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Performance Indicators for Primary Care Management in the NHS

Antonio Giuffrida
Hugh Gravelle
Martin Roland

DISCUSSION PAPER 160

PERFORMANCE INDICATORS FOR PRIMARY CARE MANAGEMENT IN THE NHS

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THE AUTHORS

National Primary Care Research and Development Centre. Antonio Giuffrida (ag19@york.ac.uk) is a Research Fellow and Hugh Gravelle (hg8@york.ac.uk) is Professor of Economics and Associate Director of Research and Development based in the Centre for Health Economics, University of York. Martin Roland (MROLAND@fs1.cpcr.man.ac.uk) is Professor of General Practice and Director of Research and Development, University of Manchester.

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ABSTRACT

There is increased emphasis on the measurement of performance in the NHS. Following the White Paper, additional high level indicators for measuring primary care performance at Health Authority level have been proposed by the NHS Executive. These include measures based on prescribing and on hospital admission rates for certain acute and chronic conditions. It is suggested that higher hospital admission rates for some conditions may indicate deficiencies in their management in primary care.

In this paper we argue that there are difficulties with some of the proposed measures. The difficulties arise because individual single indicators are used to attempt to reflect more than one aspect of performance, may have large year to year variation and be subject to confounding. Using data on Family Health Services Authorities (FHSAs) from 1989/90 to 1994/5 we investigate how admission rates, and the ranking of FHSAs by admission rates, vary as socio-economic and secondary and primary care supply conditions are allowed for. The impact of socio-economic factors on admission rates and rankings is at least as large as the impact of the age and sex structure of FHSA populations. Allowing also for secondary care supply conditions has a smaller, but still noticeable, effect.

We suggest that if admission rates are used as performance indicators in primary care they should be standardised for socio-economic and supply conditions, as well as for demographic factors. We also make a number of other suggestions for improving the indicators.

1. INTRODUCTION

The increasing policy emphasis on quality in the National Health Service (NHS) has led to greater interest in performance indicators in all areas, including primary care. In setting out its future policy on the NHS in the White Paper *The New NHS: Modern, Dependable* (Department of Health, 1997), the incoming Labour government stressed the need for a new performance framework to measure progress towards its objectives.

The recent consultation paper produced by the National Health Service Executive (NHS Executive, 1998) proposed additional performance indicators for the comparison of the quality of primary health care provided in Health Authorities (HAs). HAs will be responsible for monitoring the performance of the Primary Care Groups (PCGs) which will be established from April 1999 to commission and deliver health care. The PCGs will in turn eventually have responsibility for monitoring the quality of primary care services delivered by their constituent general practices.

The greater emphasis on performance monitoring and accountability increases the importance of understanding the merits and drawbacks of the measures used. The aim of this paper is to examine the newly proposed primary care performance indicators as a means of illustrating some of the issues raised in the selection and interpretation of performance indicators.

The new primary care performance indicators relate to aspects of prescribing and care for acute and chronic conditions and are intended to show the extent to which HAs are effectively delivering appropriate health care. Section 2 describes the measures and discusses their suitability as primary care performance indicators. We then concentrate on a subset of the new indicators: the admission rates for the three chronic conditions - asthma, diabetes and epilepsy. Admission rates may be influenced by factors such as socio-economic characteristics of the area and the supply of secondary care facilities, as well as by the quality of primary care provided. Section 3 discusses different methods of allowing for confounding. In section 4 we investigate the magnitude of the confounding problem using data on admission rates in English Family Health Services Authorities (FHSAs)[1] over a six year period from 1989/90 to 1995/6. Section 5 summarises our conclusions about the new primary care indicators and makes suggestions for improvement.

[1] The 90 FHSAs were responsible for the administration of primary health care services in England until April 1996 when they were replace by 95 HAs with roughly similar geographical coverage. The HAs are responsible for both primary and secondary care.

2. THE NEW PRIMARY CARE PERFORMANCE INDICATORS

The consultation document on the national framework for assessing performance suggests a set of high level indicators to assess primary care performance in HAs (NHS Executive, 1998). The indicators are intended to measure whether HAs have cost-effective delivery of appropriate health care. Some, such as the percentage of the female population aged 20 to 64 screened for cervical cancer and the percentage of children vaccinated, were included in the Health Service Indicators produced by the NHS Executive over the years 1990/1 to 1994/5 (NHS Executive, 1995). Additional indicators, relating to prescribing, hospital admission rates for certain acute conditions, and admission rates for three chronic conditions (asthma, diabetes and epilepsy) are now proposed.

Prescribing indicators. Two new prescribing indicators are proposed. The cost effectiveness of prescribing is to be monitored by use of *a composite measure based on the cost per ASTRO-PU*[2] *of combination products, modified release products, drugs of limited clinical value and cost per defined daily dose of inhaled corticosteroids*. The justification for the indicators is that they "cover areas where there is often over-prescribing of expensive drugs, or of any drug, when clinical need can be met by cheaper alternative" (NHS Executive 1998, page 34).

The cost of drug prescribing will depend on how many prescriptions are written and what is prescribed. Cost effective prescribing requires (a) that drugs are only prescribed when they are effective and (b) that the cheapest of a set of therapeutically equivalent drugs is prescribed. These two attributes of cost effective prescribing require separate indicators. The use of cost per ASTRO-PU (i.e. as cost per weighted head of population) will not provide information about either attribute. An HA could have a lower cost per ASTRO-PU because fewer prescriptions are written or because on average for each prescription less expensive drugs are chosen. Since the weights in the ASTRO-PU formula do not provide sufficiently sensitive adjustments of HA populations to reflect differences in need for combination and modified release products, it is not possible to determine whether a lower rate of prescribing is appropriate. Thus the indicator may provide misleading signals about the cost-effectiveness of prescribing and could create perverse incentives to underprescribe effective drugs.

It would be better to use cost per defined daily dose as the indicator, as with inhaled corticosteroids, rather than per ASTRO-PU, so that one aspect of cost-effective prescribing is more appropriately measured, rather than attempting and failing to capture both aspects.

[2] The ASTRO-PU (Age, Sex and Temporary Resident Originated Prescribing Unit) is a measure of total population with weights on constituent sections of the population reflecting prescribing costs (Roberts and Harris, 1993).

The second prescribing indicator is a *composite of the volume of benzodiazepines and the ratio of antidepressants to benzodiazepines prescribed*. The justification for the indicator is that its components "attempt to measure the level of detection of, and appropriate prescribing for, mental health conditions in primary care" (NHS Executive 1998, page 33). The widespread use of benzodiazepines is regarded as poor practice, and in general, prescription of anti-depressants is a more appropriate response to depression.

The indicator is intended measure two distinct aspects of the quality of care in mental health: the number of cases detected and the quality of management of detected cases. Consequently it may do neither job well. Thus suppose that more mental health problems are detected (good) but are all treated with benzodiazepines (bad). The volume of benzodiazepines will increase and the ratio of antidepressants to benzodiazepines will fall. Both indicators will suggest a worsening of both aspects of quality of care whereas one aspect (detection) has improved. It would be better just to use the ratio of antidepressants to benzodiazepines as a measure of quality of care for a given number of cases and to seek another measure of detection.

