A review of the epidemiological approach to resource allocation in health care: investigating the assumption of proportionality using *Health Survey for England* data

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Summary

The need component of the current formulae for allocating resources for hospital services and prescribing in England is based on a utilisation approach. This assumes that expenditure on NHS activity in different geographical areas reflects relative needs and supply conditions and these can be disentangled by multiple regression models to yield an estimate of relative need for NHS expenditure. These assumptions have been challenged on the grounds that the needs of some groups may be systematically 'unmet'. Critics have suggested an alternative based on the prevalence of health conditions, called the 'epidemiological approach'.

The epidemiological approach uses direct measures of morbidity to allocate health care resources. It divides the total national budget into programmes based on primary diagnosis, computes the proportion of total cases for each programme in each geographical area, and then allocates budgets to geographical areas proportional to their share of total cases.

The main objection to the epidemiological approach has been seen as its very rich data requirements. But there are also methodological limitations. They centre on the assumption of proportionality, which at the small area level requires that the average level of need for 'cases' within each programme is the same in every area. We illustrate the epidemiological approach, and test the proportionality assumption underpinning it using data from the 2002-2004 rounds of the *Health Survey for England*. We find regional variation in

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disease severity for major diseases, which suggests that health care needs for some conditions vary by area, and therefore that the proportionality assumption underpinning the epidemiological approach is unlikely to hold.

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Introduction

The current approach to resource allocation in the NHS in England contains both a needs element, which attempts to allocate resources according to the health care needs of local populations, and a cost element, which considers geographical variation in unavoidable costs of delivering health care services (Department of Health, 2005). The needs element contains four separate components covering HCHS, prescribing, primary care services and HIV/AIDS. The cost element applies to HCHS, primary care services and HIV/AIDS.

The needs element of the formula for HCHS and prescribing was derived using a utilisation approach applied to small areas (Sutton et al., 2002, Gravelle et al., 2003). Underpinning the utilisation approach is the idea that the provision of health care in different areas contains information on relative needs, and that while needs are not observed directly they may be derived from utilisation data using appropriate statistical techniques. The utilisation of services U is determined by needs N and supply factors S. We cannot observe needs directly but we assume they are an aggregate of decisions made by health care professionals best placed to assess relative needs subject to resource constraints and will depend on socioeconomic factors X and morbidity M. By examining the relationship between utilisation and socioeconomic status and morbidity after sterilising the effects of supply, we can identify the *X* and *M* variables that determine needs and estimate the strength of their effect on needs for health care. If we know the levels of these needs variable in different areas it is then possible to use the results from the model to estimate relative needs in each area and to allocate resources accordingly.

There have been a number of criticisms of this element of the formula (see, e.g., Stone and Galbraith, 2006, Asthana et al., 2004, Asthana and Gibson, 2006), which essentially fall into one of two categories. The first is a series of criticisms concerning the modelling approach. The second is a more general concern about NHS deficits and how this relates to the funding formulae, specifically whether or not PCTs in rural areas were disadvantaged compared to urban areas. Strong doubts about the validity of this second set of criticisms have been raised in recent work conducted by the Chief Economist at the Department of Health, which suggests that PCT deficits are unlikely to have been caused by the current needs formulae (Department of Health, 2007). With respect to the first category, the main criticism is that historical patterns of uptake of health services are inappropriate for assessing health care needs (Asthana et al., 2004).

In light of these criticisms there has been a growing interest in alternative approaches to the utilisation approach and one which has received attention in recent years is called the epidemiological approach. This involves the direct use of morbidity data to allocate health care resources. It has been used to allocate health care resources in Wales (see, e.g., National Assembly for Wales Health and Social Services Committee, 2001) and has been assessed in the context of allocating resources for coronary heart disease (CHD) in England (Asthana et al. 2004). In this paper we investigate the epidemiological approach in greater detail, focusing on a key assumption underpinning the approach, namely the assumption of proportionality.

The epidemiological approach

The epidemiological approach involves the direct use of morbidity data to allocate health care resources. The general approach is to:

1. Divide the total national budget into programmes based on primary diagnosis.
2. Estimate the proportion of total national cases of disease for each programme that are resident in each geographical area.
3. Allocate budgets to geographical areas according to their share of total cases.

For example, if a country spends £*X* on CHD, and 10% of CHD cases are resident in region *A*, then region *A* receives 0.1*£*X*. Note that the proportion of total cases simultaneously account for the size of the resident population, the extent to which its demographic structure influences disease prevalence and the extent to which additional need factors (e.g., socioeconomic status and lifestyle) influence prevalence. As with the utilisation approach, the overall budget is centrally determined and whether or not this is sufficient to treat all cases in accordance with best clinical practice is beyond the scope of this paper.

This is the broad approach used by the National Assembly for Wales Health and Social Services Committee (2001) in the Welsh Review of resource allocation. A variant of this approach is that rather than basing allocations on the share of total actual cases in each area they are instead based on the share of total predicted cases. For example, cases in every area are predicted according to age, gender, ethnicity and socioeconomic data. This is the approach used to compute morbidity indices in the current utilisation-based formula, and is also the approach used by Asthana et al. (2004) in their feasibility study of the epidemiological approach.

