budgeting data. This paper employs updated budgeting and mortality data for the new 152 PCTs to re-estimate health production and expenditure functions, and also presents updated estimates of the marginal cost of a life year saved in each programme. Although there are some differences, the results obtained are broadly similar to those presented in our two previous studies.

## Executive summary

1. One of the most fundamental issues in health policy is the extent to which additional health care expenditure yields patient benefits, in the form of improved health outcomes. Nolte and McKee (2004) document numerous studies examining the link between health spending and improved health outcomes, but results have hitherto been inconclusive, with researchers handicapped by crucial informational gaps.[1] Yet improved knowledge of the marginal value of increased health care spending is essential if policy makers are to make informed decisions about how much to spend on health care, and about which services the money is best spent on.

2. English programme budgeting data have yielded major new insights into the link between health care spending and health outcomes. Our two previous studies, funded by the Health Foundation under the Quest for Quality and Improved Performance (QQuIP) initiative, employed programme budgeting data for 2004/05 and 2005/06 for 295 English Primary Care Trusts (PCTs). They found that in several important programmes of care – cancer, circulation problems, respiratory problems, gastro-intestinal problems, trauma burns and injury, and diabetes – expenditure had the anticipated negative effect on health outcomes, as measured by the disease-specific mortality rate.[2]

3. In 2006 there was a fundamental reorganization of PCTs, largely in the form of PCT mergers, that led to a reduction to 152 in the number of PCTs. This note summarizes results from applying our previous research methods to this new configuration of PCTs for the financial year 2006/07.

4. Since 2003 data on expenditure on health care across 23 'programmes' of care have been prepared by each Primary Care Trust (PCT) in the English NHS. These 'programme budgeting' data seek to allocate exhaustively to disease categories all items of NHS expenditure, including expenditure on inpatient care, outpatient care, community care, primary care and pharmaceuticals and devices. In 2006/07 the average size of the programmes varied considerably, with the largest being mental health (£163.90 per head per year), primary care (£140.60), circulatory disease (£121.10) and cancer (£80.90).

5. Expenditure on any particular programme of care also varied considerably across PCTs. For example in 2006/07 expenditure per person – having adjusted for unavoidable geographical variation in local input costs – on cancers and tumours averages £82 across all PCTs but this varies between £43 and over £151 per head.[3] Similarly, expenditure per head on circulation problems averages £124 across all PCTs but this varies between £68 and over £200 per person.

6. Total (across all programmes) per capita expenditure is typically greatest around London and the traditional industrial heartlands in the north-east, the north-west, West Yorkshire, and the West Midlands. These are also the areas with the largest mortality rates. This positive correlation between expenditure and adverse health outcomes seems to imply that expenditure has little effect on outcomes. However, it merely reflects a major barrier to the analysis of the relationship between expenditure and health outcomes; namely, the difficulty of disentangling cause and effect. Areas with high health needs and poor health outcomes tend to attract high levels of health care spending.

7. This phenomenon can be illustrated by comparing the correlation between programme budgeting expenditure and health outcomes, first without and then with a control for health care need. Across the 152 PCTs, the correlation coefficient between expenditure and aggregate health outcome (in the form of the under-75 SMR for all causes of death deemed amenable to health care) is 0.7077. This illustrates the usual counter-intuitive pattern of poorer health outcomes in areas with higher levels of spending.

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[1] Nolte, E and McKee, M (2004). *Does health care save lives?* The Nuffield Trust, London.
[2] See Martin, S., Rice, N. and Smith, P. C. (2008). *Does health care spending improve health outcomes? Evidence from English programme budgeting data.* Journal of Health Economics, 24, 826-842. Also see Martin, S., Rice, N. and Smith, P. C. (2007). *Further evidence on the link between health care spending and health outcomes in England.* Centre for Health Economics Research Paper 32, University of York, December.
[3] This cost adjustment reflects the fact that health economy input prices vary considerably across the country and are up to 40% higher in London and the south east of England than elsewhere.

8. However, this counter-intuitive result disappears after making a rudimentary adjustment for the level of health care needs in each PCT. The previously observed positive association between expenditure and mortality is now negative (with a correlation coefficient of -0.1675). Areas with higher levels of spending secure more favourable health outcomes. Similar patterns can be found in individual programmes of care, such as those for cancer and circulatory disease.

9. A fundamental question for policy makers is therefore whether – *after adjusting for need* – extra spending gives rise to better health outcomes. Addressing this question properly requires additional data (in order to model needs) and advanced statistical methods. Our research seeks to examine the link between expenditure and outcomes in the major programmes of care for which useable expenditure and mortality data are available. Our methodology models PCT performance in two stages. First it models the expenditure decisions of PCTs on each programme as a function of need, PCT income, and other calls on the PCT's resources. It then models the disease-specific health outcomes secured by PCTs as a function of expenditure and the need for health care.

10. Our results for 2006/07 confirm our earlier findings for several programmes of care including: cancer, circulation problems, respiratory problems, gastro-intestinal problems, trauma and injuries, and diabetes. For these programmes it is possible to develop robust and well-specified statistical models in line with expectations. These models were subjected to a battery of statistical tests to confirm their reliability and these tests yielded little evidence of mis-specification. These models demonstrate a strong positive link between expenditure and better health outcomes (lower mortality rate) when the need for health care is held constant.

11. Using a measure of ‘years of life lost’ instead of the mortality rate as the measure of health outcome, it is also possible to estimate the expenditure required to ‘save’ a year of life in some of the programmes of care. We estimate that in 2006/07, for a PCT with average needs and expenditure, the marginal cost of a life year saved in cancer is about £15,387. It must be emphasized that this result has quite a large 95% confidence interval (from £9,606 to £38,642).

12. Our estimates of the cost of a life year saved for 2006/07 for five programmes of care are as follows:

    - £ 15,387 for cancer (£13,931 for 2005/06)
    - £ 9,974 for circulation problems (£8,426 for 2005/06)
    - £ 5,425 for respiratory problems (£7,397 for 2005/06)
    - £ 21,538 for gastro-intestinal problems (£18,999 for 2005/06)
    - £ 26,428 for diabetes (£26,453 for 2005/06).

13. The 'cost of an additional life year saved' estimates using budgeting data for 2005/06 and mortality data for 2002/04 are very similar to those using budgeting data for 2006/07 and mortality data for 2004/06. That we should obtain such similar results for both years despite several changes to the construction of the data in 2006/07 -- including (a) the merger of many PCTs, (b) the re-allocation of many disease codes from one budgeting category to another, and (c) the introduction of a new method to cost patient care -- provides further evidence of the reliability of our results.

14. Nevertheless, our estimates of the marginal cost of a life year saved should be treated with some caution. Most importantly, they are not adjusted for the quality of the life year saved. However, we have undertaken an approximate quality of life adjustment that suggests that our results translate very roughly into a cost of a QALY in cancer of £22,332, whilst for circulatory diseases the corresponding figure is £14,909. Although these figures are rudimentary, they do suggest that the existing cost of a QALY secured in these programmes of care may be lower than many commentators have assumed. In particular, they do appear to compare favourably with the threshold of £30,000 per quality adjusted life year (QALY) often attributed to NICE.

15. We recognize that this research 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 become available. Furthermore, although immensely promising, the English programme budgeting project is still under development, and there remain unresolved issues. Some NHS expenditure is difficult to assign to programmes, most notably in primary care and in secondary care where the patient is not admitted to hospital. Furthermore, accounting practice is variable, and we would recommend that programme budgeting accounts should in the future be properly audited.

16. We have modelled just a single year's data. 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.

17. Notwithstanding these limitations, the study offers clear confirmation that current expenditure by PCTs on some important programmes of care is highly cost-effective. Expenditure on circulatory disease yields greater benefits in terms of life years than expenditure on other programmes. This is to be expected. Recent developments in circulatory drug therapies (especially statins) are acknowledged to be highly cost-effective in saving lives. Furthermore, a substantial element of some of the other programmes is devoted to aspects of care (such as palliative care) that are unlikely to be measured to any great extent in increased life expectancy.

18. This study indicates that the results secured from previous years' programme budgeting data remain remarkably stable when replicated for the new configuration of PCTs. We therefore feel increasingly confident that they can act as a secure basis for setting national policy. For example, they offer an important resource for informing and complementing the work of NICE, helping determine whether their threshold for accepting new technologies is set at an appropriate level. They can also help the Treasury and national politicians make more informed decisions on whether health care expenditure offers value for money. More operationally, programme budgeting data can help the Department of Health and PCTs make better informed decisions about where their limited budgets are best spent. They bring together for the first time clinical data (in the form of health outcomes) and expenditure data, and therefore have the potential to engage clinicians in value-for-money issues where more conventional budgetary approaches have failed.

# 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 two recent studies we took advantage of the availability of a major new dataset to examine the relationship between health care expenditure and mortality rates for several disease categories (Martin, Rice and Smith: 2008a, 2008b). 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) health outcome as a function of expenditure and need. Using programme budgeting data for financial year (FY) 2004/05 we found that, in the two care programmes examined (cancer and circulation problems), such expenditure was positively associated with both income and need but negatively associated with other calls on resources, and that health outcomes improved with expenditure but were adversely associated with need (Martin, Rice, and Smith, 2008a). We were also able to use the health outcome equation to estimate the expenditure required to 'save' an additional year of life in each disease category. We found that this was about £13,000 for cancer and about £8,000 for circulation problems.

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

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

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

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

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

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

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

In 2006/07 the number of PCTs was reduced from 303 to 152, largely through a series of mergers.[4] In addition, two major changes were made to the methods employed to construct the programme budgeting data. First, expert medical opinion was employed to re-evaluate the existing mapping from inpatient diagnosis codes to programme budget category. This led to the re-assignment of just over 10% of all diagnosis (ICD10) codes from one programme budgeting category to another.[5] [6] Second, activity to be costed used the newly introduced version 4 of the Healthcare Resource Group (HRG) software which, among other things, changed the methodology for calculating non-admitted patient care costs. HRG4 reflected advances in clinical practice and was designed to generate a much more accurate costing of complex cases.

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

Given the changes to the way in which the expenditure data is constructed, we want to discover whether our earlier results are reproducible using the new PCT geographies. In addition, our two previous studies used mortality data for the three year period from 2002 to 2004. However, mortality data for the new PCTs for 2004 to 2006 have recently been released by the National Centre for Health Outcomes Development (NCHOD). This paper therefore employs the most recent budgeting and mortality data for the152 new PCTs to re-estimate health production and expenditure functions. It uses these results to also present updated estimates of the marginal cost of a life year saved in each programme and compares these estimates with those presented previously.

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

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 2006/07 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 studies, 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 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 8.

[4] In a small number of cases, the geographic area covered by an existing PCT was split between two or more new PCTs.
[5] This figure ignores intra-category changes (for example, where an ICD10 code is re-allocated from category 1A to 1B) and only counts cross-category changes (for example, where the code is switched from category 1 to category 2).
[6] This expert review also led to the introduction of 40 additional sub-categories including 10 sub-categories for the cancer and tumour programme.

## 2. Previous studies[7]

There is a considerable literature on the impact of health care and other related explanatory variables on some measure of health care outcome (Nolte and McKee, 2004). However, most attempts to analyse the magnitude of the macro-link between spending and health have been inconclusive. For example, in an early cross-sectional study of 18 developed countries, Cochrane, St Leger and Moore (1978) applied regression analysis to the statistical relationship between mortality rates and per capita consumption of inputs such as health care provision. They found that the indicators of health care were generally not associated with outcomes in the form of mortality rates. This 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 (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 potential lag between expenditure and outcomes and, particularly with international comparisons, the problem of data heterogeneity). One fundamental obstacle to any statistical analysis is the difficulty of disentangling cause and effect. Areas or countries with relatively high health needs and poor outcomes may tend (other things equal) to direct high levels of spending to health care. For policy makers the issue is whether – *after adjusting for need* – extra spending gives rise to better health outcomes.

