Derivation of a needs based capitation formula for allocating prescribing budgets to health authorities and primary care groups in England: regression analysis

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Abstract

Objective To develop a weighted capitation formula for setting target allocations for prescribing expenditures for health authorities and primary care groups in England.

Design Regression analysis relating prescribing costs to the demographic, morbidity, and mortality composition of practice lists.

Setting 8500 general practices in England.

Subjects Data from the 1991 census were attributed to practice lists on the basis of the place of residence of the practice population.

Main outcome measures Variation in age, sex, and temporary resident originated prescribing units (ASTRO(97)-PUs) adjusted net ingredient cost of general practices in England for 1997-8 modelled for the impact of health and social needs after controlling for differences in supply.

Results A needs gradient based on the four variables: permanent sickness, percentage of dependants in no carer households, percentage of students, and percentage of births on practice lists. These, together with supply characteristics, explained 41% of variation in prescribing costs per ASTRO(97)-PU adjusted capita across practices. The latter alone explained about 35% of variation in total costs per head across practices.

Conclusions The model has good statistical specification and contains intuitively plausible needs drivers of prescribing expenditure. Together with adjustments made for differences in ASTRO(97)-PUs the model is capable of explaining 62% (35% + 0.65% (41%)) of variation in prescribing expenditure at practice level. The results of the study have formed the basis for setting target budgets for 1999-2000 allocations for prescribing expenditure for health authorities and primary care groups.

Introduction

The publication of the white paper *The New NHS, Modern, Dependable*[1] proposing the creation of primary care groups with responsibilities to meet the healthcare needs of their populations within an annual budget, together with the government's commitment to provide healthcare services on an equitable basis,[2] has highlighted the need to define practice budgets on a rational basis and to link expenditure to population healthcare needs. For hospital and community health services expenditure, mechanisms already exist for allocating monies from central government to health authorities, and thence to general practice,[3] on the basis of population need. For prescribing expenditure, allocations have only recently moved towards a weighted capitation system to allocate monies to health authorities, and in 1996-7, for the first time, a proportion of the prescribing budget was based on a needs weighting. After appropriate adjustments for the age, sex, and temporary resident characteristics of practices using what are termed age, sex, and temporary resident originating prescribing units (ASTRO-PUs)[4], a weighting for the proportion of people in the 1991 census declaring themselves as unable to work owing to permanent sickness or disability was applied to calculate health authority allocations.[5]

The methodology for devolving health authority prescribing budgets to individual general practices on the basis of population need is much less advanced. Primary care prescribing budgets have largely been based on previous years' spending, with adjustments for an uplift plus growth factor for practices whose budget share, adjusted for the demographics of practice lists and other (unspecified) need factors, was below the local average.[6] Little regard has been given to differences in population need.

We report on the results of a study commissioned by the NHS Executive to examine the determinants of NHS prescribing expenditures at practice level by relating costs to population needs, with the explicit purpose of developing a needs based capitation formula capable of allocating annually about £4.5 billion of NHS revenues to health authorities and primary care groups. At the time this study was commissioned the composition of primary care groups was unknown and in their absence general practice, which represents the lowest unit of analysis possible using current data, was used as the focus of the work. Target allocations to primary care groups and health authorities can be seen as aggregates of allocations for individual practices for which they are responsible. The results of this study have informed target allocations for prescribing budgets for the year 1999-2000. Full details of the study can be found in Rice et al.[7]

Methods

The demand for health care is a complex process, but in order to proceed the following were assumed to be of relevance for prescribing. Demand was measured as expressed demand for prescriptions using utilisation in the form of total practice net ingredient costs for 1997-8. We consider two types of determinants of this demand to be important: the health needs of registered list populations and the supply characteristics of general practices. It is assumed that underlying socioeconomic and demographic characteristics of populations give rise to healthcare needs, in terms of morbidity. This in turn gives rise to the demand for healthcare services including prescriptions. It is also assumed that other socioeconomic characteristics, such as social needs and expectations, independently influence demand over and above those operating through health needs.

The adopted style of general practice can be assumed to have a significant impact on the costs of prescribing. For example, more innovative and better informed practices actively encouraging cost effective prescribing may be cheaper per capita for a given level of need. As well as influencing utilisation, supply may itself be influenced by past use and needs, creating, over time, a feedback loop between supply and utilisation. This renders the use of conventional statistical methods, such as ordinary least squares, inappropriate; instead methods akin to two stage least square, which explicitly aim to take account of the potential simultaneous determination of utilisation and supply, are required. Therefore, an important feature of the work presented here is the attempt to separate out the independent effects of needs and supply on utilisation.[3]

Data

Total prescription costs were made available for all practices for 1997-8 and were measured as net ingredient costs. Practice population demographics were measured in ASTRO(97)-PUs.[8] These reflect both the size of the practice list and its age, sex, and temporary resident structure and were used to standardise costs. A further demographic variable representing the percentage of births per year per practice (pbirths) was constructed.