Data limitations are commonly seen as the main problem with the epidemiological approach. The two crucial data requirements are:

a. The appropriate division of the total national budget into programmes based on diagnoses of diseases.
b. The share of national cases of disease in each geographical area.

With respect to the first requirement a potential source of data is the National Programme Budget Project which divides NHS expenditure into 23 programmes based on the primary diagnosis underpinning different types of activity. However, to use these data requires the assumption that resources are currently allocated appropriately to programmes. The second data requirement needs rich epidemiological data. The Welsh Review was based mainly on the *Welsh Health Survey*, supplemented with data for specific programmes of care (e.g., cancer). In their analysis Asthana et al. (2004) use the *Health Survey for England* (HSE). While Asthana et al. demonstrated the feasibility of the approach in England using the HSE, it was in the context of a single disease area with relatively rich data (CHD). There is no evidence currently that the approach can be extended to other diseases.

The data requirements pose a major problem for the feasibility of the epidemiological approach. Less commonly discussed are the methodological limitations of the approach (McConnachie and Sutton, 2004). They centre on the assumption of proportionality, which applies *inter alia* to the relationship between morbidity and needs: since the allocation of resources is proportional to cases this means that all cases should have the same level of health care needs. In practice, because resources are allocated to areas, it is not necessary that all cases have the same needs: if we assume that needs are cardinally measurable then what is required is that the mean level of needs for cases is the same in every area.

The proportionality assumption also applies to individuals not reporting any conditions. At its simplest it implies that the needs for health care among those who do not report disease (the 'non-cases') is zero. At the area level, it requires that the total area need for non-cases is proportional to the total area needs for cases at the same rate in every area.

In the next section we provide an illustrative example of the epidemiological approach using crude prevalence data from the HSE. In the following section we investigate whether the proportionality assumption underpinning the epidemiological approach holds, focusing in particular on whether cases and non-cases have the same mean level of health care needs across areas.

An illustrative example

In this section we present an illustration of how the epidemiological approach might be applied using crude prevalence data from the HSE. The data used were taken the 2002-2004 rounds of the HSE and the conditions we focus on are based on the self-reported longstanding illness variables in the HSE, which cover the following 14 diagnoses:[1]

- Infectious Disease (Infect)
- Neoplasms & benign growths (Neoplas)
- Endocrine & metabolic (Endoc)
- Blood & related organs (Blood)

[1] Respondents are asked *"Do you have any long-standing illness, disability or infirmity? By long-standing I mean anything that has troubled you over a period of time, or that is likely to affect you over a period of time?"* If they answer yes they are then asked to list up to six longstanding illnesses they are suffering from. In the survey these are grouped into 14 diagnoses

- Mental disorders (Mental)
- Nervous System (Nerv)
- Eye complaints (Eye)
- Ear complaints (Ear)
- Heart & circulatory system (Circul)
- Respiratory system (Resp)
- Digestive system (Digest)
- Genitourinary system (GU)
- Skin complaints (Skin)
- Musculoskeletal system (Muscul)

The units of analysis in this example are Strategic Health Authorities (StHAs), of which there were 28 in England at the time of the analysis, and which are recorded in the individual level HSE data. We calculated the proportion of total national cases in the HSE that are in each StHA. We used these data to compute indicative allocations for StHAs. To do this we utilised data from the National Programme Budgeting project on net NHS expenditure by programme budgeting category for 2004/5. We excluded expenditure figures for the following programme budget categories because they did not correspond with the HSE longstanding illnesses: Trauma & Injuries (includes burns); Maternity & Reproductive Health; Dental Problems; Learning Disability Problems; Social Care Needs; Healthy Individuals; Neonate Conditions; Poisoning; Other Areas of Spend/Conditions. The total net NHS expenditure for the included categories was £38.5 billion, representing 72% of total.

We illustrate the method below for one StHA (South West Peninsula) and for three longstanding illnesses (heart and circulatory, respiratory, musculoskeletal; see Table 1). Based on HSE data the prevalence of heart and circulatory problems in South West Peninsula StHA is 8.7%, which is lower than the national value (9.7%). In the HSE data there are 112 cases of disease of the heart and circulatory system in South West Peninsula StHA, which is 2.9% of the national figure in the HSE data (3,921 cases; note that 3.2% of the English population reside in South West Peninsula StHA). Applying the epidemiological method South West Peninsula StHA would receive 2.9% of the budget for diseases of the heart and circulatory system. Given the total programme budget for these diseases of £5.9 billion, South West Peninsula StHA would receive £171.5 million for activity related to diseases of the heart and circulatory system.

The monies allocated for each programme budget category are summed and reported for each StHA in Table 2. This reports the net expenditure for every StHA and the % of total national net expenditure. Also reported in Table 2 are indicative allocations based on the utilisation approach using current models. These figures were computed as follows:

- From Table 5.12 of the Exposition Book for 2004/5 we retained figures for the 2001 crude population, Age index and Need index for every PCT.
- We computed weighted populations by multiplying the crude populations of every PCT by the Age index and the Need index.
- We rescaled the weighted populations so that the total weighted population is equal to the total crude population.
- We computed StHA rescaled weighted populations based on the sum of the PCT rescaled weighted populations in every StHA.
- We computed indicative shares for every StHA by dividing the StHA rescaled weighted population by the total population.