A study by Cremieux et al (1999) sought to overcome data heterogeneity problems by examining the relationship between expenditure and outcomes across 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, their 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) 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 the 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 concluded 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 as described in section 4. We believe

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

that this may lead to a more convincing and better specified model of health outcomes than that used in many previous studies.

## 3. Programme budgeting in England

The English National Health Service (NHS) is financed almost entirely from national taxation, with access to care generally free to the patient. Primary care is an important element of the system, and general practitioners act as gatekeepers to secondary care and pharmaceuticals. The system is organized geographically, with most of the local expenditure on health care being the responsibility of the local PCTs. Since October 2006 there have been 152 PCTs with an average population of about 330,000.[8] 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.

Since April 2003 each PCT has prepared expenditure data disaggregated according to 23 programmes of health care. These programmes are defined with reference to the International Classification of Diseases (ICD) Version 10 codes at the four digit level, and most programme budget categories reflect broad ICD 10 chapter headings. In most cases the 23 categories are broken down into further sub-categories. Summary programme budgeting data for 2005/06 and 2006/07 are presented in Table 1.[9] The first two columns show the national average NHS expenditure per person by programme budget category in 2005/06 and 2006/07 respectively.

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

Next come eight programme budget categories – cancers and tumours (£81), gastro-intestinal problems (£73), genito-urinary problems (£69), musculo-skeletal problems (£66), respiratory problems (£65), maternity and reproductive conditions (£57), trauma and injuries (£57), and neurological problems (£55) – with an annual expenditure of between £55 and £81 per person.

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

Table 1 also shows the growth in expenditure per person by programme budget category for 2006/07. Across all categories expenditure per person increased by 2.8% but there were some dramatic changes for individual categories (for example, expenditure on dental problems more than doubled). The growth rates for 2006/07 are unusual because of the relatively large number of categories with a negative growth rate. These growth rates will partly reflect real changes in expenditure levels. However, they will also reflect changes in the construction of the programme budgeting data. For example, responsibility for commissioning dental services passed from Dental Practice Boards to PCTs on April 1 2006, but there were pilot transfers run during 2005/06. This transfer of commissioning accounts for the large increases in dental expenditure per head by PCTs in 2005/06 and 2006/07. In addition, the large increase in expenditure for category 23x in 2006/07 is due to a

[8] Until October 2006 there were 303 PCTs with an average population of about 160,000. In October 2006 the 303 PCTs became 152 PCTs. Some PCT boundaries remained unchanged while other PCTs were merged with one or more neighbours to form a new, larger, PCT. In a few cases the geographic area covered by an existing PCT was split between two or more new PCTs.

[9] See Table A1 in the Appendix for details of the sub-categories.

[10] The population figure used by the Department of Health increased by 2.6% in 2006/07 (this was up from 49,175,998 in 2005/06 to 50,476,231 in 2006/07) so total expenditure increased by just over 5%.

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

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

Note: descriptive statistics across PCTs are unweighted 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.
Source: calculated by the authors from data from the Programme Budget section of the Department of Health's website at http://www.dh.gov.uk/.

change in the methodology used to map non-admitted patient care (NAPC) expenditure to particular budgeting categories.

There is rarely a diagnosis code associated with non-admitted patient care. Prior to 2006/07 the apportionment of NAPC expenditure across programme budgeting categories was carried out on the basis of admitted patient care apportionment. Thus if 10% of the admitted patient care spend was allocated to a particular PBC then so too was 10% of the NAPC spend that could not be mapped directly to a programme budgeting category. However, the NAPC mapping was changed in 2006/07 and all expenditure that could not be directly mapped to a particular category was included in category 23x rather than apportioned across all categories in line with the apportionment of admitted patient care expenditure. Therefore category 23x in 2006/07 will include costs, such as A&E costs, whereas previously these would have been apportioned out over the 23 programme budgeting categories. [11]

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. For each programme budgeting category the unweighted average of the PCT per capita expenditure figures –

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

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.[12] The final column shows the coefficient of variation. As was the case for 2005/06, the variation in expenditure levels across PCTs in 2006/07 is considerable. For example, expenditure per head on cancers and tumours averages £82 across all PCTs but this varies between £43 and £152 per head. Similarly, expenditure per head on circulation problems averages £124 across all PCTs but this varies between £68 and £200 per head. Although there is considerable variation within these two particular programme budget categories, this variation is small relative to that in some other programmes of care. Programme budget categories such as infectious diseases and hearing problems have much larger coefficients of variation, indicating substantially more variation than that in the cancer and circulation categories.

To further illustrate the geographic variation in expenditure levels, Figure 1 shows (input price adjusted) expenditure per head by PCT for 2006/07 with each PCT allocated to one of five quintiles (quintile 1 contains the 30 PCTs with the smallest spend per head and quintile 5 contains the 30 PCTs with the largest spend per head).[13] This shows that per capita expenditure is typically greatest around London and the traditional industrial heartlands in the north-east, the north-west, West Yorkshire, and the West Midlands. Figure 2 uses an age and sex standardised mortality rate (SMR) to allocate PCTs to one of five mortality quintiles (quintile 1 contains the 30 PCTs with the smallest SMR and quintile 5 contains the 30 PCTs with the largest SMR).[14] Mortality rates seem to be greatest in those areas with the largest expenditure.

These maps illustrate a major barrier to analysing the relationship between expenditure and health outcomes; namely, the difficulty of disentangling cause and effect. Areas with high health needs and poor health outcomes tend to attract high levels of health care spending. This phenomenon is confirmed by examining the link between programme budgeting expenditure and health outcomes, in the form of standardized mortality rates (SMRs) amongst the 152 PCTs. Figure 3 shows the link between expenditure (adjusted for local input prices) and aggregate health outcome (in the form of the under-75 SMR for all causes of death deemed amenable to health care).[15] It reveals a clear positive relationship between these two variables (with a correlation coefficient 0.7077) and shows the usual pattern of poorer health outcomes in areas with higher levels of spending.

[12] This cost adjustment reflects the fact that health economy input prices vary considerably across the country and are up to 40% higher in London and the south east of England than elsewhere. We have used the Market Forces Factor Indices (MFFs) that feed into the Payment by Results tariffs for 2007/08 to adjust expenditure for local input prices (see DH, 2007).

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

[14] The SMR is for people aged under 75 years and relates to all causes of death considered amenable to health care over the period 2004-06.

[15] For details of deaths considered amenable to health care see Martin, Rice and Smith (2008b).