Acute care management indicator: aggregation of age and sex standardised admission rates for severe ENT infection, kidney/urinary tract infection and heart failure. The rationale for the indicator is that it provides "a measure of the level of potentially 'avoidable hospitalisations' as a result of conditions which should, at least in part, be treatable in primary care" (NHS Executive 1998, page 31).

While there are adverse consequences from delayed treatment of these conditions, admissions represent a tiny proportion of ENT and urinary tract infection cases seen in primary care. For ENT infection in particular, it would be unfortunate if GPs were to respond to the indicator by increasing their prescribing of antibiotics to the bulk of patients with respiratory disease (e.g., coughs and colds, simple bronchitis) who are not at risk of admission and where the risks of antibiotic treatment outweigh the benefits.

Good primary care management of heart failure is likely to reduce the need for admission, especially through the wider prescribing of ACE inhibitors. However, many exacerbations of heart failure are managed by obtaining an outpatient specialist opinion rather than by admission. Although outpatient referral data has been quite poor in many HAs, it is now improving. If the indicator is to used to monitor the quality of primary care management of the condition, it should be combined with information on rates of referral to outpatient departments.

Chronic disease management indicator: *aggregation of age and sex standardised admission rates for asthma, diabetes and epilepsy*. It is argued that the conditions are substantially managed in primary care so that "high hospital admission rates for these conditions may indicate poor management of these conditions in primary care" (NHS Executive 1998, page 32).

Admission rates for certain chronic conditions have been used in other countries, principally the United States, as measures of primary care performance (Arnold and Zuvekas, 1989; Billing and Hasselblad, 1989). Such conditions are often termed ambulatory care sensitive conditions (ACSCs) and are defined as conditions where timely and effective ambulatory care could help reduce the risk of hospitalisation either by preventing the onset of illness, controlling an acute episode of illness or better long term management. The assumption underlying the use of hospitalisation rates for ACSCs (Rutstein et al., 1976) is that informed patients receiving continuous and good primary care will require fewer hospitalisations. ACSC admission rates have been used extensively in the US as measures of access to primary care (Arnold and Zuvekas, 1989; Billing and Hasselblad, 1989; Massachusetts Division of Health Care Finance and Policy, 1995; Ricketts et al., 1998).

Previous research in the UK suggests that some characteristics of primary care which might be taken to reflect practice quality are indeed related to ACSC admission rates. For example, lower admission rates for asthma have been found in practices whose prescribing patterns suggested better preventive care (Griffiths et al., 1996; Aveyard, 1997), and in practices with better organised diabetic care (Farmer and Coulter, 1990). Griffiths et al., (1997) found that higher admission rates for asthma in East London were negatively associated with numbers of partners in a practice and positively with high night visiting rates. It was suggested that smaller partnerships found it more difficult to develop systems for identifying, reviewing and educating asthma patients.

US studies also indicate that higher ACSCs admission rates are more likely among communities with poor access to primary care (Begley et al., 1994; Bindman et al., 1995; Billings et al., 1996; Weissman, 1992).

Confounding problems. The interpretation of admissions for the chronic conditions used in the proposed indicator may not be straightforward because of the potentially confounding effects of hospital admission policies, the supply of secondary care and socio-economic factors which affect the prevalence of the conditions or propensity to seek care.

Although hospital admission for stabilisation of diabetes used to be common, it is now rare, and secular trends in diabetes admission rates are likely to show a steady fall as a result of changing hospital practices. Most admissions for diabetic control are of insulin dependent diabetics who tend to be managed by specialists in secondary care. Non insulin dependent diabetics are in the majority and are usually managed from primary care. They will normally only be admitted with the complications of diabetes which could indeed be related to poor primary care management. However, there may be a long lag between poor quality primary care management of a case and resulting problems such as blindness, which require admission.

Trends in asthma admission rates need to be interpreted against a background of encouragement to patients to seek admission when they are unwell, including in many cases allowing patients to admit themselves directly to respiratory wards. This policy has been used to try to reduce the number of asthma deaths which result from delayed admission or from failure to recognise the severity of an attack. Asthma admission rates may therefore be dependent on local secondary care policies and only partially on the quality of primary care management. For example, Durojaiye et al. (1989) found that asthma admission rates in Nottingham increased markedly between 1975 and 1985, a period of time when there appeared to be improvements in primary care, possibly because of changing admission policies for asthma.

Watson et al. (1996) found that asthma admission rate in the West Midlands was strongly associated with deprivation in the community as measured by the Townsend Index. Similarly the finding by Griffiths et al. (1997) that practice level asthma admission rates were associated with high night visiting rates may be because high rates for night visiting may reflect higher patient demand from a less healthy population. US studies also find that socio-economic conditions affect admission rates (Begley et al., 1994; Bindman et al., 1995; Billings et al., 1996; Weissman, 1992).

In New Zealand, where hospital utilisation is controlled via GP gate-keeping, Brown and Barnett (1992) found that regional differences in diabetes admission rates were mainly explained by hospital bed supply, rather than availability of GPs per population, even after controlling for socio-demographic characteristics of the population.

However, a Spanish study (Casanova and Starfield, 1995) of admission rates for children found that, unlike the US, they were not correlated with supply side or socio-economic factors. The authors suggested that this was due to the provision of a universal free health service in Spain.

Although admission rates for similar conditions to those in the proposed chronic conditions indicator are widely used as markers of access to care in the US, cultural, socio-economic and organisational differences between the US and the England, and the problems posed by confounding, may mean that the indicator is not a suitable measure of primary care quality in England. We address this issue in the next two sections. In section 3 we discuss four methods of allowing for confounding and in section 4 we apply one of these methods (multiple regression) to English data. We examine the extent to which socio-economic factors and supply side variables influence the admission rates used in the proposed performance indicator and thus cloud any possible relationship between it and the quality of primary care.

3. COMPARING LIKE WITH LIKE: ALLOWING FOR CONFOUNDING

The confounding problem is that admission rates will be influenced by a number of other factors in addition to the quality of primary care. In order to assess performance it is necessary to remove the effects of factors which are outside the control of the decision makers whose performance is being measured. There are four methods of allowing for the influence of confounding factors so that the remaining variation in admission rates can be attributed to the quality of primary care.

Standardisation. The characteristics of the population in an area could affect admission rates. Obvious examples are the age and sex composition of the population, but other possibilities include income, education level, and car ownership, which may influence either health status or the propensity to seek care. The admission rate for an area will therefore depend on the mix of such characteristics in the population.

Standardisation is an attempt to correct for the impact of the population mix on admission rates so that any remaining differences in admission rates can be attributed to differences in primary care quality. Because of the absence of data on other population characteristics, it is usual to standardise only for the age and sex composition of the population and to compare standardised admission ratios. The standardised admission ratio for an area is a weighted average of the ratios of the age and sex specific admission rates in an area to the age and sex specific admission rates for some reference population (typically the national population). A high standardised admission ratio is a signal that the area has relatively higher admission rates after allowing for the demographic mix in the area. Standardisation has the advantages that it reduces the importance of random fluctuations in age and sex specific admission rates and provides a single composite measure.

