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Measurement of inequality : implications of spatial factors An application to general practitioners

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Abstract

We construct measures of geographical inequality in the distribution of general practitioners in England and Wales based on the concept of the per capita equivalised value of GP resources in an area. Equivalised value is a function of the number of GPs, and the characteristics of the population and area. Spatial models suggest (a) that GPs per capita is likely to be a poor measure of equivalised resources in an area and (b) that within-area inequality is important because of differences in the accessibility of practices to patients. The impact of alternative equivalised resource functions and levels of aggregation are examined.

Keywords: Equity; inequality; geographical distribution; primary care; general practitioners.

Introduction

Although expenditure on general practice is only about 8% of NHS exenditure, general practice is the most salient aspect of the NHS for most patients most of the time and has a symbolic importance in public perceptions of the NHS. General Practitioners are the gatekeepers of the NHS and geographical variations in GP provision may result in geographical inequities in the volume and quality of care consumed. Policy concern with geographical equity manifested itself at the founding of the NHS in 1948 when the Medical Practices Committee was established by statute to regulate the distribution of GPs.

Resources for primary care are not allocated by formula, though there has been recent investigation of the possibility (Carr-Hill, Rice and Smith, 1997). The relatively few studies of geographical equity in primary care indicate there is substantial inequity at both Regional Health Authority and Family Health Service Authority levels[1] (Buxton and Klein, 1979, Birch and Maynard, 1986 ; Bevan and Charlton, 1987 ; Bloor and Maynard, 1995 ; Benzeval and Judge, 1996 ; and that the inequity is persistent (Gravelle and Sutton, 1998).

In this paper we extend the earlier work on geographical equity in primary care by incorporating insights from spatial models of access and by using practice level data, rather than working at the much higher levels of aggregation implied by the use of data on provision at regional or FHSA level. Although the empirical analysis is concerned with the distribution of GPs, the methods and implications are relevant for the analysis of geographical equity in the provision of other health care resources.

In section 2 we argue that resources are inevitably spatially specific and location is an important influence on access. We suggest that summary measures of equity should be based on equivalised

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[1] *From 1990 to April 1996 primary care in England and Wales was administered by 98 FHSAs containing, on average, about 500,000 patients, 100 practices and 300 GPs. The number of health service regions was reduced from 15 to 9 in April 1996.*

resources per capita in each area and consider what data are required for the measurement of geographical equity. We argue that the measurement of equivalised resources per capita is not just a question of the appropriate method for the adjustment of raw population figures for « need ». Equivalised resources should reflect the value of resources to the populations they serve and consequently should take account of the costs those populations bear in using them. We show how even very simple spatial models suggest that the value of resources in different areas is unlikely to be captured properly by the ratio of resources to the « need » adjusted population.

We explore the empirical implications of sections 2 using a data set not previously utilised for this purpose. The data set, which is described in section 3, contains information on numbers of GPs and numbers of patients in some 9600 practices in England and Wales in 1995.

Section 4 examines first the extent of the underestimate of inequality which results from using FHSA level data compared with practice level data and second the downward bias in inequality measures from neglect of spatial factors by simulating a simple spatial model.

Finally, section 5 contains some conclusions.

1. Equivalised resources

Health-care for individuals in different socio-economic categories is produced by resources which are inevitably spatially specific and not linked directly to characteristics of individuals. Although the concern is ultimate with individual welfare, health-care resource-allocation policy is primarily focussed on allocation to heterogeneous groups of individuals grouped in areas. The lack of data on the impact of these area-specific resources on individuals means that the evaluation of policy rests on measures which are derived from area level aggregates, such as the total amount of resource provided and the characteristics of the population. It is instructive to consider the relationship between the measures typically used and the measures which should be used if there was better, individual level, information.

1.1. Individuals' equivalised ressources

With sufficient data it would relatively straightforward to construct measures of the inequity of distribution of health care services. The social valuation y_i^j of individual *j*'s access to resources in area *i* is a function of the characteristics of the resources (including location), the characteristics of the individual (including their location) and the characteristics of the area. We refer to y_i^j as the equivalised resource available to individual *j* in area *i*.

In a simple case we could define the individual equivalised resource function:

$$y_i^j = u(r_i, \ell_i, \ell_i^j, x_i^j, z_i) \qquad (1)$$

where r_i is the quantity of resource (number of GPs say), ℓ_i is the location of the resource, ℓ_i is the location of individual *j*, x_i^j is a vector of characteristics of the individual and z_i is a vector describing the characteristics of the area which affect the social benefit derived by *j* from the resource in area *i*. x_i is the vector $(x_i^1, \ldots, x_i^{n_i})$ where n_i is the number of people in area *i*.