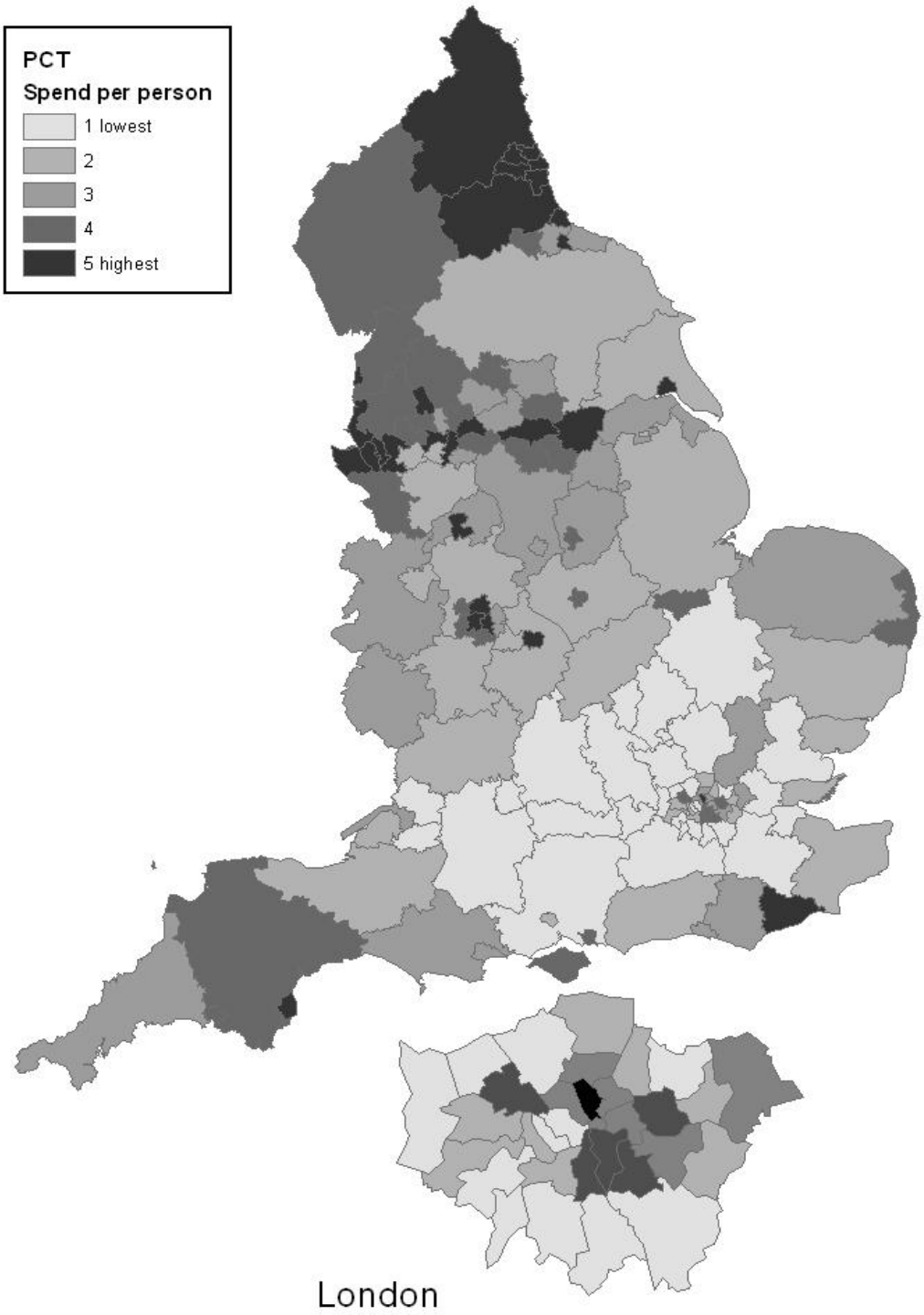


**Figure 1: Expenditure per person by PCT, 2006/07**

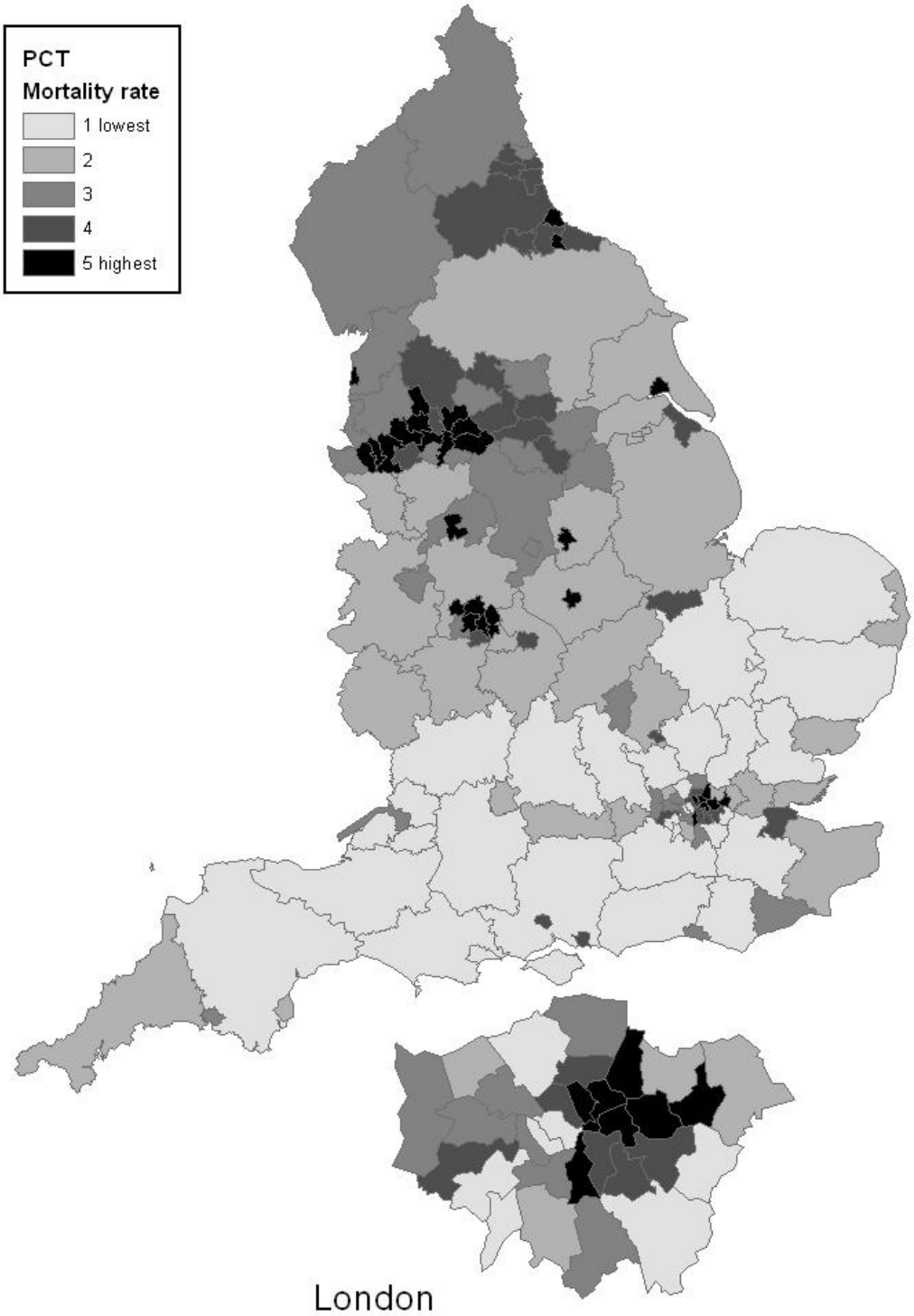


**Figure 2: Mortality rate by PCT, 2004-06**

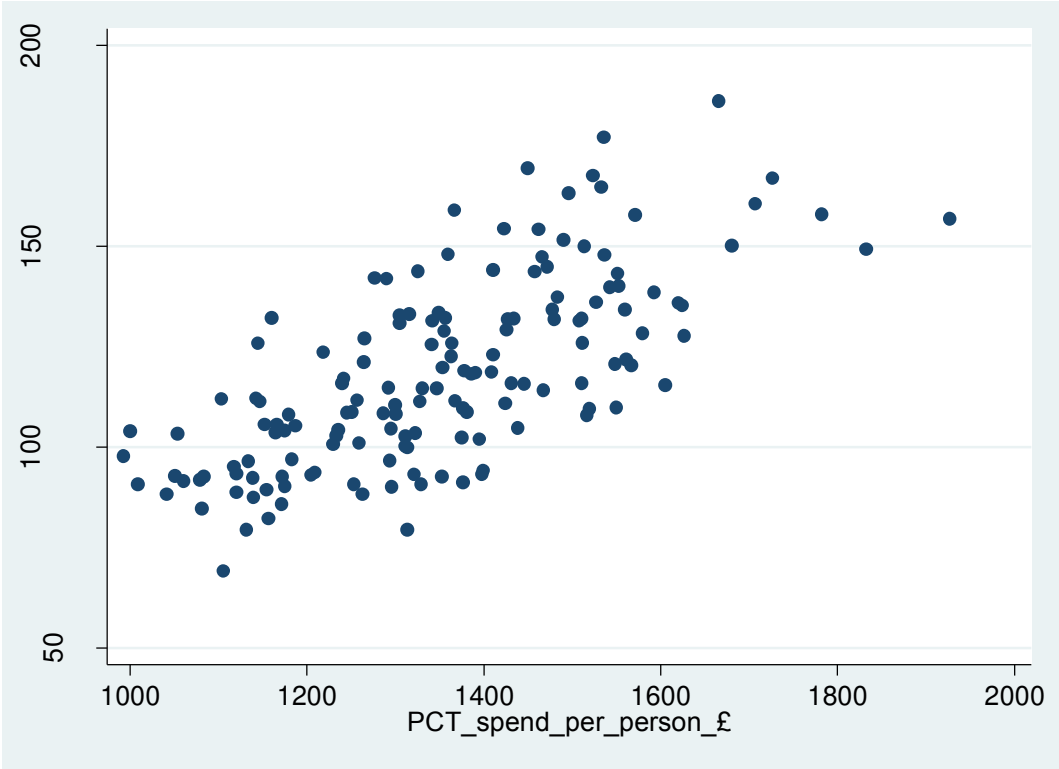


**Figure 3: PCT expenditure adjusted for local input prices and the SMR for people aged under 75 years**

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

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

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

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

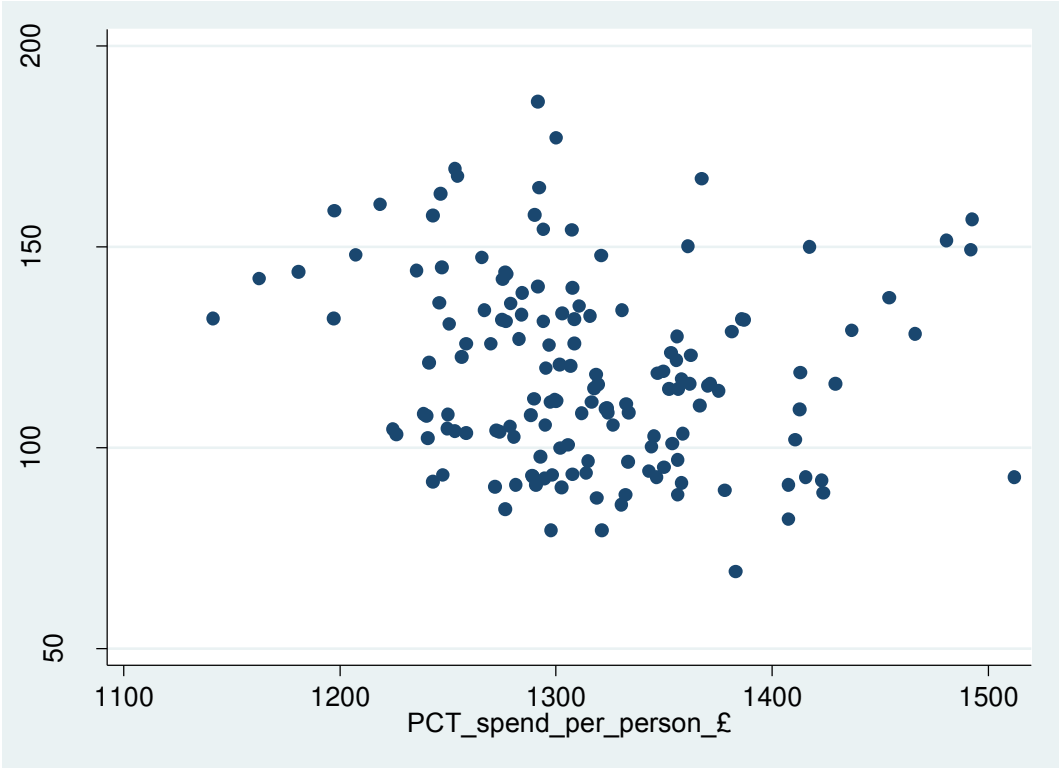


**Figure 4: PCT expenditure adjusted for both local input prices and the local need for Health care and the SMR for people aged under 75 years**

Some of the within programme variation in (cost adjusted) per capita expenditure across PCTs revealed in Table 1 will reflect different levels of the need for health care. Consequently, the degree of variation in expenditure across PCTs declines for most of the programme budget categories when the expenditure per head data in Table 1 is adjusted for each PCT's need for health care. However, this decline is relatively small and there are still substantial differences in expenditure per head even after allowing for differences in local cost and need. For example, for cancer and tumours the minimum and maximum spend per head is £43 and £152 using the cost adjusted expenditure data (from Table 1) but £47 and £117 using the cost and need adjusted population data. Similarly, expenditure per head in the circulation problems category varies between £68 and £200 using cost adjusted expenditure data (from Table 1) but lies between £75 and £167 using cost and need adjusted population data. Such variation in expenditure levels raises the issue of whether those PCTs that spend more in a particular programme of care achieve a better outcome. Clearly, for each disease category expenditure per head varies considerably geographically and this variation – holding constant input prices and the need for 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 paper 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 and 7.

## 4. Theoretical model[16]

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

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

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. 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 ($\boldsymbol{n_{i1}, n_{i2}, \ldots, n_{iJ}}$), environmental variables affecting the production of health outcomes in each category ($\boldsymbol{z_{i1}, z_{i2}, \ldots, z_{iJ}}$), and PCT income ($y_i$) so that:

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

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: issues and strategy[17]

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.

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

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

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

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

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 Department of Health's resource allocation formula. This needs element is 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 estimate models using two alternative measures of health outcome: the disease-specific standardized mortality rate 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 first study – where we were modelling only two (cancer and circulation) care programmes – we employed the circulation mortality rate as the proxy for the need for competing programmes in the cancer expenditure equation, and we employed the cancer mortality rate as the proxy for the need for competing programmes in the circulation expenditure equation (Martin, Rice and Smith, 2008a). As these are both programmes that attract considerable expenditure it is not implausible that expenditure in one of the programmes will impact upon expenditure in the other and, in this study, we have persevered with this approach when re-estimating the expenditure functions for the cancer and circulation problems for 2006/07.

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 in the other expenditure equations estimated we have employed either (a) the death rate from all causes amenable to health care for people aged under 75 year or (b) the SYLL rate for all deaths of those aged under 75 as the proxy for other calls on PCT resources. Although these proxy measures will include some 'own specialty' deaths, these will comprise a small proportion of the total. For example, in 2004 cancer and circulation problems accounted for over two-thirds of all deaths for those under 75 years of age and the third largest category – respiratory problems – accounted for less than one in ten of all deaths (NCHOD, 2007 and ONS, 2007). We therefore feel that the 'all causes' mortality indices are reasonable proxies for demands on the PCT budget from other specialties.

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.[18] 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 test proposed by Durbin (1954). Under the null hypothesis of exogeneity, OLS will yield consistent parameter estimates.