The indicative shares using this method are reported in the final column of Table 2. Net expenditures for every StHA are computed by multiplying the relevant total budget (£38.5 billion) by the share of resources allocated to every StHA.

The figures allow us to compare how a budget of £38.5 billion would be allocated to StHAs using an epidemiological approach based on crude prevalences and the utilisation approach. The indicative shares using both methods are compared in Figure 1. The correlation coefficient between the two sets of allocations is 0.8292. In the figure the linear prediction is steeper than the 45 degree line but the slope and intercept terms for these two lines are not significantly different (p=0.8304). The biggest differences between the two approaches are with the allocations to Trent, Surrey and Sussex, and Shropshire and Staffordshire StHAs, who all receive larger indicative shares with the epidemiological approach. London StHAs all receive smaller shares using the epidemiological approach compared with the utilisation approach, as does South West Peninsula StHA. The sum of the absolute differences between the two sets of the allocations across all StHAs is £5.5 billion, which is 14% of the total budget.

A comparison between the utilisation and epidemiological approaches is also made by Asthana et al (2004), though in their study the comparison is between indicative allocations computed using the epidemiological approach applied to CHD only and those computed using a utilisation based approach applied to all diseases.

This example is intended to illustrate the method underpinning the epidemiological approach. It also serves to highlight the types of data required for the approach, and some of the difficulties associated with using these data. For example, the use of health survey data is problematic because such surveys often have limited sample sizes with small numbers in each geographical area, the morbidity data are commonly based on self-reported morbidity that may be differentially reported in a systematic way that varies across areas, and the data may not be representative because the response rate may be biased and the target population usually omits the homeless, those in institutions, and the mobile (i.e., travellers).

Testing the proportionality assumption

Generic measures of severity

In this section, we investigate the assumption of proportionality underpinning the epidemiological approach. As stated above, this basically assumes that the mean level of needs for every diagnosis is the same in every area. To investigate the plausibility of this assumption we examine whether or not the mean health care needs for each longstanding illness in the HSE is the same in every StHA. Health care needs are not directly observable; we therefore proxy them by measures of disease severity in the HSE. The assumption underpinning the analysis is that if disease severity varies by area then so will health care needs for that disease. We also investigate whether severity is correlated with health care utilisation.

We use the 2002-2004 rounds of the HSE, which has a combined total number of observations of 45,305, though there are missing values for some of the variables. The conditions we focus on are the 14 longstanding illness variables used in the illustrative example above. Note again that these conditions are self-reported. Individuals who did not report any of those conditions are considered to be non-cases. We measure disease severity using the following measures:

- Self-assessed general health[2]
- Number of longstanding illnesses (comorbidity)
- Limiting longstanding illness[3]
- Days cut down on normal activities[4]
- EQ5D score

These are also self-reported measures. Our method to testing the proportionality assumption is as follows:

1. We take the sample of patients reporting a particular condition in the HSE.
2. Using this sample we regress the measure of disease severity against area (StHA) indicators.
3. We then test whether the coefficients on the regional indicators are equal to zero (i.e., equal to the omitted StHA). If they are not this suggests there is regional variation in severity, and therefore, by our assumption, in health care needs.

With respect to the self-assessed general health variable, because this gives ordered responses we estimate these models using ordered probit models. The comorbidity variable is a count of the number of longstanding illnesses (0,1,2,3,4 or more). Because some of the categories are grouped these models are also estimated using ordered probit models. The limiting longstanding illness variable is a binary measure and we estimate these models using logistic regression. The days cut down on normal activities variable produces grouped responses (0, 1-3, 4-6, 7-13, 14 days) and therefore these data are modelled using ordered probit regression. The EQ5D data are modelling using OLS. We use HSE sample weights throughout and the standard errors are adjusted for clustered sampling within primary sampling units (PSUs).

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[2] Respondents are asked *"How is your health in general? Would you say it was ...READ OUT... 1 …very good 2 good 3 fair 4 bad 5 very bad?"*

[3] "*Does this illness or disability/do any of these illnesses or disabilities limit your activities in any way? 1 Yes 2 No"*

[4] "*Now I'd like you to think about the two weeks ending yesterday. During those two weeks did you have to cut down on any of the things you usually do about the house or at school/work/or in your free time because of a condition you have just told me about or some other illness or injury? 1 Yes 2 No IF = Yes THEN How many days was this in all during these 2 weeks, including Saturdays and Sundays? Range: 1..14*"

We also consider non-cases as a separate entity in the analysis. Note that testing for regional variation in severity in this group is only a partial test for the proportionality assumption with respect to non-cases at the area level because variations in severity may be offset by variations in the number of cases such that the total area need for non-cases is proportional to the total area needs for cases at the same rate in every area.