The characteristics x_i^j include age, sex, access to public and private transport, health state etc which affect the value the individual derives from the resource. The area characteristics z_i might include climate, environment, and social capital. They could also include the rule by which access to the resource is rationed, for example, queuing, triage systems, or social status. The x_i^j vector could affect social value of the resource for individual *j* because, for example, the rationing rule might depend on the number of other individuals with similar characteristics.

The form of the function *u*(.) reflects both social value judgements and positive findings about the effect of location and other factors on the benefits individuals derive from the resources provided.

We could use (1) to measure inequality in the distribution of health care resources by applying standard income distribution measures to the distribution of the equivalised resources y_i^j across individuals. Geographical location would only be relevant only in so far as it had a direct effect on the equivalised resources of individuals, for example because some areas were more unhealthy than others or because access costs differed. The rules for allocating resources to areas would be judged, *inter alia*, by their effect on the inequality measure calculated over all individuals.

The degree of horizontal equity in the system could be calculated by examining whether the equivalised resource provided to particular types of individuals was systematically related to characteristics which we do not believe should influence y_i^j, for example income. We could test for geographical horizontal inequity by examining whether the individual equivalised resources varied with the area, other than through the characteristics z_i which we believe to be relevant for social value. One such irrelevant characteristic is the identity of the area: having allowed for its characteristics z_i the index *i* should not affect the per capita social value. Another example of an irrelevant area characteristic might be its distance from London or the average income of its inhabitants.

1.2. Per capita equivalised resource functions

Unfortunately, the data do not enable us to measure individuals' equivalised resources to test for geographical inequity. Rather than individual level data, we typically have only area level information on resources r_i, area characteristics z_i and the distribution of some of the characteristics in x_i^j across the population. The usual procedure is to construct a measure of the « need » adjusted population from the information on the population characteristics : $p_i = q(x_i)$. A measure $y(r_i, p_i, z_i)$ of the per capita equivalised resource in area *i* is compared across areas to measure geographical inequity. Typically the measure used is GPs per head of the need adjusted population: $y(r_i, p_i, z_i) = r_i / p_i$.

Although such a procedure may be the best that can be done given the data, it is important to be aware of its limitations. What we would like to measure is per capita equivalised resource in area *i* calculated from the individual equivalised resources of the n_i individuals in the area

$$\frac{1}{n_i}\sum_{j}^{n_i} u = u(r_i, \ell_i, \ell_i^j, x_i^j, z_i) \qquad (2)$$

The measure of per capita equivalised resources r_i / p_i typically used will be equal to the true per capita value (2) under very strong restrictions. First, it must be assumed that benefits to individuals from resources must be independent of the location of the individuals and the resources, and the area characteristics, so that spatial factors are assumed away. Second, *u*(.) must be additively or multiplicatively separable in the individual characteristics. An additive form would imply that the marginal benefit from increased resources in an area was independent of the number and characteristics of individuals. This seems highly implausible. Third individual benefits must be proportional to resources, which as, we will see is also implausible.

Comparison of per capita equivalised resources neglects inevitable within area inequalities. Even if individuals were identical, in the sense of having the same personal characteristics x_i^j, they will have differential access to health care resources, since resources and individuals are spatially located. We turn next to a more detailed consideration of the bias in geographical inequity measures caused by neglect of spatial factors, first in measuring per capita equivalised resources and second in ignoring within area inequalities.

1.3. Spatial factors and the equivalised per capita resource function

Previous studies of geographical equity in primary care have written the equivalised per capita resource function as $y_i = r_i / p_i$, where r_i is the number of GPs or expenditure on primary care. Such a formulation implies that doubling the number of GPs in an area doubles the equivalised resources. However, spatial models of the use of health care facilities suggest that whilst per capita benefit to patients increase with the number of GPs, it will do so at a declining rate.

For example, consider the model in Gravelle (1998) based on the standard circular road product differentiation or transport cost model (Salop, 1979). Patients are identical except for their location around a circular road of circumference K_i. Every patient visits a GP once in a period and gets a benefit worth *x* from the visit. A patient who is distance *d* from the surgery incurs a distance cost $t_i d$ when making a visit. The n_i patients are uniformly distributed with respect to distance and the r_i GPs are evenly spaced around the circle. Each GP has a list-size of n_i / r_i. Patients have a net benefit $x - t_i d$.