Where there is evidence of endogeneity of expenditure and health outcomes we implement two-stage least squares (2SLS). This involves replacing the endogenous variables in the equation of interest with their predicted values from an OLS regression which regresses the endogenous variable on a set of instrumental variables. These excluded instruments should be strong predictors of the endogenous variable (they are relevant) but should be appropriately excluded from the equation of interest (they are valid).[19]

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

For the case of a single regressor, Staiger and Stock (1997) suggest applying the criterion that if the first-stage F-statistic, testing the hypothesis that the instrument set does not significantly predict the endogenous regressor, is less than 10 then the instruments can be thought to be weak. Stock and Yogo (2002) extend these ideas to the case where there can be multiple endogenous regressors and propose a test for the null that the instruments are weak and provide appropriate critical values. This is an extension of the Cragg and Donald (1993) test for instrument relevance which is similar to Anderson's canonical correlations test. For the case of a single endogenous regressor, the Cragg-

[18] 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 are outside the remit of the model. In contrast, an endogenous variable is the result of the inner-working or the relationships of the model; it is either an output of the model or correlated through unobserved terms with outputs of the model. Thus in the cancer deaths model it is reasonable to assume that cancer expenditure is unlikely to be exogenous but will be influenced by, inter alia, expenditure on other care programmes. This distinction between exogenous and endogenous variables is important because it affects whether OLS or alternative estimation methods should be employed.

[19] We have a number of potential instruments available, mostly derived from 2001 Population Census, and these are described in Martin, Rice and Smith (2008b). In both of our earlier studies we found that a small sub-set of these instruments proved sufficient to generate plausible results and we have re-calculated these indicators for the new PCT boundaries. The construction of these instruments is shown 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 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 local authority IMD 2007 scores – were selected to be used as instruments on the basis of their theoretical and empirical relevance and validity. This set of instruments was modified if, for example, the Sargan test suggested that the set under test was not valid. A discussion of the choice of instruments for each pair of expenditure and outcome equations, together with details of the first stage regression results for the models presented in section 6, can be found in Appendix B.

Donald statistic is simply the F-statistic of the test of the hypothesis that the instruments do not enter the first-stage regression. Stock and Yogo provide critical values of the F-statistic (and the Cragg-Donald statistic for multiple endogenous regressors) that tabulates the ratio of 2SLS bias to the bias of OLS. The weakness or otherwise of the instruments can then be assessed by the relative bias exceeding a given threshold (for example, 2SLS bias exceeding 5% of OLS bias).[20]

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

## 6. Empirical results: programmes with plausible outcome and expenditure equations

In our initial study we presented outcome and expenditure equations using expenditure data for 2004/05 for cancer and for circulation problems (Martin, Rice and Smith, 2008a). With the release of budgeting data for 2005/06, we validated our models for cancer and circulation problems using this new data and extended our initial study by applying the expenditure and outcome models to the other 21 categories (Martin, Rice and Smith, 2008b). However, the only available reliable outcome measures relate to condition-specific mortality and so the outcome model could only be applied to those programme budgeting categories where a suitable mortality indicator was available. In 2006/07 a series of mergers reduced the number of PCTs from 303 to 152. Here we update the results for 2005/06 (which were estimated across 295 PCTs with mortality data for 2002/04) by employing expenditure data for 2006/07 and mortality data for the three year period from 2004 to 2006.[22] These models for 2006/07 are estimated across 152 PCTs.

We chose cancer and circulation problems as the first categories for the earlier study because these encompass medical conditions that are regularly associated with death (in England 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). Moreover, for these conditions the specialty coverage of the mortality data corresponds very closely to the specialty coverage of the budgeting data. However, for most of the remaining budgeting categories death is 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, using expenditure data for 2005/06 Martin, Rice and Smith (2008b) found that, even where mortality was not the most appropriate outcome measure, it was still possible to obtain plausible results and, as we shall see, this is also possible using expenditure data for 2006/07.

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

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

[22] The number of observations in the 2005/06 regression equations was 295 not 303. There were 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.

## Cancer programme of care

Results for the cancer programme of care are in Table 2. Columns under (1) present ordinary least squares (OLS) results using standardized mortality rates (SMRs) as the measure of health outcome.[23] Columns under (2) present 2SLS estimates using SMRs as the measure of health outcome while columns under (3) present 2SLS estimates using the standardized years of life lost (SYLL) rate as the outcome measure.[24] All variables have been log transformed and accordingly parameter estimates can be interpreted as elasticities.[25]

**Table 2 Results for cancer programme of care, 2006-07**

| N = 152 | OLS (1) | | 2SLS (2) | | 2SLS (3) | |
|---|---|---|---|---|---|---|
| | Cancer deaths | Cancer expenditure | Cancer deaths | Cancer expenditure | Cancer SYLL | Cancer expenditure |
| Constant | 4.699 (0.109) | -1.153 (0.419) | 3.689 (0.317) | 0.270 (0.544) | 4.139 (0.277) | 0.356 (0.541) |
| Need | 0.716 (0.058) | 1.183 (0.288) | 1.142 (0.161) | 1.512 (0.288) | 1.048 (0.142) | 1.557 (0.284) |
| Cancer expenditure | -0.032 (0.043 | | -0.425 (0.125) | | -0.355 (0.109) | |
| Total Budget | | 0.309 (0.275) | | 0.352 (0.272) | | 0.388 (0.271) |
| Circulation deaths | | -0.331 (0.094) | | -0.654 (0.123) | | |
| SMR | | | | | | -0.649 (0.118) |
| Circulation SYLL | | | | | | |
| *Test statistics:* | | | | | | |
| Sargan ( $\chi_1^2$ ) | | | 0.59 (0.440) | 1.24 (0.265) | 0.39 (0.529) | 0.70 (0.401) |
| Anderson ( $\chi_2^2$ ) | | | 30.4 (0.000) | 92.2 (0.000) | 30.4 (0.000) | 86.6 (0.000) |
| Cragg-Donald (F stat) | | | 18.5 (<0.05) | 113.6 (<0.05) | 18.5 (<0.05) | 97.5 (<0.05) |
| Partial $R^2$ | | | 0.200 | 0.607 | 0.200 | 0.570 |
| Reset: | | | | | | |
| F(3,146) | 5.78 (0.000) | | | | | |
| F(3,145) | | 1.30 (0.276) | | | | |
| Pesaran-Taylor ( $\chi_1^2$ ) | | | 3.90 (0.048) | 0.22 (0.642) | 4.13 (0.042) | 0.17 (0.677) |
| Endogeneity ( $\chi_1^2$ ): | | | | | | |
| Cancer expenditure | | | 27.6 (0.000) | | 23.3 (0.000) | |
| Circulation deaths | | | | 20.0 (0.000) | | |
| Circulation SYLL | | | | | | 20.2 (0.000) |

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

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 is insignificant at conventional levels and the effect is very small (the coefficient on the expenditure term is -0.032). With regard to the expenditure equation, other calls on expenditure – as proxied here by the circulation death rate – has the anticipated negative effect on cancer expenditure. The estimated coefficient (-0.331) suggests that a 10% increase in other calls on expenditure results in a 3.31% reduction in cancer expenditure.

One major difference between the expenditure equation for 2006/07 and that for 2005/06 is that in 2006/07 the coefficient on need has more than doubled while that on PCT income has more than halved. As we shall see, this occurs in the expenditure equation for several programme budgeting categories. This might be because of the increasing co-linearity between the need and PCT income

[23] These direct SMRs are for those aged under 75 years.
[24] This SYLL rate is calculated on the basis of a 75 year life expectancy.
[25] Descriptive statistics for various mortality rates and the census variables employed in the regressions can be found in appendix C.

variables as, each year, PCTs move closer towards their target resource allocation.[26] [27] If the expenditure equation is re-estimated without the need variable, the coefficient on PCT income jumps from 0.309 to 1.314 (with a robust standard error of 0.143). This supports the idea that the co-linearity between need and income makes it difficult to disentangle these two effects.

The second set of results present 2SLS estimates under (2). 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 employs instruments to obtain independent variation in expenditure to identify is impact on health outcomes. The 2SLS results under (2) indicate that a 10% increase in cancer programme expenditure results in approximately a 4.25% reduction in adverse health outcomes, observed through cancer deaths. Generally the results are similar to those for 2005/06.

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 a 1% increase in cancer expenditure per head – which was £80.9 in 2006/7 – gives rise, ceteris paribus, to a 0.355% reduction in years of life lost. Between 2004 and 2006, the total number of life years lost to cancer deaths in England in those aged under 75 was 2,221,529 (it was 2,268,541 in 2002-04).[28] This averaged 740,510 life years per annum which, across the English population of 50 million, averages out at 0.0148 life years (5.406 days) per person. Thus a 1% increase in expenditure per head (£0.809) is associated with a 0.355% reduction in life years lost (0.01919 days) and implies that one life year would cost £15,387 (£13,931 using expenditure data for 2005/06 and mortality data for 2002/04).

There is evidence that the OLS deaths model is misspecified $(F(3,146) = 5.78;\ p = 0.000)$, and it should therefore be rejected in favour of the 2SLS model which shows little evidence of misspecification (Pesaran-Taylor statistic=3.90, p=0.048). Although the OLS expenditure model is not misspecified, neither is the 2SLS model and there is evidence from the relevant test that the circulation deaths term is endogenous. Further support for the 2SLS 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. Taken together these tests indicate that the instrument set is both valid and relevant.

The measure of the need for cancer care employed here is not 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 expenditure equation it is statistically insignificant but the need term remains significant. Alternatively, if the all condition need variable is dropped and the prevalence rate is added, the latter is now significant but the other calls on resources term is now insignificant. If the prevalence rate is added to the outcome (death rate) equation both it and need become insignificant, and if the need term is dropped the prevalence rate becomes significant but with a negative sign. Overall, the cancer prevalence term appears to offer little improvement over the use of the more general need for health care variable. These findings are similar to those obtained using expenditure data for 2005/06.

[26] The Department of Health's resource allocation formula generates a target allocation for each PCT. To avoid large changes in PCT allocations that might follow that introduction of a new funding formula, actual annual allocations are gradually moved towards the latest target.
[27] The correlation coefficient between need and total PCT expenditure increased from 0.8768 in 2005/06 to 0.9341 in 2006/07.
[28] See the NCHOD website at http://www.nchod.nhs.uk/NCHOD/compendium.nsf/($All)/9381A0E301F343BC802573B5003E6184/$File/11D_072CR_06_V1_D.xls?OpenElement.

## Circulation programme of care

Results for circulatory problems are shown in Table 3 and these are similar to those presented previously for 2005/06 (see Martin, Rice and Smith, 2008b). In general, the estimated coefficients exhibit the same qualitative characteristics as for cancer 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 -1.166 on circulatory expenditure in the 2SLS deaths models implies that circulatory deaths are more responsive to increases in expenditure than are cancer deaths (where the comparable coefficient is -0.425) and that a 10% increase in expenditure is associated with a 11.66% reduction in the circulation death rate.