In *direct standardisation* the weights are the population shares in the reference population. *Indirect standardisation* uses the population shares in the area in question as the weights. Direct standardisation has greater information requirements since the area's age and sex specific admission rates, as well as its age and sex mix, must be known. Indirectly standardised ratios can be calculated using only information on the total number of admissions and the population shares in an area: the age and sex specific admission rates for an area are not required.

The admission rates suggested as a performance indicator in the NHSE consultation document are age and sex standardised (NHS Executive, 1998). The consultation document does not suggest which method of standardisation should be used. There are no data problems which prevent direct standardisation being used and an earlier document on hospital clinical indicators uses direct standardisation (NHS Executive, 1997).

Although standardisation is relatively simple it has two main drawbacks as a means of allowing for confounding factors:

- In order for standardisation to remove the effects of confounding by the population characteristics, in addition to age and sex, which affect admission rates it is necessary to calculate specific admission rates for the subsets of the population defined by these other characteristics. In most cases suitable routine data does not exist, so that standardisation cannot allow for confounding by population characteristics other than age and sex. For example, it is plausible that employment status is a proxy measure of health status (Bethune, 1997), so that the probability of hospitalisation depends on whether an individual is employed or unemployed as well as on their age and sex. It would in principle be possible to attempt to allow the potential confounding effects of differences between areas in the proportions of the population who are employed or unemployed by calculating age, sex and employment status standardised admission ratios for areas. However, routine admission data do not record employment status, nor is there routinely collected information on the numbers of unemployed by age and sex in a HA. Since routine data do not permit classification of the population by the other characteristics which might affect admission probabilities, standardisation cannot allow for the effects of potential confounders, apart from age and sex mix.

- Even if age and sex were the only factors which confounded the relationship between primary care quality and admission rates, standardisation would correctly identify the effect of an area's primary care quality on admission rates only under quite stringent assumptions about the way in which quality affects admission rates (Freeman and Holford, 1980). Since the assumptions are somewhat less demanding in the case of direct standardisation it is better to directly standardise when there is sufficient information. Direct standardisation is also preferable when areas are being compared against each other (Freeman and Holford, 1980; Kilpatrick, 1959; Silcock, 1962), as they tend to be in most uses of performance indicators.

Cluster analysis groups HAs with similar socio-economic conditions together so that an HA can then compared with the other HAs in its socio-economic cluster. The Office of National Statistics has produced a general purpose classification of health authorities which can be used for this purpose (Wallace, 1996) The technique was used extensively in the NHS Executive consultation document on clinical indicators in secondary care in an attempt to allow for socio-economic factors which might confound comparisons of age and sex standardised rates, for example for perioperative myocardial infarctions (NHS Executive 1997, page 50). It was also used illustratively in the performance assessment consultation document (NHS Executive 1998, page 10) to compare HAs rates of emergency admissions for those over 75 years old.

There are four problems with this approach:

- Supply conditions are not one of the characteristics used to group HAs, so that comparisons within clusters are still vulnerable to confounding by supply conditions.
- Each HA is compared with a relatively small number of HAs, so that more HAs may be appear to have unusually good or bad performance.
- The criteria used to cluster HAs are essentially arbitrary.

- The same clusters are used for all performance indicators. This would be justifiable only if the socio-economic variables used to cluster HAs affected the different admission rates in the same way. HAs can justify their performance by arguing that they have been compared with the wrong cluster and that for the indicator in question they should be included in some other cluster.

Data envelopment analysis. Data envelopment analysis (DEA) is a means of comparing the admission rates for HAs which are similar with each other in other respects so that potentially confounding factors are allowed for. DEA calculates the lowest possible admission rate which can be achieved with given levels of the confounding variables measuring secondary care supply and socio-economic conditions. An area's performance is then measured as the difference between its actual admission rate and the best possible (lowest) admission rate that it could have achieved given its supply and socio-economic characteristics

DEA is much more flexible than cluster analysis since the set of comparator HAs for an HA will vary with the performance indicator being considered. It has the conceptual advantage over cluster analysis that it is possible to give a sensible and policy relevant interpretation to the method by which DEA selects the set of comparator HAs (Giuffrida and Gravelle, 1997).

Multiple regression analysis attempts to allow for confounding variables by using information on all the decision making units (HAs) being compared (Aveyard, 1997). The regression model predicts the admission rate that an HA should have given the values of the confounding variables. The difference between the actual value and the predicted value (the residual) is a measure of how well or badly the HA is doing given the values of the confounding variables. In effect regression analysis standardises for a range of possible determinants of the performance indicator.

Regression analysis has a number of advantages compared with the other methods of allowing for confounding:

- Flexibility - different confounding variables can by considered for different indicators.
- Statistical tests can be performed which indicate whether the assumptions used are good ones and whether observed relationships between potential confounders and admission rates are likely to be genuine or to have arisen by chance.
- Regression is relatively transparent compared with cluster analysis and with DEA.

4. AN ANALYSIS OF FHSAs HOSPITALISATION RATES

This section uses regression analysis to relate the variation in admission rates for asthma, diabetes and epilepsy across areas to characteristics of primary care, secondary care and socio- economic characteristics of the areas. The aim is to assess the magnitude of the potential confounding by these factors.

Data. The hospitalisation data were obtained from the Hospital Episodes Statistics (HES) unit at the Department of Health for each of the financial years 1989/90 to 1994/95. The data covered the 367 English local authorities, and were aggregated to Family Health Services Authority (FHSA) level. The measure of hospitalisation for an area is the number of residents with ordinary admissions or day cases episodes having asthma (ICD-10 codes J45-J46), diabetes mellitus (ICD-10 codes E10-E14) and epilepsy (ICD-10 codes G40-G41) as primary diagnosis. Hospitalisation rates are measured per 10,000 residents.

Summary statistics for hospitalisation rates for asthma, diabetes and epilepsy rates are presented in Table 1. The table shows, for each of the 6 years from 1989/90 to 1994/5, the unweighted mean FHSA admission rate, and the minimum and maximum rates and the standard deviation. Hospitalisation rates for asthma were quite stable during the period, whilst both diabetes and epilepsy rates increased. For all three diseases there is a large variation in admission rates amongst the 90 FHSAs.

Table 1: Descriptive statistics: unstandardised hospitalisation rates per 10,000 population

Condition	Year	Mean	Std. Dev	Minimum	Maximum
Asthma	1989/90	19.908	6.036	9.778	35.997
	1990/91	19.619	5.972	6.397	35.404
	1991/92	21.574	5.825	9.443	35.827
	1992/93	20.948	5.780	9.938	36.468
	1993/94	22.173	5.687	12.579	40.922
	1994/95	20.273	5.873	3.241	34.728
Diabetes	1989/90	10.479	2.922	4.426	19.910
	1990/91	10.892	3.571	4.742	21.406
	1991/92	11.737	4.550	4.053	27.112
	1992/93	12.458	5.256	4.857	30.553
	1993/94	12.504	5.538	4.834	35.642
	1994/95	13.000	5.462	2.191	31.504
Epilepsy	1989/90	7.567	2.460	3.127	14.380
	1990/91	7.874	2.515	3.493	14.945
	1991/92	8.404	2.544	4.077	17.244
	1992/93	8.344	2.331	4.169	14.258
	1993/94	8.267	2.286	3.824	16.982
	1994/95	8.717	2.754	1.823	16.519

Direct versus indirect standardisation. We noted in the discussion of standardisation that direct standardisation is preferable on theoretical grounds but may not always be possible because it requires age and sex specific admission rates for each area. We were able to use both methods of standardisation. We found that the rankings of FHSAs by hospitalisation rates was virtually unaffected by the method of standardisation: the lowest rank correlation was 0.997 (for epilepsy admissions in 1993/4). Hence if age and sex specific admission rates are not available at area level, for these three conditions indirect standardisation will yield very similar results to the theoretically more desirable direct standardisation.