Mortality and morbidity data available to the study comprised standarised mortality ratios (ages 0-74 years)[3] and limiting long term illness, the latter defined from the self report questionnaire in the 1991 census of populations. Three variants of the limiting long term illness were considered: the proportion of the total population of an area that self reported such illness; the proportion of children in an area that report such illness, and the standardised illness ratio (ages 0-74 years). We also used as a further morbidity measure the percentage of the adult population who reported permanent sickness.

The Jarman score[9] was used as a measure of area deprivation. We also considered separately the component variables used to construct the Jarman score. Other socioeconomic characteristics covering such aspects as home circumstances, availability of amenities, social class, and educational and economic status were also included.

Practice supply characteristics available to the study were fundholding status (and wave of fundholding), training status, dispensing status, whether the practice was single handed, number of full time equivalent general practitioners, and practice list size.

In an attempt to control for differential list inflation in the subsequent regression analysis, an estimate of practice list inflation was derived. This was calculated by attributing health authority list inflation for five year age and sex groups to practice populations within their respective health authorities. Health authority list inflation was calculated as the ratio of the sum of general practice registrations in all the enumeration districts of a health authority to the Office of National Statistics estimates of the health authority population.

We considered the use of low income scheme data, which have been shown elsewhere to be an important measure of deprivation linked to prescribing,[10] but rejected it on the grounds of limited coverage of the practices used in this study.

Attributing small area statistics to general practices

Most of the data made available for this study were derived from routine data sources such as census data, which are measured at the area level (electoral wards). To construct a database at practice level these were attributed to practices on the basis of place of residence of the practice population. The place of residence of the practice populations were obtained from data for all patient registrations in England and Wales. By aggregating the raw registration data it was possible to compute the proportion of each practice population in each of the wards. Census variables were then computed for each ward and combined with the proportions of a practice population in each ward to give a weighted average for the practice.

Statistical methods

The analysis took the form of a multivariate regression model using as the dependent variable net ingredient cost per ASTRO(97)-PU, with need and supply variables forming the set of potential explanatory variables. Tests to determine whether simultaneity between supply and utilisation were carried out, and where present adjustments using the method of control function to the regression model were made.[11]

Additive versus multiplicative model specifications were tested, and additive models proved to have greater statistical specification when applying the general reset test proposed by Ramsey.[12] The data consisted of general practices located with health authorities, and to account for health authority effects fixed versus random effect specifications were tested using the Hausman test.[13] Health authority effects are assumed to represent differences in supply configurations, which impact equally on all individuals registered with practices within the health authority. Fixed effects proved superior and accordingly dummy variables were included in the regression to represent health authority effects.

We were interested in finding as parsimonious and transparent a model as possible—that is, a model with the least number of variables, which sensibly capture variations in supply adjusted utilisation, but one that is also intuitively plausible. Initially all potential needs variables (set of morbidity and socioeconomic variables) were entered into the regression equation. This model was then progressively restricted by omitting needs variables in order of the following criteria:

Table 1 Final model (costs in £ sterling)

Variables	Dependent cost/ASTRO(97)-PU* Coefficient	t value
Constant	24.99	23.11
Need†:		
psick	0.59	11.40
pnocare	0.03	2.17
pstudent	−0.23	−9.24
pbirths	1.88	17.57
Supply:		
Dispensing practice	0.68	6.81
Not training status	0.32	4.02
No of general practitioners per patient	909.6	4.02
Single handed practice	−0.50	−4.59
General practice fundholding status	−1.15	−17.28
R^2	0.41	
Reset F(3, 8392)	0.24	P=0.86

*Age, sex, and temporary resident originated prescribing units.
†For definitions see table 2.

remove if counterintuitive sign and coefficient is significant, remove if counterintuitive sign and coefficient is not significant, and remove if not significant. Throughout this process all supply variables, the estimate of list inflation, and health authority fixed effects were forced into the regression. This process was continued until all remaining needs variables were statistically significantly different from zero. Tests were then made to ensure that this selected model was statistically well specified using Ramsey's reset method.[12] Plots of standardised residuals against normal scores were also used to check that the residuals conformed to assumptions of normality. All regressions were weighted by practice list size.