**Table 3 Results for circulation programme of care, 2006-07**

| N = 152 | OLS (1) | | 2SLS (2) | | 2SLS (3) | |
|---|---|---|---|---|---|---|
| | CHD deaths | CHD expenditure | CHD deaths | CHD expenditure | CHD SYLL | CHD expenditure |
| Constant | 3.778 (0.135) | -0.857 (0.583) | 1.971 (0.429) | 2.380 (1.212) | 1.982 (0.454) | 3.246 (1.572) |
| Need | 1.497 (0.098) | 0.028 (0.233) | 2.442 (0.239) | 0.623 (0.354) | 2.657 (0.256) | 0.732 (0.389) |
| CHD expenditure | -0.318 (0.063) | | -1.166 (0.202) | | -1.244 (0.214) | |
| Total Budget | | 0.801 (0.227) | | 0.861 (0.239) | | 0.836 (0.229) |
| Cancer deaths SMR | | 0.024 (0.125) | | -0.765 (0.298) | | |
| Cancer SYLL | | | | | | -0.903 (0.365) |
| % white ethnic group | | 0.147 (0.068) | | 0.215 (0.078) | | 0.232 (0.083) |
| % pop unpaid carers | | 0.691 (0.143) | | 0.457 (0.204) | | 0.437 (0.212) |
| *Test statistics:* | | | | | | |
| Sargan ( $\chi_1^2$ ) | | | 9.35 (0.024) | 4.54 (0.033) | 6.81 (0.078) | 4.55 (0.032) |
| Anderson ( $\chi_2^2$ ) | | | 55.9 (0.000) | 35.7 (0.000) | 55.9 (0.000) | 31.3 (0.000) |
| Cragg-Donald (F stat) | | | 21.2 (<0.05) | 22.3 (<0.05) | 21.2 (<0.05) | 18.8 (<0.05) |
| Partial $R^2$ | | | 0.367 | 0.235 | 0.367 | 0.206 |
| Reset: | | | | | | |
| F(3,146) | 0.97 (0.410) | | | | | |
| F(3,143) | | 0.96 (0.413) | | | | |
| Pesaran-Taylor ( $\chi_1^2$ ) | | | 0.09 (0.769) | 0.00 (0.946) | 0.27 (0.600) | 0.05 (0.819) |
| Endogeneity ( $\chi_1^2$ ): | | | | | | |
| CHD expenditure | | | 80.4 (0.000) | | 83.5 (0.000) | |
| Cancer deaths | | | | 10.45 (0.001) | | |
| Cancer SYLL | | | | | | 8.70 (0.003) |

Notes:
1. Parentheses show robust standard errors for parameter estimates and p-values for the test statistics.
2. The instrument set for CHD expenditure includes the proportion of households that are lone pensioner households, the proportion of the population providing unpaid care, the population weighted index of multiple deprivation based on local authority IMD 2007 scores, and the proportion of residents in the white ethnic group.
3. The instrument sets for cancer deaths (SMR) and cancer SYLL include the proportion of households that are lone pensioner households and the population weighted index of multiple deprivation based on local authority level IMD 2007 scores.
4. The term 'CHD' is used as a shorthand for 'circulation problems'.
5. Similar results are obtainable if expenditure data adjusted for (1) PCT lead/host commissioning arrangements and (2) expenditure funded from PCT income is used.

As was the case for 2005/06, two additional 'needs' variables – in the form of the percentage of the population in a 'white' ethnic group and the proportion of the population providing unpaid care – are included in the expenditure models.[29] The positive sign on the unpaid carer regressor implies either that lower levels of need exist in those areas with fewer unpaid carers (patients may buy care in more affluent areas) or that there is some unmet need in those areas with fewer unpaid carers. The positive sign on the 'white' ethnic group variable might indicate some unmet need in those areas with a smaller proportion of the population in the 'white' ethnic group.

Both pairs of death and expenditure equations (under (1) and (2)) show no evidence of misspecification (Pesaran-Taylor test). The cancer deaths term is clearly endogenous in both expenditure equations and the circulation expenditure term is clearly endogenous in both of the outcome equations. Although the instruments are relevant in all four equations (see the Anderson and Cragg-Donald tests), there is a little evidence from the Sargan test that the validity of the instrument set is slightly borderline in three of the four equations. However, we concentrate on the years of life lost outcome equation below where the validity of the instrument set cannot be rejected at the 5% level.[30]

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 (-1.244) implies that a 1% increase in expenditure gives rise to a 1.244% reduction in life years lost. Across 2004-06, the total life years lost to all circulation deaths in those aged under 75 was 1,463,911 (1,607,171 life years in 2002-04).[31] This averaged 487,970 life years per annum which, across an English population of 50 million, averages out at 0.0097594 life years (3.562181 days) per person. Thus a 1% increase in expenditure per head (£1.211) is associated with a 1.244% reduction in life years lost (0.0443135 days) and implies that one life year would cost £9,974 (£8,427 using 2005/06 expenditure data and 2002-04 mortality data).

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

Our cost of a life year saved estimates for cancer and circulation problems are presented in terms of unadjusted life years. In order to give a very rough indication 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 within the programme budgeting areas of cancer and circulatory diseases where these match with the HODaR

[29] 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

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

[31] See the NCHOD website at http://www.nchod.nhs.uk/NCHOD/compendium.nsf/($All)/06BB46F2C83EE7BA802573B5003E6278/$File/06B_107CR_06_V1_D.xls?OpenElement.

categories, and averaged the scores across the categories.[32] Using this method, for cancer expenditure the cost of a QALY is £22,332 (=£15,387/0.689), whilst for circulatory diseases the corresponding figure is £14,909 (=£9,974/0.669). 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.

The results for cancer and circulation problems for 2006/07 are very similar to those for 2005/06. However, cancer and circulation problems comprise just two of the 23 programme budgeting categories and next we attempt to apply the expenditure and outcome models to the other 21 budgeting categories. Unfortunately, the only outcome measures available are mortality rates and so we can apply our outcome model only to those programme budgeting categories where a suitable mortality rate is available. Relevant mortality rates are available for several programme budgeting categories and results for those categories where our models prove to be relevant are presented below (to save space, only 2SLS results are reported).

## Neurological programme of care

Results for the neurological programme of care with deaths caused by epilepsy as the outcome indicator are shown in Table 4.[33] 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.[34] 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, outcome and expenditure models have been estimated 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 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 outcome equation with the epilepsy SMR as the dependent variable only the need term is significant. The Pesaran-Taylor test suggests no evidence of misspecification and tests indicate that the instruments are relevant and valid but that they may be weak. The model with the epilepsy SYLL rate as the dependent variable is poor in that neither the need nor the expenditure term is significant. For both outcomes (SMR and SYLL rate), Shea's partial R-squared is small and the F-statistic for the Cragg-Donald test does not exceed the Staiger and Stock criterion of being greater than 10, indicating a potential problem with weak instruments. This may account for these poor results.

[32] 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 0.689. The corresponding calculation for circulatory diseases is 0.669. Note that these are very rough estimates. To accurately calculate the cost of a 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.

[33] Only 2SLS results are shown.

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

**Table 4 Results for neurological programme of care, 2006-07**

| N = 152 | 2SLS (1) | | 2SLS (2) | |
|---|---|---|---|---|
| | Neurological deaths | Neurological expenditure | Neurological SYLL | Neurological expenditure |
| Constant | 1.852 (1.597) | -0.602 (0.875) | 1.575 (1.520) | 2.074 (1.665) |
| Need | 1.738 (0.609) | 1.064 (0.434) | 0.913 (0.530) | 1.195 (0.448) |
| Neurological expenditure | -0.744 (0.545) | | 0.003 (0.518) | |
| Total Budget | | 0.532 (0.396) | | 0.747 (0.413) |
| All amenable deaths SMR | | -0.523 (0.180) | | |
| All deaths (SYLL) | | | | -0.848 (0.272) |
| *Test statistics:* | | | | |
| Sargan ( $\chi_1^2$ ) | 1.97 (0.372) | 6.94 (0.031) | 2.52 (0.285) | 4.94 (0.084) |
| Anderson ( $\chi_2^2$ ) | 13.6 (0.003) | 92.5 (0.000) | 13.6 (0.003) | 77.2 (0.000) |
| Cragg-Donald (F statistic) | 4.82 (<0.05) | 75.7 (<0.05) | 4.82 (<0.05) | 50.2 (<0.05) |
| Partial $R^2$ | 0.090 | 0.608 | 0.090 | 0.508 |
| Reset: Pesaran-Taylor ( $\chi_1^2$ ) | 2.90 (0.088) | 0.40 (0.527) | 0.11 (0.736) | 0.94 (0.332) |
| Endogeneity ( $\chi_1^2$ ): | | | | |
| Neurological expenditure | 2.45 (0.117) | | 0.00 (0.932) | |
| All amenable deaths | | 8.79 (0.003) | | |
| All deaths (SYLL) | | | | 13.21 (0.000) |

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

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. However, when we employed both the cancer and circulation death rates as proxies for the other calls on resources in the neurological expenditure equation, co-linearity difficulties were encountered with the 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.[35] 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 both of the neurological expenditure equations, two of the three regressors (need and the 'other calls on resources' term) have the anticipated effect on neurological expenditure and the test statistics reveal no evidence of mis-specification. Although the total budget term is insignificant, re-estimation of the expenditure equations dropping the need term results in a highly significant total income term. Again it appears that co-linearity between total budget and need makes it difficult to disentangle the need and income effect.

[35] See Martin, Rice and Smith (2008a) for details of which deaths are deemed amenable to health care.

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, the use of this condition-specific measure of need offers little improvement over the more condition-specific measure of need.

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

## Respiratory problems programme of care

Results for the respiratory programme of care are shown in Table 5.[36] As the mortality outcome indicator we employ the sum of the under 75 years direct SMRs (or SYLL rates) for asthma, for bronchitis, for pneumonia, and for tuberculosis.[37] In 2004 these four causes accounted for about 52,000 of the 65,000 all age deaths attributable to the respiratory problems care programme (NCHOD, 2007 and ONS, VS3 Mortality by Cause, 2004 Registrations).

In both of the outcome equations (see Table 5, columns 1 and 3), need and expenditure have the anticipated signs and are significant. The usual tests indicate that the instruments are relevant and valid, that expenditure is endogenous, and that there is no evidence of misspecification. There is, however, indication that the instruments may be weakly associated with expenditure. Shea's R-squared is low and the Cragg-Donald F-statistic does not exceed Staiger and Stock's recommended criterion of 10. Stock and Yogo (2002) do not provide critical values for the expected ratio of 2SLS bias to OLS bias for two excluded instruments (as is the case here) and so we cannot assess the likely extent of bias related to OLS for these models but some caution should be exercised in the interpretation of these results.

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

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

The results for the outcome model with the SYLL rate as the dependent variable (see column 3) can be used to calculate the marginal cost of one life year. A 1% increase in respiratory expenditure per head – which was £64.7 in 2006/07 – gives rise *ceteris paribus* to a 5.568% reduction in years of life lost. Across 2004-06, the total life years lost to respiratory (asthma, bronchitis and other, pneumonia, and TB) deaths in those aged under 75 was 321,263 or 107,087 per annum (324,735 life years were lost in 2002-04).[38] Across the English population of 50 million, this suggests the loss of 0.0021417 life years (0.78172 days) per person. Thus a 1% increase in expenditure per head (£0.647) is associated

[36] Only 2SLS results are shown.
[37] In our previous study we did not have access to direct SMRs and therefore took weighted averages of the indirect SMRs for asthma, bronchitis and pneumonia with weights reflecting the number of deaths in each category.
[38] See the NCHOD website. For example, the years of life lost to asthma are at: http://www.nchod.nhs.uk/NCHOD/compendium.nsf/($All)/144EAE11245EB562802573B5003E607F/$File/23H_027CR_06_V1_D.xls?OpenElement.

with a 5.568% reduction in life years lost (0.0435261 days) and this implies that one extra life year would cost £5,425 (£7,397 using expenditure data for 2005/06 and mortality data for 2002/04).