Variations in the five measures of severity across StHA for diseases of the heart and circulatory system are shown in five panels of Figure 2. These suggest variation in severity across StHAs. The key regression results are summarised in Tables 3 and 4, which presents for the five measures of severity the p-value for the hypothesis test that the coefficients on the StHA indicators in the regression models are equal to zero. Table 3 presents results with no additional covariates. Results are presented for non-cases and all the longstanding illnesses except infectious disease, where the sample size was too small for model estimation. The null hypothesis in every case is that the coefficients on the StHA indicators are jointly equal to zero. A rejection ($p < 0.05$) suggests that the coefficients on the StHA indicators are not equal, which indicates that there is variation in severity across StHA. All instances where $p > 0.05$, i.e., where the hypothesis that the StHA coefficients are jointly equal to zero is not defeated are shaded in grey. In the 68 models we fail to reject the null hypothesis in 19 cases. For diseases of the heart and circulatory system, diseases of the respiratory system and diseases of the musculoskeletal system in all instances there is evidence of regional variation in severity. Note that these are also the illnesses with the highest number of cases (i.e., which have the largest sample size in the modelling). Ear complaints have the least variation in severity, with no significant variation in 3 of the 5 measures. With respect to non-cases note that the level of the general health, and the number of days cut down over past two weeks varies significantly across areas. The extent of this variation is important given the number non-cases. There is least evidence of variation in severity using the limiting longstanding illness measure (8 out of 13 conditions indicate no variation in severity across StHAs). This may be because this is a binary measure, permitting the least variation of all the measures.

Table 4 reports similar results, where in the regression models comprehensive controls are also added for age, gender, socioeconomic status and ethnicity. Thus, these models report whether there is variation in severity across regions after controlling for these characteristics. As before, there is evidence of variation in disease severity across areas and level of need for non-cases. Of the 65 valid models we fail to reject the null hypothesis in 24 cases.

Disease specific severity

We repeat the analysis using data from the 2003-2004 rounds of the HSE, focusing specifically on cardiovascular disease (CVD). One advantage in using these data is that it permits analysis of disease-specific measures of severity, which are more likely to capture variations in needs associated with CVD than the generic measures discussed above. The 2003 and 2004 rounds of the HSE consider specifically individuals with a history of CVD and the survey categorises such individuals into the following levels of severity (manifestations of CVD):

1. Murmur or irregular heart rhythm only
2. High blood pressure or diabetes only
3. Angina only
4. Heart attack or stroke

The bottom right panel of Figure 2 shows the proportion of individuals reporting each of these CVD conditions in each StHA. Since these categories are ordered in the survey we repeat the regression analysis above using an ordered probit model to regress CVD severity against the StHA indicators, both with and without covariates. In both cases we reject the hypothesis that the coefficients on the StHA indicators are equal to zero ($p = 0.0007$ and $p = 0.0001$). Therefore, there is evidence of variation in disease-specific severity for those with cardiovascular diseases across areas.

A potential criticism of the analysis is that rather than being treated as different levels of severity of CVD, each of the manifestations should be treated as a separate disease in its own right. In this case, epidemiological data would be required for each of the manifestations of CVD. In Table 5 we consider the manifestations as separate diseases and repeat the analyses in Tables 3 and 4 using the generic severity measures. Using the CVD manifestations data we also find evidence of significant regional variation in severity for these conditions.

Impact on health service use

The analysis so far has shown that there is variation in generic and disease-specific severity across StHAs. In this section we investigate whether or not severity is correlated with health service utilisation. The rationale for doing this is that it allows us to assess the materiality of regional variations in severity: if proportionality does not hold with respect to severity, but severity does not affect health service use then the lack of proportionality may be unimportant.

We investigate the impact on health service use using the sample of patients with CVD in the 2003-2004 rounds of the HSE. Using this sample, we regress, using logistic regression, health service utilisation against the generic and disease specific severity measures. The four measures of utilisation are:

- Talking to a doctor in the previous two weeks[5]
- Visiting a practice nurse in the previous two weeks[6]
- Staying in hospital as an inpatient in the previous 12 months[7]
- Attending hospital as an outpatient in the previous 12 months[8]

We include all the severity measures in a single model for each type of health service use and we also control for survey year, age, gender, psychosocial disorder (ghq-12 scores), social class, education, employment status, household income and ethnic group. All models adjust for clustered sampling within PSUs and use sample weights. The results are in Table 6. In most cases, severity is positively correlated with use, conditional on the other variables.

Concluding remarks

In this paper we have investigated the epidemiological approach to resource allocation in health care as an alternative to the utilisation approach. We provided an example of the method and then investigated the assumption of proportionality. We found that there are regional variations in disease severity for major longstanding illnesses, which implies that health care needs for specific cases vary by area. We have also found that variations in severity translate into variations in utilisation. Our interpretation is that the proportionality assumption underpinning the epidemiological approach is unlikely to hold, and that this casts doubts on the viability of the epidemiological approach. We recommend that further research is undertaken to investigate the feasibility of the epidemiological approach.