Impact of age-sex standardisation. Even if there were no confounding factors apart from age and sex, direct standardisation might not reveal the true primary care quality related differences in admission rates between areas. Unless improvements in primary care quality reduce all age and sex specific admission rates by the same amount or reduce them all in the same proportion, direct standardisation will not correct appropriately for differences in age and sex structure across areas (Freeman and Holford, 1980). If quality does not act uniformly on age and sex specific admission rates the analyst faces a dilemma. One can compare age and sex specific admission rates across areas but such a mass of comparisons may be difficult to interpret. Or one can standardise and take a weighted average of the age and sex specific rates knowing that such an aggregate may be misleading.

Faced with this dilemma one might be tempted just to use crude admission rates (total admissions for all age and sex groups divided by the total population) on the grounds that such aggregation is simple. The impact of using direct standardisation compared with crude admission rates is shown in Tables 2 and 3. Table 2 shows the impact on the rankings of FHSAs by their admission rates and Table 3 the size of the changes in admission rates.

Standardisation has a marked impact, so that it clearly does matter whether one uses crude or standardised rates. It is conventional to assume that it is better to attempt to separate out differences across areas due to differences in demographic composition from those due to genuine area effects, even if the method adopted is accurate only under quite strong assumptions about the way quality differences affect admission rates. We agree and feel that standardisation is better than using crude admission rates. In what follows we examine the impact of confounding by socio-economic and supply side variables on the directly standardised admission rates, rather than on the crude admission rates.

Table 2: Impact of standardisation[a] versus crude rates on FHSA ranking by hospitalisation rates

Difference in ranking	1989/90	1990/91	1991/92	1992/93	1993/94	1994/95
Asthma						
<10	73	76	81	78	76	74
10-20	7	3	2	4	5	4
>20	10	11	7	8	9	12
Average[b]	8	8	7	7	7	9
Correlation[c]	0.797**	0.81**	0.833**	0.882**	0.861**	0.795**
Diabetes						
<10	68	73	70	74	76	77
10-20	9	6	11	7	5	4
>20	13	11	9	9	9	9
Average[b]	10	8	8	8	8	7
Correlation[c]	0.712**	0.858**	0.85**	0.821**	0.817**	0.834**
Epilepsy						
<10	77	79	79	80	79	77
10-20	5	4	4	3	5	4
>20	8	7	7	7	6	9
Average[b]	5	5	6	5	5	6
Correlation[c]	0.914**	0.898**	0.881**	0.929**	0.921**	0.895**

a: Hospitalisation rates are directly standardised for age and sex. The reference year is 1991/92
b: Average absolute change in ranking
c: Spearman's rank correlation
** Correlation is significant at the .01 level (2-tailed)

Composite or separate indicators? The NHSE consultation document suggests that the admission rates for asthma, diabetes and epilepsy be combined to yield a single composite indicator (NHS Executive 1998, page 32). Combining the three rates is an attempt to reduce the influence of random factors which affect the rates for each condition and to make comparison easier by reducing the amount of information presented. But there is a potential disadvantage: the three admission rates may be measuring different aspects of the quality of primary care. If so adding the rates will not necessarily yield a more accurate indicator of quality.

Table 3: Differences between crude and standardised hospitalisation rates[a]

Change in hospitalisation rate[a]	1989/90	1990/91	1991/92	1992/93	1993/94	1994/95
Asthma						
< -5	6	5	4	3	4	5
-3 -5	1	1	0	1	0	0
-1 -3	6	4	5	4	5	3
-1 +1	65	68	67	67	68	71
+1 +3	6	5	9	9	8	2
+3 +5	0	2	0	1	0	2
> +5	6	5	5	5	5	7
Average[b]	2.101	1.868	1.815	1.657	1.487	1.746
Diabetes						
< -5	3	4	4	4	4	3
-3 -5	4	1	0	2	2	3
-1 -3	3	4	5	4	3	4
-1 +1	70	72	69	70	70	63
+1 +3	4	3	7	6	7	12
+3 +5	5	4	2	1	1	2
> +5	1	2	3	3	3	3
Average[b]	1.169	1.246	1.612	1.884	1.452	1.652
Epilepsy						
< -5	0	2	1	1	1	1
-3 -5	1	1	0	0	0	1
-1 -3	4	1	4	4	2	4
-1 +1	79	80	80	81	82	76
+1 +3	6	5	3	3	4	7
+3 +5	0	1	2	1	1	1
> +5	0	0	0	0	0	0
Average[b]	0.344	0.402	0.426	0.376	0.341	0.433

a: Per 10,000 per population
b: Average absolute change

Table 4 reports the correlation between the hospitalisation rates for the three conditions. The rates are positively and significantly correlated, as we would expect if they were all influenced in the same way by the same aspects of quality and the confounding factors, but the correlation is by no means perfect. Since it is clearly possible for GPs to devote different amounts of effort and resources to care of these three conditions, it may be more sensible not to aggregate them to provide a single indicator.

Table 4: Correlation among[a] hospitalisation rates[b]

Asthma	1		
Diabetes	0.621**	1	
Epilepsy	0.674**	0.561**	1
	Asthma	Diabetes	Epilepsy

a: Pearson correlation coefficient
b: Direct age and sex standardisation
** Correlation significant at the .01 level (2-tailed)
Number of observations: 540

Stability of admission rates. If there are large random fluctuations in admission rates each year at area level their usefulness as indicators would be undermined. Table 5 shows the distribution of changes in rankings between years and the correlations in the area rankings in consecutive years. There are quite large changes in rankings from one year to the next. Using the change in the rankings by asthma admission rates between 1993/94 and 1994/95 as an example, we see that 23 areas moved between 10 and 20 places in the rankings and 13 moved more than 20 places. The correlation between area rankings by asthma admission rates in these two years was 0.865.

Table 5 shows that adding up the three rates does not yield noticeably more stable rankings than any of the three rates used separately. Temporal stability is therefore not a strong argument for using a single composite measure. It would be better to use a moving average of several years admission rates. This would reduce the importance of random fluctuations in any one year though it would take longer for genuine changes in admission rates to become apparent. A two or three year average would seem a suitable compromise.

Allowing for confounding with regression analysis. The literature suggests that admission rates for the asthma, diabetes and epilepsy may be influenced by both socio-economic factors and by the supply of secondary care. We used multiple regression to explore the confounding problem. We looked at the relationship between directly standardised admission rates and a large number of potential explanatory variables relating to both socio-economic conditions and the supply of care. Table A1 in the appendix lists the variables.