**Table 5 Results for respiratory programme of care, 2006-07**

| N = 152 | 2SLS (1) | | 2SLS (2) | |
|---|---|---|---|---|
| | Respiratory deaths | Respiratory Expenditure | Respiratory SYLL | Respiratory expenditure |
| Constant | -10.27 (5.898) | -0.142 (1.249) | -12.21 (6.563) | 2.953 (2.334) |
| Need | 8.008 (2.968) | 1.714 (0.596) | 9.158 (3.298) | 1.741 (0.497) |
| Respiratory expenditure | -4.845 (2.146) | | -5.568 (2.388) | |
| Total Budget | | 0.780 (0.317) | | 1.044 (0.369) |
| All amenable deaths SMR | | -0.802 (0.396) | | |
| All deaths (SYLL) | | | | -1.109 (0.454) |
| %lone pensioner h-holds | | -0.497 (0.346) | | -0.419 (0.251) |
| *Test statistics:* | | | | |
| Sargan ( $\chi_1^2$ ) | 0.32 (0.569) | 2.27 (0.131) | 0.32 (0.566) | 0.25 (0.617) |
| Anderson ( $\chi_2^2$ ) | 7.4 (0.024) | 25.0 (0.000) | 7.4 (0.024) | 27.8 (0.000) |
| Cragg-Donald (F statistic) | 3.82 (<0.05) | 14.3 (<0.05) | 3.82 (<0.05) | 16.3 (<0.05) |
| Partial $R^2$ | 0.049 | 0.165 | 0.049 | 0.183 |
| Reset: Pesaran-Taylor ( $\chi_1^2$ ) | 1.46 (0.226) | 0.27 (0.602) | 2.52 (0.112) | 0.11 (0.735) |
| Endogeneity ( $\chi_1^2$ ): | | | | |
| Respiratory expenditure | 71.67 (0.000) | | 73.20 (0.000) | |
| All amenable deaths | | 9.71 (0.001) | | |
| All deaths (SYLL) | | | | 11.76 (0.000) |

Notes:
1. Parentheses show robust standard errors for parameter estimates and p-values for the test statistics.
2. The instrument set for respiratory expenditure includes the proportion of the population providing unpaid care, and the population weighted index of multiple deprivation based on local authority IMD 2007 scores.
3. The instrument sets for all amenable deaths (SMR) and all deaths (SYLL) include the proportion of the population providing unpaid care, and the population weighted index of multiple deprivation based on local authority level IMD 2007 scores.
4. The negative coefficient on the lone pensioner households variable might reflect a selection effect. This variable is also significant and has a negative sign in the first stage regressions predicting the endogenous terms 'all amenable deaths' and 'all deaths SYLL'.
5. The deaths (under 75 years direct SMR) outcome indicator is the sum of individual asthma, bronchitis, pneumonia and TB SMRs while the under 75 years SYLL rate outcome indicator is the sum of the asthma, bronchitis, pneumonia and TB SYLL rates.
6. Similar results are obtainable if expenditure data adjusted for (1) PCT lead/host commissioning arrangements and (2) expenditure funded from PCT income is used.

## Gastro-intestinal programme of care

Results for the gastro-intestinal programme of care are shown in Table 6.[39] As mortality outcome indicators we use the sum of the direct SMRs and the sum of the SYLL rates for deaths from liver disease and from an ulcer for those aged under 75 years.[40] 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 of a life-year estimates are likely to be too high.

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

[39] Only 2SLS results are shown.
[40] When estimating the outcome equations previously, we only had access to indirect SMRs which we calculated by taking a weighted average if the indirect SMRs for both causes of death (liver diseases and ulcers).

significant. Again, the usual tests indicate that the instruments are relevant and valid, that the all amenable deaths term is endogenous, and that there is little evidence of misspecification

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

| N = 152 | 2SLS (1) | | 2SLS (2) | |
|---|---|---|---|---|
| | Gastro deaths | Gastro expenditure | Gastro SYLL | Gastro expenditure |
| Constant | -2.154 (1.046) | 2.133 (1.762) | -0.954 (1.054) | 8.378 (3.337) |
| Need | 3.852 (0.551) | 2.626 (0.851) | 3.966 (0.557) | 2.839 (0.758) |
| Gastro expenditure | -1.754 (0.396) | | -1.544 (0.399) | |
| Total Budget | | 0.538 (0.355) | | 1.058 (0.445) |
| All amenable deaths SMR | | -1.386 (0.565) | | |
| All deaths (SYLL) | | | | -2.093 (0.663) |
| % lone pensioner h-holds | | -0.838 (0.491) | | -0.793 (0.384) |
| *Test statistics:* | | | | |
| Sargan ( $\chi_1^2$ ) | 3.46 (0.176) | 9.52 (0.002) | 5.01 (0.081) | 1.98 (0.159) |
| Anderson ( $\chi_2^2$ ) | 29.3 (0.000) | 25.0 (0.000) | 29.3 (0.000) | 27.8 (0.000) |
| Cragg-Donald (F statistic) | 11.7 (<0.05) | 14.3 (<0.05) | 11.7 (<0.05) | 16.3 (<0.05) |
| Partial $R^2$ | 0.193 | 0.164 | 0.193 | 0.183 |
| Reset: Pesaran-Taylor ( $\chi_1^2$ ) | 0.22 (0.640) | 0.01 (0.938) | 1.01 (0.315) | 0.13 (0.722) |
| Endogeneity ( $\chi_1^2$ ): | | | | |
| Gastro expenditure | 31.72 (0.000) | | 20.80 (0.000) | |
| All amenable deaths | | 14.72 (0.000) | | |
| All deaths (SYLL) | | | | 24.65 (0.000) |

Notes:
1. Parentheses show robust standard errors for parameter estimates and p-values for the test statistics.
2. The instrument set for gastro-intestinal expenditure includes the proportion of households that are lone pensioner households, the proportion of the population providing unpaid care, and the population weighted index of multiple deprivation based on local authority level IMD 2007 scores.
3. The instrument sets for all amenable deaths (SMR) and all deaths (SYLL) include the proportion of households that are lone pensioner households and the population weighted index of multiple deprivation based on local authority level IMD 2007 scores.
4. The deaths (under 75 years direct SMR) outcome indicator is the sum of the direct SMRs for liver disease and for ulcers while the SYLL rate outcome indicator is the sum of the under 75 liver disease and ulcer SYLL rates.
5. Similar results are obtainable if expenditure data adjusted for (1) PCT lead/host commissioning arrangements and (2) expenditure funded from PCT income is used.

The results from the gastro-intestinal outcome model with the SYLL rate as the dependent variable can be used to calculate the marginal cost of a single life year. The gastro-intestinal expenditure coefficient of -1.544 implies that a 1% increase in expenditure gives rise to a 1.544% reduction in life years lost. A 1% increase in gastro-intestinal expenditure per head – which was £72.9 in 2006/07 – gives rise *ceteris paribus* to a 1.544% reduction in years of life lost. Across 2004-06, the total life years lost to gastro-intestinal deaths in those aged under 75 was 328,834 (or 109,611 life years per annum).[41] Across the English population of 50 million, this suggests the loss of 0.0021922 life years (0.800153 days) per person. Thus a 1% increase in expenditure per head (£0.729) is associated with a 1.544% reduction in life years lost (0.0123543 days) and implies that one extra life year would cost £21,538 (£19,000 using mortality data for 2002-04 and expenditure data for 2005/06).

## Trauma and injuries programme of care

2SLS results for the trauma and injuries programme of care are shown in Table 7. For the mortality outcome indicator we employ the sum of the direct SMRs for deaths from a fractured femur (ages 65-84) and from a skull fracture (ages under 75).[42] No SYLL rate data is available for these causes of

[41] See the NCHOD website. For example, the years of life lost from liver disease are at: http://www.nchod.nhs.uk/NCHOD/compendium.nsf/($All)/68ADC9892E7338C3802573B5003E6178/$File/25B_067CR_06_V1_D.xls?OpenElement.

[42] When estimating the outcome equations previously, we only had access to indirect SMRs which we calculated by taking a weighted average if the indirect SMRs for both causes of death (fractured femur and skull).

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).

In the outcome equation (see column 1 of Table 7) only the need term is significant with the anticipated sign. There is, however, indication that the instruments may be weakly associated with expenditure (for example, the Cragg-Donald F-statistic does not exceed Staiger and Stock's recommended level of 10) and this may account for the insignificance of the expenditure term. In both of the expenditure equations (see columns 2 and 4), need and the other calls on resources terms have the anticipated effect on expenditure and are statistically significant. Only the total budget term is insignificant and this becomes significant in both equations if the equation is re-estimated with the need term is dropped. The usual tests indicate that the instruments are relevant and valid, that the deaths term is endogenous, and that there is no evidence of misspecification.

**Table 7 Results for trauma and injuries programme of care, 2006-07**

| **N = 152** | **2SLS (2)** | | **2SLS (3)** | |
|---|---|---|---|---|
| | **Trauma deaths** | **Trauma expenditure** | **Trauma SYLL** | **Trauma expenditure** |
| Constant | 1.934 (1.493) | 1.373 (1.104) | | 5.640 (2.299) |
| Need | 1.444 (0.630) | 1.906 (0.590) | | 2.081 (0.677) |
| Trauma expenditure | -0.120 (0.516) | | | |
| Total Budget | | 0.222 (0.519) | | 0.580 (0.544) |
| All amenable deaths SMR | | -0.916 (0.226) | | |
| All deaths (SYLL) | | | | -1.416 (0.371) |
| *Test statistics:* | | | | |
| Sargan ( $\chi_1^2$ ) | 0.271 (0.256) | 1.84 (0.396) | | 0.51 (0.772) |
| Anderson ( $\chi_2^2$ ) | 20.0 (0.000) | 92.5 (0.000) | | 77.2 (0.000) |
| Cragg-Donald (F statistic) | 7.46 (<0.05) | 75.7 (<0.05) | | 50.2 (<0.05) |
| Partial $R^2$ | 0.132 | 0.608 | | 0.508 |
| Reset: Pesaran-Taylor ( $\chi_1^2$ ) | 0.26 (0.609) | 0.26 (0.611) | | 0.17 (0.680) |
| Endogeneity ( $\chi_1^2$ ): | | | | |
| Trauma expenditure | 0.816 (0.366) | | | |
| All amenable deaths | | 23.38 (0.000) | | |
| All deaths (SYLL) | | | | 29.18 (0.000) |

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

## Diabetes programme of care

2SLS outcome and expenditure equations for the diabetes programme of care are shown in Table 8. 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 in the expenditure equations so the latter replaced the former in the two expenditure equations. However, the two other terms in the expenditure equations – PCT income and other calls on resources – are insignificant.