Results

Table 1 presents the model selected adopting the above procedures. Health authority effects and the list inflation variable are not shown. Four needs variables were selected: percentage of adults in households permanently sick (psick), percentage of dependants in no carer households (pnocare), percentage of working age population who are students (pstudents), and percentage of births on practice lists (pbirths). Table 2 provides full definitions of these needs variables together with descriptive statistics. Positive coefficients indicate that higher percentages of these variables were associated with greater cost per ASTRO(97)-PU; the converse was true for negative coefficients. The needs and supply variables together explained 41% of variation in cost per ASTRO(97)-PU. A separate regression of net ingredient cost per capita on ASTRO(97)-PUs and supply resulted in an R^2 of 0.35. Inspection of standardised residuals against normal scores showed no serious signs of departure from normality, and the reset test indicated no evidence to reject the null hypothesis of adequate model specification, $F(3, 8392) = 0.24$; $P = 0.86$.

The four variables selected are intuitively plausible as needs drivers of prescribing expenditure, and exhibited the expected signs of association with costs. Permanent sickness played a dominant role in the modelling, and although there are some doubts over its interpretation (self reported morbidity which limits activity, rather than an objective measure of morbidity), it was found to be a stronger predictor than standardised mortality or illness ratios or self reported limiting long term illness. It is also in line with the current formula used to allocate prescribing monies to health authorities.[5] The percentage of dependants with no carers is likely to be reflective of wider socioeconomic circumstances, whereas the inclusion of the percentage of births on practice lists is likely to capture both an effect of women of childbearing age and the increased demands of young children. The percentage of students is likely to reflect several factors including those associated with young mobile healthy populations and a lack of permanent residence.

It should be emphasised that for allocation purposes only the coefficients attached to the needs (and constant) variables are of relevance. Supply variables were included in the modelling procedure to condition upon to ensure that we were able to control for any correlation that may have existed between needs and supply. However, it is only the needs coefficients that determine the gradient upon which actual target allocations are intended to be based. In no way is it intended that, for example, dispensing and non-dispensing practices should be treated differently when deriving needs based allocations; it is only the needs composition of their respective lists that are of importance.

Discussion

We derived a robust needs based capitation formula capable of setting target budgets for health authority and primary care group prescribing allocations. The resulting model contains four intuitively plausible needs drivers, has good statistical specification, and is capable of explaining up to 62% (35% + 0.65% (41%)) of variation in prescribing expenditure at practice level. The formula has been implemented by the NHS Executive to set target allocations for health authorities and primary care groups for 1999-2000.[14]

The possibility for further refinements to the model seems limited using current data sources. In future, enhancements to the model would be gained through

Table 2 Variable definitions and summary statistics

Variable name	Variable definition	Mean (SD)	Range	Data source
Cost	Net ingredient costs per capita	83.34 (20.39)	9.36-219.28	Prescription Pricing Authority
ASTRO(97)-PU*	ASTRO(97)-PUs per capita	4.24 (0.62)	1.63-8.51	Prescribing Support Unit, Leeds
psick	% of adult population in households permanently sick	3.66 (1.76)	0.77-14.51	Small area statistics
pnocare	% of dependants in no carer households	15.06 (3.89)	3.58-38.06	Small area statistics
pstudent	% of working age population who are students	5.12 (1.74)	2.16-21.03	Local base statistics
pbirths†	% of births on practice lists	1.3 (0.4)	0-6.7	Prescription Pricing Authority and Office of National Statistics

*Age, sex, and temporary resident originated prescribing units.
†Estimated as product of proportion of 0-4 year olds on practice list and weighted average of ratios of Office of National Statistics estimate of births to Office of National Statistics estimate of 0-4 year olds for health authorities in which practice has registrations

the use of income related data and data on nursing home patients should these become readily available. Income related data may take several forms, but the inclusion of data provided through the low income scheme and income support is likely to prove most valuable. It was not possible to include data on nursing home residents in this study owing to a lack of comprehensive and reliable data, but in recognition of the need for local flexibility health authorities will be allowed to make adjustments to target shares for primary care groups to reflect the extra costs of prescribing to nursing home residents.[14]

Further advances in understanding the needs based mechanisms of prescribing may best be achieved through moving to data measured at the individual patient level. Although, for the foreseeable future, it seems unlikely that such data will be collected on a routine basis, much could be gained from a survey of individual patients and their practices. This may form the basis of a future research agenda not only in the area of prescribing but also to inform resource allocation methodology in other areas of the NHS budget.

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What is already known on this topic

Primary care groups are required to meet the healthcare needs of the populations they serve within an annual budget. This, coupled with the government's commitment to provide healthcare services on an equitable basis, has highlighted the need to define budgets on a rational basis linked to population needs

One component of the unified budget is prescribing expenditure

What this paper adds

This study derives for the first time a needs based capitation formula capable of defining primary care group target expenditures for prescribing

Year 1999-2000 target budgets for primary care group prescribing have been allocated on the basis of the four needs variables identified in this study: permanent sickness, dependants with no carers, students, and births

Commentary: The emphasis on transparency weakens the formula

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The regression model developed here represents an advance on what has gone before. By simultaneously adjusting for supply variables, it identifies the underlying relation between prescribing costs and need. This approach breaks, or at least weakens, the vicious circle that has operated in the past whereby authorities spending the most money are predicted to need the most in the future.