Table 5: Changes in FHSA ranking by hospitalisation rates[a] between subsequent years

Change in ranking	1989/90 - 1990/91	1990/91 - 1991/92	1991/92 - 1992/93	1992/93 - 1993/94	1993/94 - 1994/95
All three conditions					
<10	49	53	67	65	62
10-20	24	25	19	23	18
>20	17	12	4	2	10
Average[b]	12	10	7	7	10
Correlation[c]	0.805**	0.85**	0.926**	0.946**	0.864**
Asthma					
<10	51	56	66	58	54
10-20	20	24	17	23	23
>20	19	10	7	9	13
Average[b]	13	10	8	9	10
Correlation[c]	0.776**	0.831**	0.911**	0.903**	0.865**
Diabetes					
<10	50	45	61	65	62
10-20	21	29	18	21	13
>20	19	16	11	4	15
Average[b]	13	12	9	7	11
Correlation[c]	0.746**	0.792**	0.885**	0.943**	0.764**
Epilepsy					
<10	57	56	65	57	54
10-20	22	21	20	30	27
>20	11	13	5	3	9
Average[b]	11	10	8	8	9
Correlation[c]	0.828**	0.852**	0.921**	0.929**	0.89**

a: Hospitalisation rates are directly standardised for age and sex. The reference year is 1991/92
b: Average absolute change in ranking
c: Spearman's rank correlation
** Correlation significant at the .01 level (2-tailed)

The regression predicts the admission rate expected in an area after taking account of the potential confounding variables. The difference between the predicted admission rate and the actual admission rate (the residual) will arise from factors which have not been included as confounding variables. We use the residual as a measure of the effect of the unobserved quality of primary care on admission rates after allowing for confounding effects. The residual is the admission rate "standardised" for the explanatory or confounding variables.

If there are factors which influence admission rates and which have been left out of the regression equation, the residual admission rates will still be confounded as measures of quality. For example, cigarette consumption, air pollution and pollen counts are likely to influence asthma admission rates. If the omitted confounders are correlated with the variables included in the regressions then part of the variation in admission rates which is due to the omitted variables will be attributed to the included variables. The residual is then more reliable as a measure of the effect of primary care quality since more of the admission rate is explained by the included variables. How much faith is placed in the residual admission rate as a measure of quality depends on how important the omitted explanatory variables are and on the extent to which they are correlated with variables we have included. The failure to allow for all confounders means that the performance indicators should be used as a trigger for a more detailed investigation in individual HAs, rather than as basis for immediate action.

The variables used in the regression analysis are in three groups. Supply conditions in secondary care are measured by the number of hospital medical staff in general medicine per 10,000 population[3] and by a variable which reflects the distance weighted number of beds per head of population. The hypothesis is that admission rates will be positively associated with both variables.

The second group of variables measure socio-economic conditions in the FHSAs. The variables cover housing conditions, social class, unemployment, and car ownership. We also included two variables, prescriptions and night visits, which reflect the propensity of the population to use primary care services. These variables reflect both the health needs of the population and their willingness to consult GPs. We would expect that greater use of primary care services is associated with higher admission rates for two reasons. First, greater utilisation is associated with worse population health and second, the greater the volume of work on GPs, the less time they have to provide high quality care for chronic conditions. We also included more direct measures of population health, such as the proportion of the working age population who were permanently sick and the standardised mortality ratio.

The third group of variables reflect supply conditions in primary care. The rationale for including such variables is that we expect the quality of primary care to be associated, positively or negatively with some of the characteristics of primary care. Some of these variables, such as the number of GPs per head, the proportion of GPs over 65 and the average distance to practices are included in our data. Others, such as practice asthma clinics, the use of registers for proactive care, or special training for practice nurses, are not measured.[4]

Although we cannot observe all the primary care determinants of quality we can use the information in the current data set on the observable variables and admission rates to make inferences about the unobserved factors associated with quality. After allowing for the primary care variables which we can measure, we assume that the unexplained variations in admission rates reflect the unobserved aspects of primary care which influence quality. Higher unexplained admission rates are a cause for concern and further investigation.

[3] This variable was measured at Regional level because data at FHSA level were not available.
[4] We are currently using another dataset to examine the relationship between admission rates and more detailed practice level variables such as the provision of asthma clinics.

Regression results. The regression results are given in the appendix, along with details of the econometric techniques used. The variables included explain around half of the variance of standardised admission rates across FHSAs for asthma, about 40% for epilepsy and 30% for diabetes. Some of the coefficients on the variables are broadly in line with expectations. Admission rates are greater in areas with more hospital beds and more hospital doctors and in areas with more prescriptions. Not all the variables are significant in the three equations. There are also some puzzling findings. For example, population density is negatively correlated with admission rates for diabetes but positively correlated with admission rates for asthma, perhaps because population density is correlated with air pollution.

Are hospitalisation rates a proxy for quality? The results concerning the primary care variables included in the regression analyses tend to support the suggestion that admission rates may be a proxy for some aspects of quality in primary care. Admission rates for all three conditions are significantly negatively related to the GP population ratio and the admission rate for asthma is significantly positively associated with the proportion of GPs over 65. Admission rates for diabetes and epilepsy are positively associated with distance to the nearest practice.

We do not examine the regression results in further detail here. We are concerned with the implications of confounding variables for the use of admission rates as quality indicators, rather than with testing the detailed implications of theories about the determinants of admission rates.

We investigate the importance of confounding in two steps. We first compare the rankings of FSHAs by standardised admission rates with their rankings after allowing for socio-economic variables. Then we compare the rankings after allowing for socio-economic variables with those after allowing for socio-economic variables *and* supply factors. We use the "unexplained" variation in admission rates across FHSAs as a proxy for primary care quality. What is unexplained depends on what confounding variables we allow for. When FHSAs are ranked by standardised rates all of the standardised rate is "unexplained". When we allow for the confounding variables via the regression analysis the "unexplained" variations are the residuals from the regressions: the difference between the actual standardised admission rate and that predicted by the regression.

Allowing for socio-economic factors. Table 6 shows the change in rankings of FHSAs when they are ranked by their residual standardised admission rates after allowing for socio-economic factors, compared with their rankings by their standardised admission rates.[5] The ranking by diabetes admission rates is affected less than the rankings by asthma and epilepsy and the impact of socio-economic factors appears to decline over time. But even in 1994/95

[5] The residuals are from a regression of standardised rates on the socio-economic variables only. The regression results are obtainable from the authors on request.

the average FHSA changes its diabetes admission rate ranking by 11 places and 13 of them change by more than 20 places when socio-economic factors are allowed for. The effects on asthma and epilepsy are greater: in 1994/95 the average change in rankings was 16 for diabetes and 15 for asthma and 24 FHSAs had ranking changes of more than 20 places for diabetes and 33 FHSAs had ranking changes of more than 20 for asthma.