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[5] Respondents are asked: *"During the two weeks ending yesterday, apart from any visit to a hospital, have you talked to a doctor on your own behalf, either in person or by telephone? 1 Yes 2 No"*

[6] *"During the last 2 weeks ending yesterday, did you see a practice nurse at the GP surgery on your own behalf? 1 Yes 2 No"*

[7] *"During the last twelve months, have you been in hospital as an inpatient, overnight or longer? 1 Yes 2 No"*

[8] *"During the last twelve months, did you attend hospital as an outpatient, day patient or casualty? 1 Yes 2 No"*

Question

Given that when we test the proportionality assumption the focus is on the statistical significance coefficients of the regional indicators in an individual level model, is there any merit in estimating hierarchical models?

References

Asthana S, Gibson A, Moon G, Dicker J and Brigham P. The pursuit of equity in NHS resource allocation: should morbidity replace utilisation as the basis for setting health care capitations? *Social Science and Medicine* 2004; 58: 539-51.

Asthana S and Gibson A. Ev 153. House of Commons Select Committee on Health. *NHS Deficits*. Sixth Report of session 2005-6. Volume II. Written Evidence. 28 June 2006.

Department of Health. *Resource Allocation: Weighted Capitation Formula, 5th Edition.* Department of Health, 2005.

Department of Health. *Explaining NHS deficits, 2003/04-2005/06*. Department of Health, 2007.

Gravelle H, Sutton M, Morris S, et al. Modelling supply and demand influences on the use of health care: implications for deriving a needs-based capitation formula. *Health Economics* 2003; 12: 984-1004

McConnachie A and Sutton M. *Derivation of an adjustment to the Arbuthnott Formula for socio-economic inequities in health care*. Report to the Standing Committee on Resource Allocation, 2004.

National Assembly for Wales Health and Social Services Committee. *Targeting Poor Health: Professor Townsend's Report of the Welsh Assembly's National Steering Group on the Allocation of NHS Resources.* National Assembly for Wales, 2001.

Stone M and Galbraith J. How not to fund hospital and community health services in England. *Journal of the Royal Statistical Society Series A* 2006; 169: 143-164.

Sutton M, Gravelle H, Morris S, Leyland A, Windmeijer F, Dibben C and Muirhead M. *Allocation of Resources to English Areas; Individual and small area determinants of morbidity and use of healthcare resources*. Report to the Department of Health. Edinburgh: Information and Statistics Division, 2002.

Table 1. Indicative allocations for three conditions to South West Peninsula StHA using an epidemiological approach.

	Heart and circulatory	Respiratory	Musculoskeletal
National prevalence (%)	9.70	9.25	15.56
Prevalence in South West Peninsula StHA (%)	8.70	10.26	15.44
Total cases	3,921	4,389	6,284
Cases in South West Peninsula StHA	112	157	201
% total cases in South West Peninsula StHA	2.88	3.56	3.19
National programme budget (£000s)	5,953,869	2,978,795	3,473,882
Indicative allocations (£000s)	171,471	106,045	110,817

Table 2. Comparison of allocations using epidemiological and utilisation approaches. Numbers may not sum due to rounding error.

	Epidemiological approach		Utilisation approach	
StHA	Net Expenditure (£000s)	Share (%)	Net Expenditure (£000s)	Share (%)
Trent	2,830,546	7.3	2,081,282	5.4
Surrey and Sussex	2,372,222	6.2	1,772,136	4.6
Greater Manchester	1,949,598	5.1	2,284,443	5.9
Cheshire & Merseyside	1,985,046	5.1	2,116,597	5.5
Cumbria and Lancashire	1,907,846	4.9	1,628,335	4.2
Birmingham and the Black Country	1,739,552	4.5	2,035,759	5.3
West Yorkshire	1,686,138	4.4	1,752,443	4.5
Shropshire and Staffordshire	1,621,275	4.2	1,142,701	3.0
Norfolk, Suffolk and Cambridgeshire	1,496,030	3.9	1,593,736	4.1
Thames Valley	1,384,112	3.6	1,320,627	3.4
Avon, Gloucestershire and Wiltshire	1,401,767	3.6	1,533,922	4.0
Bedfordshire and Hertfordshire	1,296,747	3.4	1,079,861	2.8
Northumberland, Tyne & Wear	1,265,334	3.3	1,270,961	3.3
Hampshire and Isle of Wight	1,256,208	3.3	1,238,618	3.2
North and East Yorkshire and Northern Lincolnshire	1,229,226	3.2	1,236,316	3.2
West Midlands South	1,215,489	3.2	1,136,183	2.9
Kent and Medway	1,200,019	3.1	1,164,757	3.0
North West London	1,138,041	3.0	1,265,569	3.3
Leicestershire, Northamptonshire and Rutland	1,166,298	3.0	1,085,230	2.8
County Durham and Tees Valley	1,126,227	2.9	1,039,041	2.7
South West Peninsula	1,064,994	2.8	1,291,537	3.4
South Yorkshire	1,054,883	2.7	1,151,393	3.0
Essex	1,006,898	2.6	1,156,551	3.0
North East London	986,005	2.6	1,313,546	3.4
Dorset and Somerset	975,186	2.5	913,641	2.4
South East London	830,757	2.2	1,175,997	3.1
South West London	691,077	1.8	853,938	2.2
North Central London	667,871	1.7	910,265	2.4
SUM	38,545,391	100.0	38,545,391	100.0

Table 3. Testing variation in the severity of longstanding illnesses and non-cases by StHA (no covariates).