The paper provides an interesting demonstration of the tension that underlies regression analyses where the fitted model is to be used to allocate large sums of money. The statistical imperative of a model that predicts the outcome optimally has to be traded off against the political need for transparency, which translates as a model that is both parsimonious and intuitively plausible.

It is evident that these two aims are to some extent contradictory. The dataset consists of a large number of need and supply variables for 8500 general practices, so there is ample opportunity to build a model of sufficient complexity to capture, as well as it can, the subtleties of prescribing behaviour in terms of need and supply. Yet the model also has to be sufficiently simple for those most affected by it to understand how it works.

The NHS Executive recognised this when commissioning the study, and it specified that the variables in the model should be intuitively appealing. That is why Rice et al removed significant variables with counterintuitive sign (see the statistical methods). But as a strategy it is not without risk.

Significant variables are informative even though their contributions to the model may not be obvious.

They often seem to have a regression coefficient of the "wrong" sign, but the variable seems counterintuitive only if considered in isolation. Consideration of other variables in the model makes the reason clear. Variables with counterintuitive sign compensate for the excess effects of other variables in the model, so that excluding them removes this opportunity for negative feedback. The result is a model that is both less subtle and less predictive—in short, the downside of transparency.

Another illustration of the tension between statistics and politics is the inclusion of the need variable defined as the percentage of dependants in no carer households. It is only marginally significant (t = 2.17, table 1) and explains just 0.06% of the variance—far less than the other variables in the model and probably less than the variables excluded as counterintuitive. So it is irrelevant in terms of improving the fit and increases the complexity of the need model by a third. Yet it is included because it is intuitively appealing.

So the good news for practitioners is that the need model is both simple and plausible. The bad news is that the model fails to explain three eighths of the variation in prescription costs, and this fraction could be reduced if the model were allowed to be less transparent.

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Analysis of the ability of the new needs adjustment formula to improve the setting of weighted capitation prescribing budgets in English general practice

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In April 1991 prescribing budgets were introduced into English general practice as part of the fundholding and indicative prescribing schemes.[1] The schemes were designed to control the growth in public expenditure on drugs and to reduce the variation in prescribing costs that existed between general practitioners in different parts of the country. Initially, practice level prescribing budgets were set on a historical cost basis. This approach was criticised, however, for being inequitable and for possibly rewarding high cost, inefficient practices with more funds.[2] In response, a move to budgets set on a weighted capitation basis was recommended as a means of promoting equity while ensuring that funding levels reflected the needs of patients locally.

The identification of several limitations of the weighted capitation formula that was used to help set prescribing budgets in England from 1993-4 onwards led to a debate about the desirability of using such an approach. Majeed argued that variations in general practice prescribing costs were too large to be explained in this way.[3] He suggested that the rigid, inflexible application of weighted capitation formulas to help set practice level prescribing budgets should be avoided. In a similar vein, Majeed and Head argued that weighted capitation formulas were very crude tools for determining general practice prescribing budgets and should be used only as a guide to allocations.[4] Greenhalgh concluded that such formulas should not be used as substitutes for factors such as reflection or negotiation during the budget setting process.[5] Maxwell, Howie, and Pryde reported that the formula used to help set practice level budgets failed to take account of factors such as patients' values, beliefs, and expectations.[6] Finally, Smith argued that the formula did not reflect all patient related variations in costs, random variations in need, and differences in clinical practice. In consequence, he argued, such formulas should be used with great caution.[7]

Despite concerns about the use of weighted capitation formulas in the setting of practice level prescribing budgets, the "new NHS" white paper announced that from April 1999 onwards all practices in England would be allocated a budget for prescribing under the auspices of the newly established primary care groups.[8] To help improve the basis on which such budgets are set, the NHS Executive commissioned researchers from York University and the Prescribing Support Unit to identify which factors other than patient age, sex and temporary resident status were associated with variations in costs. In June 1999 the NHS Executive published the final formula produced by the research team with the recommendation that it be used by primary care groups to help guide practice level prescribing allocations. In response, we outline some of the main deficiencies of the formula and conclude that the approach used during its construction may have institutionalised historical prescribing patterns and failed to measure variations in patients' needs for prescribed drugs.

Summary points

The existing weighted capitation formula used for setting prescribing budgets in English general practice has known limitations

A new needs adjustment formula was designed to address many of these limitations

As the new formula was developed using a similar procedure for identifying patients' needs, it embodies some of the limitations of its predecessor

In particular, the new formula may have institutionalised historical prescribing patterns and may fail to measure patients' needs directly

The new formula should be subjected to piloting and a formal evaluation before it is recommended for use nationally