Table 6: Impact of socio-economic factors on FHSA ranking by hospitalisation rates

Change in ranking	1989/90	1990/91	1991/92	1992/93	1993/94	1994/95
Asthma						
<10	36	30	27	28	26	32
10-20	31	27	24	28	26	25
>20	23	33	39	34	38	33
Average[b]	14	16	18	17	19	15
Correlation[c]	0.788**	0.703**	0.635**	0.677**	0.612**	0.734**
Diabetes						
<10	32	44	50	48	50	50
10-20	33	25	19	23	26	27
>20	25	21	21	19	14	13
Average[b]	15	12	12	12	11	11
Correlation[c]	0.754**	0.819**	0.817**	0.821**	0.831**	0.858**
Epilepsy						
<10	31	35	41	39	35	39
10-20	29	22	19	20	25	27
>20	30	33	30	31	30	24
Average[b]	16	17	17	17	18	16
Correlation[c]	0.692**	0.642**	0.626**	0.604**	0.571**	0.673**

a: Hospitalisation rates are directly standardised for age and sex. The reference year is 1991/92
b: Average absolute change in ranking
c: Spearman's rank correlation
** Correlation significant at the .01 level (2-tailed)

Comparing Table 6 with Table 2 we see that allowing for socio-economic factors has at least as large or larger effect on rankings as allowing for demographic factors by age and sex standardisation. The implication is that, if standardisation is felt to be required to allow for confounding by demographic factors, then allowance should also be made for socio-economic confounding variables.

Allowing for supply factors. Next we examine the additional impact of secondary and primary care supply factors. We rank FHSAs by the difference between actual admission rates and those predicted from regressions containing both socio-economic and supply variables. Although we made a distinction between secondary and primary care supply factors in our regression analysis we found that their combined effect was small in comparison with the socio-economic factors. Hence in what follows when we refer to supply we mean both secondary and primary care supply factors.

Table 7: Impact of supply factors on FHSA ranking by hospitalisation rates after allowing for socio-economic factors

Change in ranking	1989/90	1990/91	1991/92	1992/93	1993/94	1994/95
Asthma						
<10	84	83	71	76	73	72
10-20	6	6	19	14	17	17
>20	0	1	0	0	0	1
Average[b]	3	4	6	5	5	6
Correlation[c]	0.984**	0.978**	0.957**	0.964**	0.962**	0.953**
Diabetes						
<10	53	60	60	64	58	64
10-20	34	27	24	19	26	20
>20	3	3	6	7	6	6
Average[b]	9	8	9	8	8	7
Correlation[c]	0.904**	0.922**	0.906**	0.909**	0.921**	0.925**
Epilepsy						
<10	70	69	63	67	62	61
10-20	18	18	19	17	20	23
>20	2	3	8	6	8	6
Average[b]	6	6	7	7	7	7
Correlation[c]	0.95**	0.943**	0.918**	0.925**	0.918**	0.925**

a: Hospitalisation rates are directly standardised for age and sex. The reference year is 1991/92
b: Average absolute change in ranking
c: Spearman's rank correlation
** Correlation significant at the .01 level (2-tailed)

Table 7 shows the change in rankings caused by allowing for supply variables in addition to the socio-economic variables. The average changes in rankings is around half that caused by the socio-economic factors and the correlations between the rankings allowing and not allowing for the supply variables is always greater than 0.90. The impact of supply factors on the rankings by asthma admission rates is considerably smaller than the impacts on the rankings by diabetes and epilepsy admission rates.

The supply variables are correlated with the socio-economic variables so that part of the effect of supply variables on admission rates is picked up in the regressions which only included socio-economic variables. Hence we may be understating the effect of supply variables by comparing the regression with supply and socio-economic variables with the regression with socio-economic variables only. To test for this we also estimated a regression containing only supply variables. We then compared the resulting ranking of FHSAs with the ranking from the regression containing supply and socio-economic variables. For all three conditions we found that the effects on FHSA rankings of adding socio-economic variables to the supply variables was greater than the effect of adding supply variables to socio-economic variables. Further, the explanatory power of the regression was greater when only socio-economic variables were included than when only supply variables were included. For example, in the case of epilepsy the R^2 was 0.339 with only supply variables, 0.491 with only socio-economic variables, and 0.528 with both sets of variables.

We conclude that supply variables are confounders but that it is more important to allow for socio-economic variables than supply variables.

Effects of confounding. Table 8 shows the 10 FHSAs which had the highest and lowest ranks in the case of asthma admission rates when no allowance is made for demographic factors (column 1), when admission rates are directly standardised (column 2), when socio-demographic factors are also allowed for (column 3) and when all the confounding variables are allowed for (column 4). Focusing on the top ten FHSAs in each column, notice that whilst seven of the directly standardised top 10 were also in the top 10 by crude admission rate, only four of those in the top 10 after allowing for socio-economic factors were in the directly standardised top 10. The table is further illustration that the ranking of FHSAs by admission rates is heavily affected by which confounding variables are allowed for and that socio-economic factors are at least as important as the age and sex composition of areas. The smaller impact of supply side factors is shown by the fact that eight of the top ten allowing for socio-economic factors are also in the top ten after allowing for supply effects as well in column 4.

Table 8: Top 10 and bottom 10 FHSAs by Asthma hospitalisation rates, 1994/95

Rank	Crude rate	Directly standardised	Allowing for socio-economic factors	Allowing for supply and socio-economic factors
1	Manchester	Kingston & Richmond	Kingston & Richmond	Kingston & Richmond
2	Rochdale	Manchester	Buckinghamshire	Buckinghamshire
3	Liverpool	Liverpool	Enfield & Haringey	Berkshire
4	St Helens & Knowsley	Rochdale	Berkshire	Enfield & Haringey
5	Bury	St Helens & Knowsley	Rochdale	Coventry
6	Sheffield	Bury	Doncaster	Doncaster
7	Oldham	Doncaster	Rotherham	Rochdale
8	Doncaster	Kensington, Ch. & Wes.	Cambridgeshire	Cambridgeshire
9	Coventry	Oldham	Norfolk	Rotherham
10	Sandwell	Coventry	Durham	Sefton
81	Cornwall and I. of Sc.	Kirklees	Kirklees	Calderdale
82	Avon	Hampshire	Redbridge & Walt. F.	Kirklees
83	Kirklees	Northumberland	Dudley	Salford
84	Essex	Somerset	Ealing, Hamm. & Hou.	Northamptonshire
85	Hampshire	North Yorkshire	Northamptonshire	Redbridge & Walt. F.
86	Northumberland	Barnet	Salford	Ealing, Hamm. & Hou
87	Somerset	Northamptonshire	Barnet	Barnet
88	North Yorkshire	Croydon	Derbyshire	Derbyshire
89	Derbyshire	Derbyshire	Croydon	Croydon
90	Bedfordshire	Bedfordshire	Bedfordshire	Bedfordshire

Ranking or rates? We have examined the importance of confounding by looking at its impact on the rankings of FHSAs since performance indicators are frequently presented in the form of league tables. However simple rankings, which depend only on whether an area has a higher or lower score than other areas, may not be the most appropriate summary of an area’s performance. Rankings take no account of the magnitude of differences in scores between areas nor of the level of the score.

Policy makers may prefer to judge HAs not by their ranking but by comparing their admission rate against a standard. For example, admission rates which are more than a certain proportion above the national average might be considered to be a cause for concern. The fact that rankings based on admission rates change quite markedly does not mean that confounding variables have important implications for admission rates themselves. It is possible that confounding variables could have quite small, though statistically significant, effects on the level of admission rates and thus have little policy significance if HA rates are being compared against a standard rate. The regression results reported in Table A2 in the appendix suggest that the confounding socio-economic and supply variables are important. They are statistically significantly associated with admission rates and jointly explain between 30% and 50% of the variation in admission rates.