	Neoplas	Endoc	Blood	Mental	Nerv	Eye	Ear	Circul	Resp	Digest	GU	Skin	Muscul	Non-cases
Self-assessed general health [1]														
p-value for test that coefs on StHA indicators=0	0.1336	0.0043	<0.0001	0.0003	0.0006	0.1725	0.0013	<0.0001	<0.0001	0.0007	0.0251	0.0001	<0.0001	<0.0001
Observations	594	2026	277	1272	1461	917	954	3919	4388	1816	795	1171	6284	28106
Comorbidity [2]														
p-value for test that coefs on StHA indicators=0	0.0151	<0.0001	0.0038	0.0093	0.0006	0.0475	0.0352	<0.0001	<0.0001	0.0081	0.7914	0.1206	0.0003	N/A
Observations	595	2027	277	1275	1462	918	955	3921	4389	1816	795	1171	6284	
Limiting longstanding illness [3]														
p-value for test that coefs on StHA indicators=0	0.1311	0.0012	0.1002	0.5496	0.3838	0.0676	0.0769	0.0037	<0.0001	0.0876	0.5266	0.0135	0.0005	N/A
Observations	595	2027	271	1275	1462	918	955	3921	4389	1816	795	1171	6284	
Days cut down [4]														
p-value for test that coefs on StHA indicators=0	0.0037	0.0007	<0.0001	0.5462	0.0792	0.0176	0.4503	0.0010	0.0013	0.2295	0.0055	<0.0001	<0.0001	0.0013
Observations	594	2027	277	1270	1462	916	955	3917	4386	1813	795	1171	6277	28106
EQ5D score [5]														
p-value for test that coefs on StHA indicators=0	0.0013	0.1022	<0.0001	0.0011	0.0001	0.0038	0.6744	0.0001	0.0045	0.0066	0.0035	<0.0001	<0.0001	0.1167
Observations	396	1359	150	641	811	493	499	2603	1830	1091	475	366	4083	10524

Notes

All models are estimated with standard errors that are adjusted for clustered sampling within PSUs and use sample weights.

[1] Based on ordered probit of self-assessed health against StHA indicators and survey year.

[2] Based on ordered probit of number of longstanding illnesses against StHA indicators and survey year.

[3] Based on logistic regression of limiting longstanding illness against StHA indicators and survey year.

[4] Based on ordered probit regression of days cut down on normal activities against StHA indicators and survey year.

[5] Based on least squares regression of EQ5D score against StHA indicators and survey year.

N/A = not applicable.

Table 4. Testing variation in the severity of longstanding illnesses and non-cases by StHA (with covariates).

	Neoplas	Endoc	Blood	Mental	Nerv	Eye	Ear	Circul	Resp	Digest	GU	Skin	Muscul	Non-cases
Self-assessed general health [1]														
p-value for test that coefs on StHA indicators=0	0.0256	0.0383	<0.0001	0.0354	0.0148	0.0087	0.0102	0.0729	0.2107	0.0910	0.3378	0.0007	<0.0001	<0.0001
Observations	594	2026	277	1272	1461	917	954	3919	4388	1816	795	1171	6284	28106
Comorbidity [2]														
p-value for test that coefs on StHA indicators=0	0.0001	0.0008	0.0094	0.0160	0.0009	0.0113	.*	0.0001	<0.0001	0.4054	0.7950	0.7006	0.0003	N/A
Observations	595	2027	277	1275	1462	918	955	3921	4389	1816	795	1171	628	
Limiting longstanding illness [3]														
p-value for test that coefs on StHA indicators=0	0.1117	0.0127	0.0001	0.4091	0.4115	0.0039	0.005	0.1109	0.0095	0.1977	0.1671	0.0580	0.0029	N/A
Observations	586	2014	263	1269	1459	909	937	3921	4384	1813	781	1156	6267	
Days cut down [4]														
p-value for test that coefs on StHA indicators=0	0.0188	.*	<0.0001	0.7873	0.1540	.*	0.0755	0.0181	0.0337	0.4085	0.0085	<0.0001	0.0003	0.0016
Observations	594	2027	277	1270	1462	916	955	3917	4386	1813	795	1171	6277	28106
EQ5D score [5]														
p-value for test that coefs on StHA indicators=0	0.1414	0.3286	0.0176	0.0001	0.0125	0.3727	0.9615	0.0036	0.2293	0.0524	0.0417	0.0026	0.0001	0.0429
Observations	396	1359	150	641	811	493	499	2603	1830	1091	475	366	4083	10524

Notes

All models are estimated with standard errors that are adjusted for clustered sampling within PSUs and use sample weights.

[1] Based on ordered probit of self-assessed health against StHA indicators, survey year, age, gender, social class, education, household income and ethnic group.

[2] Based on ordered probit of number of longstanding illnesses against StHA indicators, survey year, age, gender, social class, education, household income and ethnic group.