**Table 8 Results for diabetes programme of care, 2006-07**

| N = 152 | 2SLS (1) | | 2SLS (2) | |
|---|---|---|---|---|
| | Diabetes deaths | Diabetes expenditure | Diabetes SYLL | Diabetes expenditure |
| Constant | -11.45 (4.958) | -2.631 (1.139) | -7.80 (4.453) | -3.131 (1.834) |
| Need | 4.096 (1.120) | | 3.411 (1.033) | |
| Diabetes expenditure | -2.146 (1.059) | | -1.648 (0.942) | |
| Total budget | | 0.280 (0.295) | | 0.214 (0.383) |
| All amenable deaths SMR | | 0.190 (0.193) | | |
| All deaths (SYLL) | | | | 0.243 (0.286) |
| % lone pensioner h-holds | -1.95 (0.540) | | -1.252 (0.508) | |
| Diabetes prevalence rate | | 0.732 (0.174) | | 0.755 (0.170) |
| *Test statistics:* | | | | |
| Sargan ( $\chi_1^2$ ) | 0.37 (0.541) | 0.87 (0.646) | 0.12 (0.719) | 1.03 (0.595) |
| Anderson ( $\chi_2^2$ ) | 4.11 (0.127) | 94.7 (0.000) | 4.11 (0.127) | 78.8 (0.000) |
| Cragg-Donald (F statistic) | 2.04 (0.133) | 80.6 (<0.05) | 2.04 (0.133) | 52.4 (<0.05) |
| Partial $R^2$ | 0.027 | 0.623 | 0.027 | 0.518 |
| Reset: Pesaran-Taylor ( $\chi_1^2$ ) | 20.54 (0.000) | 0.01 (0.912) | 3.74 (0.053) | 0.00 (0.944) |
| Endogeneity ( $\chi_1^2$ ): | | | | |
| Diabetes expenditure | 21.62 (0.000) | | 8.25 (0.004) | |
| All amenable deaths | | 0.98 (0.320) | | |
| All deaths (SYLL) | | | | 0.50 (0.476) |

Notes:
1. Parentheses show robust standard errors for parameter estimates and p-values for the test statistics.
2. The instrument set for diabetes expenditure includes the proportion of households that are lone pensioner households, the proportion of the population providing unpaid care, and the population weighted index of multiple deprivation based on local authority level IMD 2007 scores.
3. The instrument sets for all amenable deaths (SMR) and all deaths (SYLL) include the proportion of households that are lone pensioner households, the proportion of the population providing unpaid care, the population weighted index of multiple deprivation based on local authority level IMD 2007 scores, and the all specialty needs index (not included as a regressor in the second-stage equations).
4. The diabetes death measure is the under 75 years direct SMR for 2004-06 and the SYLL rate is for those aged under 75 over the same three year period. The expenditure and outcome data have identical ICD 10 coverage.
5. Similar results are obtainable if expenditure data adjusted for (1) PCT lead/host commissioning arrangements and (2) expenditure funded from PCT income is used.

The need term is significant in both outcome equations and, although expenditure is significant in the SMR outcome equation, it is only significant at the 10% level in the SYLL outcome equation. There is also evidence that the instruments are weak. This implies that caution should be exercised in using the coefficient on the diabetes expenditure variable (this is -1.648) to estimate the marginal cost of an additional life year saved in this budgeting category. Nevertheless, we can calculate that a 1% increase in diabetes expenditure per head – which was £17.6 in 2006/07 – gives rise *ceteris paribus* to a 1.648% reduction in the years of life lost. Across 2004-06, the total life years lost to diabetes deaths in those aged under 75 was 60,614 (or 20,205 life years per annum).[43] Across the English population of 50 million, this suggests a loss of 0.0004041 life years (0.14750 days) per person. Thus a 1% increase in expenditure per head (£0.176) is associated with a 1.648% reduction in life years lost (0.0024307 days) and implies that one extra life year would cost £26,429 (£26,453 using mortality data for 2002-04 and expenditure data for 2005/06).

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

[43] See the NCHOD website at: http://www.nchod.nhs.uk/NCHOD/compendium.nsf/($All)/F838A93421F4EAC9802573B5003E617D/$File/27R_069CR_06_V1_D.xls?OpenElement.

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

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

For some budgeting categories no relevant mortality indicator is available 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.[44] These results illustrate the applicability of our expenditure model to programmes of care even when the absence of a mortality measure precludes the application of our outcome model.[45]

**Table 9 Expenditure equations for vision problems and endocrine/metabolic problems**

| **N = 152** | **Vision expenditure (PBC 8)** | | **Endocrine/metabolic expenditure (PBC 4)** | |
|---|---|---|---|---|
| | **2SLS** | **2SLS** | **2SLS** | **2SLS** |
| Constant | 0.673 (1.220) | 5.383 (2.402) | -1.873 (0.833) | -1.483 (1.322) |
| Need | 1.769 (0.546) | 1.989 (0.586) | | |
| Total Budget | 0.556 (0.465) | 0.940 (0.514) | 0.885 (0.185) | 0.943 (0.247) |
| All amenable deaths (SMR) | -0.948 (0.254) | | -0.085 (0.135) | |
| All deaths (SYLL) | | -1.514 (0.394) | | -0.137 (0.200) |
| Diabetes prevalence rate | | | 0.391 (0.123) | 0.382 (0.120) |
| *Test statistics:* | | | | |
| Sargan ( $\chi_1^2$ ) | 7.13 (0.007) | 4.59 (0.032) | 0.29 (0.024) | 0.21 (0.647) |
| Anderson ( $\chi_2^2$ ) | 92.2 (0.000) | 76.0 (0.000) | 92.3 (0.000) | 78.1 (0.000) |
| Cragg-Donald | 113.4 (<0.05) | 73.5 (0.05) | 113.9 (<0.05) | 77.7 (<0.05) |
| Partial $R^2$ | 0.606 | 0.500 | 0.607 | 0.514 |
| Reset: Pesaran-Taylor ( $\chi_1^2$ ) | 0.05 (0.824) | 0.01 (0.920) | 0.22 (0.638) | 0.18 (0.671) |
| Endogeneity ( $\chi_1^2$ ): | | | | |
| All amenable deaths (SMR) | 9.44 (0.002) | | 7.65 (0.005) | |
| All deaths (SYLL) | | 12.60 (0.000) | | 5.26 (0.021) |

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

[44] Only 2SLS results are shown.
[45] 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.

## Vision problems

Expenditure equations for vision problems are shown in columns 1 and 2 of Table 9. In both equations the need and other calls on resources terms are significant and have the correct sign.

The coefficient on PCT income is positive but insignificant although if the need term is dropped then the coefficient on PCT income increases and become significant. The Sargan test suggests that there might be some misspecification in one of the equations but, generally, the diagnostic statistics do not reveal any problems.

## Endocrine, nutritional and metabolic problems

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

## Mental health programme of care

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

| **N = 150 (mental health)**<br>**N = 152 (musculo-skeletal)** | **Mental health expenditure (PBC 5)** | | **Musculo-skeletal expenditure (PBC 15)** | |
|---|---|---|---|---|
| | **2SLS** | **2SLS** | **2SLS** | **2SLS** |
| Constant | 9.729 (3.117) | 33.44 (13.872) | 1.741 (1.448) | 6.418 (2.857) |
| Need | 2.125 (0.500) | 3.120 (1.135) | 2.110 (0.760) | 2.338 (0.862) |
| Total Budget | 2.072 (0.418) | 4.135 (1.366) | -0.009 (0.583) | 0.359 (0.581) |
| All amenable deaths (SMR) | -2.958 (0.093) | | -0.952 (0.289) | |
| All deaths (SYLL) | | -6.157 (2.314) | | -1.511 (0.455) |
| % lone pensioner h-holds | -0.940 (0.273) | -0.701 (0.483) | | |
| *Test statistics:* | | | | |
| Sargan ( $\chi_1^2$ ) | 0.20 (0.654) | 1.97 (0.159) | 4.85 (0.027) | 2.71 (0.099) |
| Anderson ( $\chi_2^2$ ) | 26.2 (0.000) | 7.1 (0.028) | 91.7 (0.000) | 75.4 (0.000) |
| Cragg-Donald | 15.2 (<0.05) | 3.5 (<0.05) | 112.9 (<0.05) | 72.8 (<0.05) |
| Partial $R^2$ | 0.175 | 0.047 | 0.607 | 0.499 |
| Reset:<br>Pesaran-Taylor ( $\chi_1^2$ ) | 2.09 (0.148) | 6.13 (0.013) | 0.09 (0.760) | 0.18 (0.675) |
| Endogeneity ( $\chi_1^2$ ): | | | | |
| All amenable deaths (SMR) | 38.11 (0.000) | | 13.36 (0.000) | |
| All deaths (SYLL) | | 38.83 (0.000) | | 17.09 (0.000) |

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

Expenditure equations for the mental health programme of care are shown in the first two columns of Table 10. These are for all mental health expenditure including that on dementia. The three usual regressors – (mental health) need, total budget, and the proxies for other calls on resources – have

the anticipated effect on expenditure in both equations and all six are statistically significant.[46] The percentage of all households that are lone pensioner households has a significant negative impact on expenditure. This might reflect a selection effect or indicate the presence of unmet need. The diagnostic statistics detect no issues with these equations. A second condition-specific measure of mental health need – the mental illness prevalence rate – is available from data collected for the Quality and Outcomes Framework (QOF). However, the use of this need indicator as a regressor led to no overall improvement in the results.

### Musculo-skeletal programme of care

Expenditure equations for the musculo-skeletal programme of care are shown in final two columns of Table 10. Two of the three regressors – need and the proxies for other calls on resources – have the anticipated effect on expenditure and are statistically significant. The proxies for the other calls on resources variables are endogenous and there is no evidence of mis-specification. Although the PCT income term is insignificant, re-estimation of both expenditure equations without the need term generates positive and significant coefficients on PCT income.

### Poisoning programme of care

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

## 8. Conclusions

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

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

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

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

[46] 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.

These figures provide evidence that expenditure on the various disease catagories yields quite consistent benefits in terms of life years saved. Furthermore, it is quite likely that the variations we observe between the costs in the different programmes can be explained by: (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 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 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. We did have available a number of additional condition-specific needs variables which have hitherto not been available, but in general these did not in general perform any better than the more generic all specialty need variable.

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

We nevertheless believe that programme budgeting is a major initiative that offers immense potential for researchers and policy makers. 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. This paper 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