Table 9 is a further illustration of the importance of confounding for comparisons of rates against a standard rate. The *z* score for an area is the difference between its admission rate and the average admission rate, expressed as a proportion of the standard deviation of the admission rate. A *z* score greater than say 2 would suggest that the area has an unusually high admission rate. Table 9 reports the correlations for four *z* scores calculated from crude admission rates, standardised admission rates, admission rates after allowing for socio-economic factors and admission rates after allowing for socio-economic and supply factors. We see that that the correlations are very similar to those between rankings of FHSAs using these four measures of admission rates. So even if the performance of an HA is judged by the level of its admission rate, rather than by its ranking, socio-economic conditions and, to a lesser extent, supply factors should be taken into account.

Table 9: Impact of confounding factors: correlations[a] of *z* scores[b] for 1994/95 asthma admission rates

Crude	1			
Standardised	0.795**	1		
Allowing for socio-economic factors[c]	0.488**	0.780**	1	
Allowing for supply and socio-economic factors[c]	0.451**	0.755**	0.976**	1
	Crude	Standardised	Allowing for socio-economic factors	Allowing for supply and socio-economic factors

a: Pearson correlation
b: *z* score for an area is the difference between its admission rate and the average admission rate as a proportion of the standard deviation of admission rates
c: Residual rates from regression
** Correlation is significant at the .01 level (2-tailed)

5. CONCLUSIONS

5.1 Policy implications

We can draw some policy conclusions from the examination of the rationale for the new primary care performance indicators (section 2), the discussion of the alternative methods of allowing for confounding (section 3) and the empirical analysis of six years of data on hospitalisation rates for asthma, diabetes and epilepsy in section 4:

- Single performance indicators should only be used to address one aspect of performance. Attempting to use a single indicator to monitor more than one aspect is likely to lead to them failing to monitor any aspect satisfactorily. The two new prescribing indicators suffer from this problem and should be reformulated as we suggest in section 2.

- The fact that the hospitalisation rates for the three chronic conditions are correlated with primary care variables which can be argued to reflect quality in primary care, provides some justification for their use as proxies for unobserved aspects of quality.

- Hospitalisation rates and rankings of FHSAs based on them are quite unstable between years. To reduce the impact of random variations unconnected with performance we suggest that the performance indicator should be based on a moving average of two or three years data, rather than on a single year.

- The rates for the three conditions are imperfectly correlated and are likely to reflect different aspects of quality. The rates should not be added up to produce a single indicator.

- Standardisation for age and sex has a major impact on the hospitalisation rates and the rankings of FHSAs, compared with the use of crude admission rates. Hospitalisation rates should be age and sex standardised. The method of standardisation (direct or indirect) does not matter since it has a negligible effect on the resulting indicator.

- Socio-economic differences across FHSAs have the same size effect on the rankings of FHSAs by hospitalisation rates as age and sex standardisation. They should therefore be allowed for in comparing authorities.

- Supply side factors also affect rankings but their effect are smaller than socio-economic factors. It is less important to allow for differences in supply conditions across authorities but we recommend it when data is readily available.

- Regression analysis is the most appropriate means of comparing like with like and allowing for the confounding effects of socio-economic and supply side influences on the chronic conditions admission rate indicator.

5.2 A general lesson

We have emphasised the problems which arise from confounding by socio-economic conditions and supply factors when admission rates are used as indicators of quality in primary care and have examined some ways of allowing for confounding variables. Any single performance indicator may be a misleading guide to the overall performance of an organisation since it covers only one dimension of that performance. It can be useful as a means of indicating unusual performance on that dimension but we should be very careful in inferring that unusual means good or bad performance.

Health care organisations use a mix of inputs to produce a large set of outputs. In evaluating performance on one dimension we need to take account of performance on all the other dimensions. We need to allow for the other outputs and their quality as well as the inputs used in order to properly compare "like with like". "Confounding" is a fundamental problem whenever we use a single indicator intended to reflect a single dimension of performance. Primary care in a HA may score badly on an indicator, such as the chronic conditions admission rate because it is producing poor quality care or because:

- It is using its resources to produce higher quality in other respects (better health promotion, or child surveillance, or better quality consultations).
- It is producing more of other types of services (more minor surgery, more night visits).
- It is using fewer resources.
- It is operating in a less favourable socio-economic environment than other HAs.
- The indicator is adversely affected by variables controlled in other sectors over which the HA has no influence.

Given the imperfections in the data available, we should exercise care in interpreting variations in the indicators as reflecting variations in performance by decision makers. However, the indicators can alert us to the possibility of unusually good or poor performance and the need for further investigation of the specific circumstances in such unusual HAs.

APPENDIX

The multiplicative regression model performed better in statistical terms than the additive model. In the multiplicative model all variables are included in the regression, after taking their natural logarithm and the coefficients estimated in the regression measure the *elasticity* of the hospitalisation rates with respect to the explanatory variables.

To deal with potential endogeneity bias in the relationship between admission rates and the variables measuring the supply of care in the FHSA (*BEDS*, *DOCP* and *GPPOP*) we use the strategy suggested by Godfrey and Hutton (1993). First, we test for the endogeneity of the variables using the *Wu-Hausman* test (Wu 1973; Hausman, 1978). If the *H test* is significant than the instrumental variable technique (IV) must be used to correct for the endogeneity bias. The *H test* is an Hausman type which is computed by adding the residuals of the regression of the potentially endogenous variables on both exogenous variables and instruments to the original regression and testing for their significance. Second, we construct a *J test* (Godfrey, 1988) to assess the specification of the model and the validity of the instrument. The *J test* statistic is given by (number of observations) × (R-squared of the regression of the residuals of the IV regression on all the endogenous variables, exogenous variables and instruments). It is distributed as a chi-squared, with degree of freedom given by (number of instruments) - (number of endogenous variables).

The large number of potentially relevant variables measuring the socio-economic characteristics and the morbidity of the population required a selection procedure to obtain a parsimonious model that satisfied the statistical requirement of correct specification. In selecting the variables in the regression models we always included the variables measuring supply of care, and density of the population. Other explanatory variables were retained in the main regression only if significant in a stepwise procedure. The socio-economic and morbidity variables were either included in the main regression or used as instruments to correct for the endogeneity of the supply variables where this was indicated by the *J test*.