[3] Based on logistic regression of limiting longstanding illness against StHA indicators, survey year, age, gender, social class, education, household income and ethnic group.

[4] Based on ordered probit regression of days cut down on normal activities against StHA indicators, survey year, age, gender, social class, education, household income and ethnic group.

[5] Based on least squares regression of EQ5D score against StHA indicators, survey year, age, gender, social class, education, household income and ethnic group.

N/A = not applicable.

* Model failed to converge.

Table 5. Testing variation in the severity of each CVD condition by StHA.

	Murmur/irregular rhythm only		High Pressure/ Diabetes only		Angina only		Heart attack/stroke	
	No covariates	**Covariates**	**No covariates**	**Covariates**	**No covariates**	**Covariates**	**No covariates**	**Covariates**
Self-assessed general health [1]								
p-value for test that coefs on StHA indicators=0	0.0635	0.0103	0.0015	0.1291	0.0853	.*	<0.0001	<0.0001
Observations	632	632	3398	3398	386	386	777	777
Comorbidity [2]								
p-value for test that coefs on StHA indicators=0	0.0144	0.0103	0.0381	0.0009	0.1162	<0.0001	0.0060	0.0003
Observations	632	632	3399	3399	386	386	776	776
Limiting longstanding illness [3]								
p-value for test that coefs on StHA indicators=0	0.0606	0.1475	0.0023	0.0038	0.5487	0.6371	0.0022	0.0004
Observations	632	590	3399	3390	376	360	777	752
Days cut down [4]								
p-value for test that coefs on StHA indicators=0	<0.0001	0.0090	0.0928	0.1193	<0.0001	<0.0001	0.2906	0.2261
Observations	632	632	3399	3399	386	386	777	777
EQ5D score [5]								
p-value for test that coefs on StHA indicators=0	0.1129	0.1720	0.0072	0.0648	<0.0001	0.0291	0.0402	0.0472
Observations	599	599	3091	3091	338	338	664	664

Notes

All models are estimated with standard errors that are adjusted for clustered sampling within PSUs and use sample weights.

[1] Based on ordered probit of self-assessed health against StHA indicators (No covariates), plus survey year, age, gender, social class, education, household income and ethnic group (Covariates).

[2] Based on ordered probit of number of longstanding illnesses against StHA indicators (No covariates), plus survey year, age, gender, social class, education, household income and ethnic group (Covariates).

[3] Based on logistic regression of limiting longstanding illness against StHA indicators (No covariates), plus survey year, age, gender, social class, education, household income and ethnic group (Covariates).

[4] Based on ordered probit regression of days cut down on normal activities against StHA indicators (No covariates), survey year, age, gender, social class, education, household income and ethnic group (Covariates).

[5] Based on least squares regression of EQ5D score against StHA indicators (No covariates), survey year, age, gender, social class, education, household income and ethnic group (Covariates).

* Model failed to converge.

Table 6. Effect of severity measures variables on health service utilisation for those with history on CVD.