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

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

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

| | Programme budget category | National expenditure per head of population, England, £ | | | | | |
|---|---|---|---|---|---|---|---|
| | | Net | Net, adj | Net | Net, adj | Net | Net, adj |
| | | 2004/05 | 2004/05 | 2005/06 | 2005/06 | 2006/07 | 2006/07 |
| **1** | **Infectious Diseases** | 20.1 | 20.2 | 23.7 | 23.6 | 21.4 | 20.9 |
| 1a | HIV and AIDS | | | | | 7.4 | 7.4 |
| 1x | Infectious diseases (Other) | | | | | 14.0 | 13.5 |
| **2** | **Cancers and Tumours** | 75.1 | 75.5 | 82.8 | 83.2 | 80.9 | 81.7 |
| 2a | Cancer, Head and Neck | | | | | 2.8 | 2.8 |
| 2b | Cancer, Upper GI | | | | | 4.0 | 4.1 |
| 2c | Cancer, Lower GI | | | | | 6.4 | 6.5 |
| 2d | Cancer, Lung | | | | | 3.9 | 3.9 |
| 2e | Cancer, Skin | | | | | 1.9 | 1.9 |
| 2f | Cancer, Breast | | | | | 7.3 | 7.4 |
| 2g | Cancer, Gynaecological | | | | | 2.9 | 3.0 |
| 2h | Cancer, Urological | | | | | 7.7 | 7.8 |
| 2i | Cancer, Haematological | | | | | 8.4 | 8.4 |
| 2x | Cancers and Tumours (Other) | | | | | 35.5 | 36.0 |
| **3** | **Disorders of Blood** | 16.9 | 17.0 | 17.4 | 17.5 | 16.5 | 16.6 |
| **4** | **Endocrine, Nutritional and Metabolic** | 31.7 | 31.9 | 37.0 | 37.3 | 36.4 | 36.7 |
| 4a | Diabetes | 13.5 | 13.6 | 16.8 | 17.0 | 17.6 | 17.8 |
| 4b | Endocrine, Nutritional and Metabolic | | | | | 6.9 | 6.9 |
| 4x | Other Endocrine, Nutritional, Metabolic | 18.2 | 18.2 | 20.1 | 20.3 | 11.9 | 12.0 |
| **5** | **Mental Health Disorders** | 145.3 | 146.8 | 156.9 | 159.0 | 163.9 | 166.5 |
| 5a | Substance Misuse | 11.9 | 12.3 | 14.0 | 14.4 | 13.1 | 13.8 |
| 5b | Organic Mental Disorders | 16.1 | 15.9 | 16.3 | 16.4 | 14.0 | 14.2 |
| 5c | Psychotic Disorders | | | | | 23.7 | 23.8 |
| 5d | Child and Adolescent Mental Health | | | | | 12.0 | 12.1 |
| 5x | Other Mental Health Disorders | 117.3 | 118.6 | 126.7 | 128.2 | 101.1 | 102.5 |
| **6** | **Problems of Learning Disability** | 42.0 | 43.4 | 44.7 | 46.5 | 46.2 | 48.4 |
| **7** | **Neurological** | 34.9 | 35.1 | 40.8 | 41.1 | 54.7 | 55.3 |
| 7a | Chronic Pain | | | | | 19.2 | 19.3 |
| 7x | Neurological (Other) | | | | | 35.5 | 36.0 |
| **8** | **Problems of Vision** | 27.5 | 27.6 | 28.0 | 28.2 | 26.8 | 27.0 |
| **9** | **Problems of Hearing** | 6.3 | 6.3 | 6.2 | 6.3 | 6.1 | 6.2 |
| **10** | **Problems of Circulation** | 122.0 | 122.4 | 123.6 | 124.3 | 121.1 | 122.1 |
| 10a | Coronary Heart Disease | | | | | 38.6 | 38.9 |
| 10b | Cerebrovascular disease | | | | | 15.9 | 16.1 |
| 10c | Problems of Rhythm | | | | | 7.2 | 7.2 |
| 10x | Problems of circulation (Other) | | | | | 59.4 | 59.9 |
| **11** | **Problems of the Respiratory System** | 62.5 | 62.7 | 69.2 | 69.6 | 64.7 | 65.1 |
| 11a | Obstructive Airways Disease | | | | | 10.6 | 10.6 |
| 11b | Asthma | | | | | 14.0 | 14.0 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 11x | Problems of the respiratory system, other | | | | | 40.1 | 40.4 |
| **12** | **Dental Problems** | 13.3 | 13.6 | 23.3 | 24.9 | 44.3 | 51.9 |
| **13** | **Problems of Gastro Intestinal System** | 73.0 | 73.2 | 80.9 | 81.3 | 72.9 | 73.3 |
| 13a | Upper GI | | | | | 19.8 | 19.9 |
| 13b | Lower GI | | | | | 20.3 | 20.5 |
| 13c | Hepatobiliary | | | | | 11.2 | 11.3 |
| 13x | Problmes of the gastro intestinal system | | | | | 21.5 | 21.7 |
| **14** | **Problems of the Skin** | 24.8 | 16.1 | 26.6 | 26.8 | 28.1 | 28.3 |
| 14a | Burns | | | | | 1.1 | 1.1 |
| 14x | Problems of the Skin | | | | | 27.0 | 27.2 |
| **15** | **Problems of Musculo Skeletal System** | 71.2 | 71.7 | 74.2 | 74.7 | 65.5 | 66.2 |
| **16** | **Problems due to Trauma and Injuries** | 71.9 | 72.1 | 75.9 | 76.4 | 56.8 | 57.3 |
| **17** | **Problems of Genito Urinary System** | 62.1 | 62.4 | 67.2 | 67.4 | 68.5 | 69.0 |
| 17a | Genital tract problems | | | | | 19.2 | 19.3 |
| 17b | Renal problems | | | | | 21.4 | 21.5 |
| 17c | STD | | | | | 4.2 | 4.3 |
| 17x | Problems of Genito Urinary system, other | | | | | 23.6 | 23.8 |
| **18** | **Maternity and Reproductive Health** | 54.7 | 55.0 | 59.9 | 60.4 | 57.2 | 57.6 |
| **19** | **Conditions of Neonates** | 13.9 | 13.9 | 13.3 | 13.4 | 13.1 | 13.2 |
| **20** | **Adverse effects and poisoning** | 12.3 | 12.3 | 14.2 | 14.3 | 14.5 | 14.6 |
| 20a | Unintended consequences of treatment | | | | | 10.5 | 10.5 |
| 20b | Poisoning | | | | | 2.1 | 2.1 |
| 20c | Violence | | | | | 0.5 | 0.5 |
| 20x | Poisoning and adverse effects | | | | | 1.4 | 1.4 |
| **21** | **Healthy Individuals** | 21.7 | 22.8 | 24.6 | 26.2 | 25.2 | 26.8 |
| 21a | NSF Prevention programme | | | | | 2.2 | 2.3 |
| 21b | NSF Mental health prevention | | | | | 0.2 | 0.2 |
| 21x | Healthy Individuals (Other) | | | | | 22.8 | 24.4 |
| **22** | **Social Care Needs** | 25.1 | 30.9 | 27.7 | 33.6 | 23.2 | 30.3 |
| **23** | **Other** | 154.7 | 157.8 | 168.1 | 171.8 | 206.6 | 209.7 |
| 23a | GMS/PMS | 126.9 | 127.4 | 145.5 | 146.1 | 140.6 | 141.4 |
| 23b | Training (WDCs) | 0.0 | -0.2 | 0.4 | 0.5 | 0.5 | 0.6 |
| 23x | Miscellaneous | 27.8 | 30.4 | 22.2 | 25.2 | 65.5 | 67.7 |
| | **Total** | 1183.1 | 1190.8 | 1286.2 | 1307.8 | 1314.5 | 1344.5 |

Note: The two differences between the net and net adjusted expenditure figures are that the latter incorporate adjustments for (1) PCT lead/host commissioning arrangements and (2) expenditure funded from charges levied by PCTs. We use the net expenditure data when estimating the regression models (although similar results are obtainable with the net adjusted data). We have used the net data in both previous studies although in Martin, Rice and Smith (2008b) it was noted that the use of the net adjusted expenditure data generated very similar results to those obtained using the net data.

Table A2 reports correlation coefficients between expenditure (cost adjusted) per head (2006-07) and various socio-economic indicators for four programme budgeting categories. Table A3 reports correlation coefficients between SMRs for three programme budgeting categories and various socio-economic indicators.

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

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

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

**Table A3 Correlation between SMRs for three programme budgeting categories and various socio-economic indicators, across all PCTs**

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

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

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

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

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

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

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

### 1. Cancer programme of care

The instrument set for the cancer programme of care includes the proportion of households that are lone pensioner households and the proportion of the population providing unpaid care. These instruments have intuitive appeal. The first stage regressions of cancer expenditure on the instruments and the need for 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.

### 7. Diabetes programme of care

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

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

| Programme 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** |
| **Diabetes** | | | | | | |
| Expenditure | 1.724** | -0.606* | 0.064 | | | -0.240 |
| Amenable SMR | 0.075 | -0.505** | 0.242* | | 0.412** | 0.306** |

Notes: (1) that *=significant at 5% level and **=significant at 1% level; and
(2) that the 'need' term in the amenable SMR equation for diabetes is the diabetes prevalence rate.

## Appendix C: Descriptive statistics for the socio-economic and mortality variables employed in the regression analysis

Table C1 reports descriptive statistics for various socio-economic and mortality variables employed in the regression analysis (these are all for variables in absolute form). The 'need for health care' index averages about 1 across all PCTs but varies substantially with some PCTs having a needs index 30% below the national average and others having a need for health care 40% above the national average. On average, lone pensioner households comprise 14% of all households and lone parent households account for 7% of all households. The 'white ethnic' group accounts for 89% of the population and 10% of the population are unpaid carers. 12% of the working age population (aged 16-74) have a limiting long-term illness and 6% are permanently sick. On average, 1% of the population is long-term unemployed.

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

In addition to the SMRs, we also employ a measure of the avoidable years of life lost (YLL). This 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 (SYLL) rate is the second health outcome variable employed in this study (Lakhani et al., 2006, p379). As Table 1 shows, on average 158 years of life were lost annually to cancer per 10,000 population over the three year period 2004-2006. For circulation problems, 108 years of life were lost each year per 10,000 population. For all causes of death 483 years of life were lost annually and 153 years of life per 10,000 population were lost annually for deaths from causes considered amenable to health care. Descriptive statistics for other causes of death are also presented in Table 1.

**Table C1 Descriptive statistics for socio-economic and mortality variables employed in the regression analysis**

| Variable | Mean | Std. Dev. | Min | Max |
|---|---|---|---|---|
| Need | 1.03 | 0.14 | 0.72 | 1.40 |
| Lone pensioners | 0.14 | 0.02 | 0.10 | 0.19 |
| Lone parents | 0.07 | 0.02 | 0.04 | 0.12 |
| White ethnic group | 0.89 | 0.13 | 0.39 | 0.99 |
| Unpaid carers | 0.10 | 0.01 | 0.07 | 0.12 |
| Working age with LLTI | 0.12 | 0.03 | 0.07 | 0.18 |
| Permanently sick | 0.06 | 0.02 | 0.02 | 0.12 |
| Long-term unemployed | 0.01 | 0.01 | 0.00 | 0.03 |
| IMD2007 | 23.63 | 9.07 | 8.06 | 46.97 |
| Cancer SMR | 120.80 | 14.76 | 76.71 | 165.98 |
| Cancer SYLL rate | 158.36 | 18.30 | 103.55 | 218.82 |
| Circulation SMR | 90.19 | 19.41 | 55.59 | 142.35 |
| Circulation SYLL rate | 108.56 | 25.21 | 65.20 | 177.80 |
| All causes SMR | 326.69 | 56.31 | 211.71 | 495.66 |
| Amenable causes SMR | 118.45 | 23.32 | 69.18 | 186.24 |
| All causes SYLL rate | 483.39 | 83.87 | 318.09 | 742.49 |
| Amenable causes SYLL rate | 153.28 | 30.97 | 88.32 | 249.26 |
| Epilepsy SMR | 1.65 | 0.61 | 0.19 | 3.93 |
| Epilepsy SYLL rate | 5.25 | 2.13 | 0.54 | 13.09 |
| Asthma SMR | 1.60 | 0.61 | 0.62 | 4.04 |
| Bronchitis SMR | 13.72 | 4.87 | 5.94 | 27.29 |
| Pneumonia SMR | 7.59 | 2.59 | 2.47 | 16.10 |
| TB SMR | 0.42 | 0.46 | 0.00 | 2.64 |
| Asthma SYLL rate | 2.39 | 1.26 | 0.13 | 6.34 |
| Bronchitis SYLL rate | 11.99 | 4.80 | 3.74 | 26.12 |
| Pneumonia SYLL rate | 9.70 | 3.72 | 3.61 | 21.89 |
| TB SYLL rate | 0.85 | 1.07 | 0.00 | 5.21 |
| Liver disease SMR | 10.99 | 4.14 | 4.83 | 32.77 |
| Ulcer SMR | 2.08 | 0.93 | 0.24 | 8.29 |
| Liver disease SYLL rate | 22.94 | 9.91 | 8.22 | 74.96 |
| Ulcer SYLL rate | 2.66 | 1.45 | 0.06 | 11.56 |
| Femur fracture SMR | 10.06 | 6.60 | 0.00 | 30.63 |
| Skull fracture SMR | 1.94 | 0.78 | 0.42 | 4.36 |
| Diabetes SMR | 3.48 | 1.47 | 1.31 | 11.20 |
| Diabetes SYLL rate | 4.52 | 2.07 | 1.27 | 15.29 |