Table A1: Description of the explanatory variables used in the regression analysis

Variables	*Description*	*Mean*	*Std. Dev.*	*Minimum*	*Maximum*	*Source*
Supply of primary care						
GPOP	Number of GPs per registered population	5.155	0.354	4.471	6.234	HSI
PRD1W	Weighted distance form the closest general practise	114.985	58.626	30.600	279.380	Census/ GMS
PGP65	Proportion of GPs over 65	2.266	2.081	0.000	16.360	HSI
Supply of secondary care						
DOCP	Hospital Medical Staff in the general medicine specialty group per 10000 population. By Regional Health Authority	2.830	0.358	2.232	3.639	DH
BEDS	Access to secondary care beds	2.849	0.754	1.288	4.640	RAWP
Socio-economic characteristics of the FHSA						
DENS	Ratio population area in hectares	17.801	20.188	0.605	100.762	ONS
UBP	Proportion of the population claiming unemployment benefits	4.201	1.620	0.684	9.771	ONS
PRES	Prescription items dispensed by pharmacies and dispensing doctors	8.865	1.340	6.040	12.436	HSI
NIGHT	Number of night visits per 10000 population	303.427	97.260	28.563	601.286	HSI
PETHN	Proportion of private households headed by a person born in the New Commonwealth or Pakistan	4.052	4.847	0.310	31.187	HSI
HOUSE	Proportion of persons in permanent buildings owner occupied	0.696	0.099	0.313	0.816	Census
RENTED	Proportion of persons in private rented	0.059	0.034	0.019	0.273	Census
CNTRHEAT	Proportion in households lacking central heating	0.170	0.082	0.049	0.464	Census
NOCAR	Proportion in households with no car	0.265	0.098	0.110	0.513	Census
MOVELA	Proportion of residents moving outside L.A. district in last year	0.038	0.018	0.018	0.127	Census
CLASS12	Percentage of persons in households with head in class 1 or 2	0.357	0.080	0.183	0.588	Census
NOSCACC	Proportion in households in non-self-contained accommodation	0.994	0.007	0.958	0.999	Census
OVERCRWD	Proportion in households in crowded accommodation (>1 per room)	0.049	0.027	0.023	0.193	Census
OLDALONE	Proportion of those aged 75+ living alone	0.487	0.034	0.423	0.581	Census
PENSALONE	Proportion of those of pensionable age living alone	0.341	0.032	0.299	0.485	Census
DEPSCARER	Proportion of dependants in single carer households	0.203	0.036	0.139	0.310	Census
CHLDNOELP	Proportion of children in non-earning lone parents households	0.088	0.037	0.039	0.223	Census
CHLDNOEH	Proportion of children in non-earning households	0.136	0.044	0.078	0.302	Census
WORKSICK	Proportion of residents of working age permanently sick	0.045	0.018	0.020	0.087	Census
ADULTSICK	Proportion of residents of adult population permanently sick	0.041	0.016	0.020	0.080	Census
STUD17	Proportion of 17 years old who are students	0.410	0.073	0.307	0.679	Census
QUALIF18	Proportion of persons aged 18+ with some qualification	0.130	0.043	0.049	0.277	Census

Census: 1991 Census of Population; GMS: General Medical Statistics at the NHS executive; HES: Hospital episodes statistics; HSI: Health service indicators; ONS: Office for national statistics; RAWP: Carr-Hill et al. (1994).

Table A2: Regression analysis of hospitalisation rates

All conditions[a]		*Asthma*[b]		*Diabetes*[c]		*Epilepsy*[d]	
Variable	*Coefficient*	*Variable*	*Coefficient*	*Variable*	*Coefficient*	*Variable*	*Coefficient*
Constant	0.076	*Constant*	2.892***	*Constant*	1.597*	*Constant*	-0.836**
	(0.718)		(0.618)		(0.842)		(0.418)
GPOP	-0.466**	*GPOP*	-0.461**	*GPOP*	-0.893***	*GPOP*	-0.448**
	(0.199)		(0.209)		(0.295)		(0.201)
PRD1W	0.019	*PRD1W*	-0.053	*PRD1W*	0.143	*PRD1W*	0.157**
	(0.049)		(0.053)		(0.075)		(0.049)
BEDS	0.250**	*BEDS*	0.070	*BEDS*[e]	1.491***	*BEDS*[e]	0.898***
	(0.100)		(0.098)		(0.222)		(0.176)
DOCP	0.174*	*DOCP*	0.186*	*DOCP*	0.221	*DOCP*	0.166*
	(0.098)		(0.100)		(0.148)		(0.095)
DENS	0.007	*DENS*	0.060**	*DENS*	-0.130***	*DENS*	-0.054
	(0.027)		(0.029)		(0.049)		(0.035)
PRES	0.786***	*PRES*	1.010***	*PRES*	0.335	*PRES*	0.536***
	(0.127)		(0.113)		(0.239)		(0.134)
UB	-0.125**	*UB*	-0.188***	*UB*	-0.178**	*NOCAR*	0.137**
	(0.049)		(0.054)		(0.072)		(0.060)
PGP65	0.017**	*PGP65*	0.020**	*MOVELA*	0.364***	*PETHN*	-0.106***
	(0.008)		(0.008)		(0.074)		(0.016)
PENSALONE	0.789***	*HOUSE*	-0.304***	*CNTRHEAT*	0.116**	*CNTRHEAT*	0.093***
	(0.194)		(0.090)		(0.041)		(0.027)
CLASS12	-0.157***	*Y2*	-0.027	*CLASS12*	-0.593***	*RENTED*	0.074**
	(0.078)		(0.038)		(0.136)		(0.029)
Y2	-0.003	*Y3*	0.113**	*NIGHT*	0.178**	*Y2*	0.028
	(0.035)		(0.045)		(0.072)		(0.034)
Y3	0.103**	*Y4*	0.071	*PETHN*	-0.058**	*Y3*	0.068*
	(0.043)		(0.050)		(0.026)		(0.036)
Y4	0.093*	*Y5*	0.101**	*Y2*	-0.023	*Y4*	0.069*
	(0.049)		(0.050)		(0.055)		(0.038)
Y5	0.096*	*Y6*	-0.055	*Y3*	0.037	*Y5*	0.043
	(0.050)		(0.047)		(0.070)		(0.041)
Y6	0.027			*Y4*	0.125	*Y6*	0.101**
	(0.048)				(0.076)		(0.044)
				Y5	0.091		
					(0.081)		
				Y6	0.126		
					(0.078)		
R^2	0.45		0.41		0.31		0.53
RESET test	1.853*		-0.288				
GPOP[f] *prob.*	0.107		0.415		0.243		0.310
BEDS[f] *prob.*	0.165		0.620		0.009***		0.004***
DOCP[f] *prob.*	0.167		0.385		0.416		0.054*
W-H test prob.	0.073		0.715		0.047**		0.001***
J-Test prob.	0.228		0.724		0.554		0.299

***indicates statistical significance at the 99% confidence level; **at the 95%; *at the 90%. Standard errors are in brackets.
a: Instruments: CNTRHEAT, NOSCACC, OLDALONE, DEPSCARER, CHLDNOELP, CHLDNOEH, WORKSICK, ADULTSICK, STUD17, QUALIF18.
b: Instruments: CNTRHEAT, MOVELA, NOSCACC, OVERCRWD, OLDALONE, PENSALONE, DEPSCARER, CHLDNOELP, CHLDNOEH, WORKSICK, ADULTSICK, STUD17.
c: Instruments: RENTED, OVERCRWD, DEPSCARER, CHLDNOEH, WORKSICK, ADULTSICK, STUD17, QUALIF18.
d: Instruments: OVERCRWD, OLDALONE, CHLDNOELP, STUD17, QUALIF18.
e: Instrumental variable: predicted value of the endogenous variable using instruments and exogenous variables.
f: Residual of the regression of the suspected endogenous variables on the exogenous variables and instruments.

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