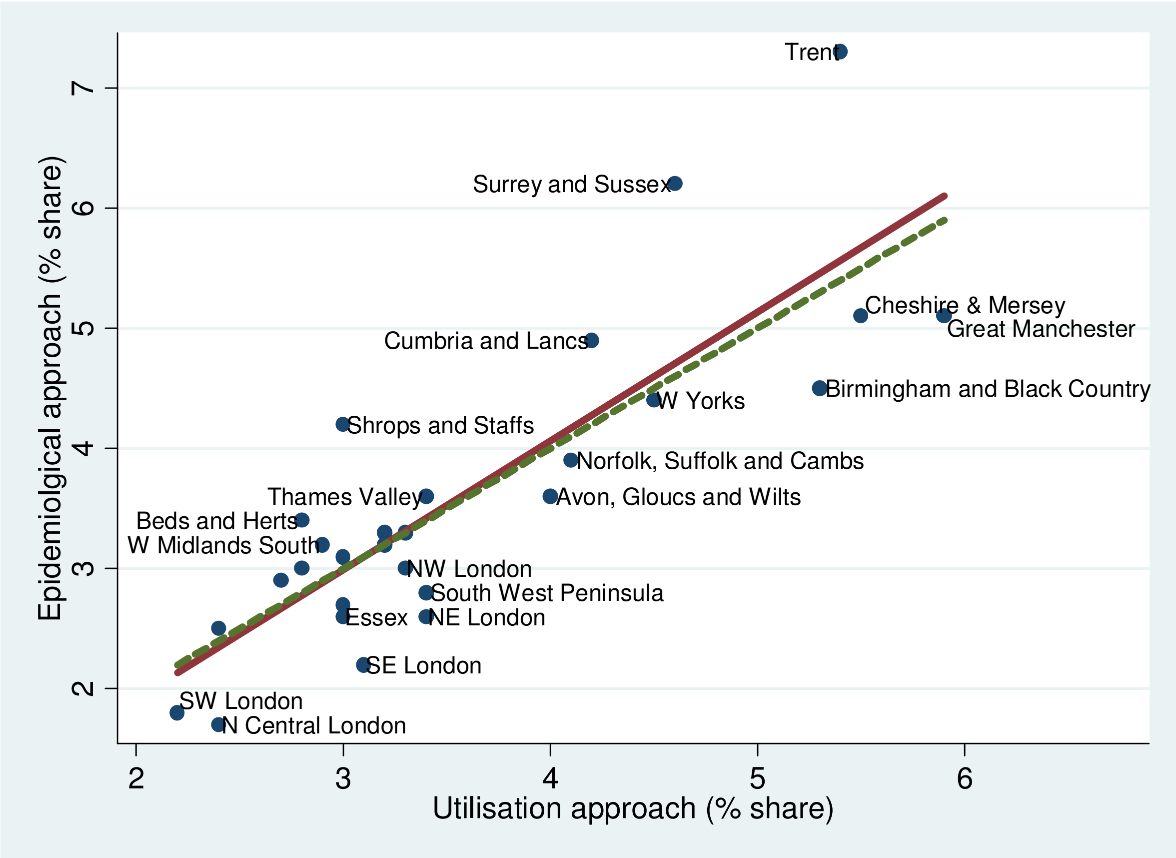
	Talk to doctor (n= 5972)		Practice Nurse (n= 5950)		Inpatient (n= 5962)		Outpatient (n= 5985)	
	Marg. Eff	**z**	**Marg. Eff**	**z**	**Marg. Eff**	**z**	**Marg. Eff**	**z**
Self-reported general health								
very good	Base category		Base category		Base category		Base category	
good	0.026	1.6	0.003	0.3	0.011	0.8	0.046	2.6
fair	0.096	4.6	0.026	1.6	0.037	2.1	0.133	6.6
bad	0.139	4.2	0.037	1.5	0.074	2.7	0.155	4.8
very bad	0.145	3.4	0.069	2.0	0.144	3.4	0.223	5.3
Limiting longstanding illness	-0.013	-0.9	-0.017	-1.5	0.013	1.0	0.060	3.4
Acute ill health (days cut down)								
0 days	Base category		Base category		Base category		Base category	
1-3 days	0.108	4.3	0.021	1.0	-0.015	-0.7	0.026	0.9
4-6 days	0.090	2.9	0.015	0.6	0.028	1.1	0.089	2.5
7-13 days	0.198	6.1	0.076	2.8	0.101	3.8	0.125	3.6
14 days	0.193	8.4	0.054	3.1	0.115	6.0	0.108	4.5
Number of longstanding illnesses								
0 or 1	Base category		Base category		Base category		Base category	
2	0.006	0.4	0.019	1.5	0.005	0.5	0.064	3.6
3	0.014	0.7	0.040	2.2	-0.016	-1.1	0.088	3.6
4 or more	0.040	1.4	0.048	1.9	-0.014	-0.7	0.170	4.9
CVD-specific severity measures								
Murmur/irregular rhythm only	Base category		Base category		Base category		Base category	
High Pressure/Diabetes only	0.018	1.4	0.039	3.2	0.0001	0.01	0.030	1.8
Angina only	0.003	0.1	0.051	2.0	0.081	3.1	0.059	1.9
Heart attack/stroke	0.016	0.8	0.030	1.5	0.080	3.7	0.036	1.4
Test of restrictions								
Self-reported general health = 0	χ^2 = 2.24, p < 0.0001		χ^2 = 7.44, p = 0.1145		χ^2 = 19.27, p = 0.0007		χ^2 = 55.77, p < 0.0001	
Acute ill health variables = 0	χ^2 = 125.04, p < 0.0001		χ^2 = 20.58, p = 0.0004		χ^2 = 63.76, p < 0.0001		χ^2 = 33.88, p < 0.0001	
Comorbidity = 0	χ^2 = 2.42, p = 0.4903		χ^2 = 7.39, p = 0.0604		χ^2 =2.23, p = 0.5259		χ^2 = 33.12, p < 0.0001	
CVD severity = 0	χ^2 = 2.24, p = 0.5239		χ^2 = 10.64, p = 0.0139		χ^2 = 34.83, p < 0.0001		χ^2 = 5.02, p = 0.1707	

Notes

All models are estimated with standard errors that are adjusted for clustered sampling within PSUs and use sample weights.

Based on logistic regression of the use of each type of service against measures of severity, survey year, age, gender, ghq-12 scores, social class, education, employment status, household income and ethnic group.

Figure 1. Comparison of indicative shares by StHA.



Notes

The solid line is the plot of the linear prediction (population weighted). The equation for this line is y = -0.228+ 1.073x (Adjusted R^2 = 0.6923). We fail to reject the null hypothesis that the constant term=0 and the slope term=1 (F=0.19, p=0.8304). The dashed line is the 45 degree line.

Figure 2. Distribution of self-assessed general health ("good" = Very good + Good categories combined; "bad" = Bad + Very bad, top left), comorbidities (mean longstanding illnesses per person, top right), proportion with limiting longstanding illness (middle left), days cut down on usual activities in last two weeks (proportion cutting down activities for the whole 14 days, middle right), EQ5D score (bottom left) by StHA among individuals with diseases of the heart and circulatory system. The figure also includes the distribution of CVD-specific conditions by StHA (bottom right).