In such a world it seems reasonable to measure per capita equivalised resources as the patients' average net benefit from the r_i GPs in the area: $y_i = x - t_i k_i / 4 r_i$. Increases in the number of GPs in an area (r_i) increase equivalised per capita resources $(\partial y_i / \partial r_i = y_{ir} = t_i K_i / 4 r_i^2 > 0)$ but at a declining rate $(\partial^2 y_i / \partial r_i^2 = y_{irr} = t_i K_i / 2 r_i^3 < 0)$.

A number of obvious extensions make the circular model more realistic but do not affect the conclusion that the marginal value of resources declines with the amount of resource.

The above formulations assumed that GPs have free choice of where to locate and that they spread themselves evenly. Neither assumption may be realistic and so we must consider the within area allocation mechanism. It would be possible to specify a within area allocation rule that had the property that, as the number of GPs increased, their equivalised number increased proportionately. Suppose, for example, that the quality of service received from a practice was proportional to the number of GPs, additional GPs always locate in existing practices, and no branch surgeries are opened. In this case, additional GPs do not reduce patients' distance related costs. Then, if the demand for consultations was completely inelastic, per capita benefits would increase in proportion to the number of GPs. However, if demand is elastic, per capita benefit will decline with the number of GPs.

Whatever the precise specification of the underlying model of within area demand and supply for GP services it seems likely that equivalised resources per capita increase less than proportionately with the number of GPs. In section 4.2 we examine the implications of non-proportional equivalised per capita resource functions for estimates of geographical inequity by simulating a simple spatial model.

1.4. Spatial factors and within-area inequality

Estimating geographical inequity by comparing per capita equivalised resources across areas neglects within area inequality. As the simple model above demonstrates, individuals within an area derive different benefits from the area's resources. Even if they are otherwise identical, patients in an area inevitably have different access costs because they are located different distances away from a health care facility and therefore get different net benefits from it. We can choose to ignore within-area inequity in constructing our measure of equivalised resource provision, but should remember that we will be understating the amount of inequality.

We can use the simple spatial models above to give some idea of the extent of the understatement in total inequality resulting from using area-level averages as the measure of equivalised resources. For example, suppose that the social value of GP services for an individual j in practice k in area i with characteristics x_i^{jk} varies with their distance from their practice d_i^{jk} and the number of GPs in the practice r_i^k according to

$$y_i^{jk} = \beta x_i^{jk} r_i^k / n_i^k - t d_i^{jk} \tag{3}$$

where n_i is the population of practice *k* in area *i*.

The total amount of inequality in the country depends on the distribution of y_i^{jk} across the population. By way of illustration we use the variance as a measure of inequality since it has the convenient property that we can write the total inequality, across individuals as

$$V\left(y_i^{jk}\right)=V_i\left(y_i\right)+\sum_i \frac{n_i}{n} V_i^k\left(y_i^k\right)+\sum_i \frac{n_i}{n} \sum_k \frac{n_i^k}{n_i} V_i^{jk}\left(y_i^{jk}\right) \tag{4}$$

where *n* is total population. $V\left(y_i^{jk}\right)$ is the variance across individuals in all practices and areas, $V_i\left(y_i\right)$ is the variance of equivalised resources per head of area population y_i^{jk} across areas, $V_i^k\left(y_i^k\right)$ is the variance of equivalised resources per head of practice population y_i^k across practices within area *i* and $V_i^{jk}\left(y_i^{jk}\right)$ is the variance of equivalised resources across the individuals in practice *k* in area *i*. Estimates of inequality based on resources per head of area population measure only the first term and neglect both across-practice within-area inequality and across-individual, within-practice inequality.

Consider a very simple case: assume that the distances patients have to travel to their practices falls, on average, as the number of practices increases, with patients in each area uniformly distributed around a circle and that practices are evenly spaced around the circle. The average distance to a practice is $K_i/4\rho_i$ where ρ_i is the number of practices in area *i*. Assume further that patient characteristics vary across areas, but not within them. Even in this very simple case the total variance across individuals is

$$\begin{aligned} V\left(y_i^{jk}\right) &= \beta^2 V_i\left(\frac{\bar{x}_i r_i}{n_i}\right)+V_i\left(\frac{t_i K_i}{4\rho_i}\right)-2\beta Cov_i\left(\frac{\bar{x}_i r_i}{n_i},\frac{t_i K_i}{4\rho_i}\right) \\ &+\sum_i \frac{n_i}{n}\left(\beta \bar{x}_i\right)^2 V_i^k\left(\frac{r_i^k}{n_i^k}\right) \\ &+\sum_i \frac{n_i}{n} t_i^2 V_i^{jk}\left(d_i^{jk}\right) \end{aligned}$$

where the first line is the across area variance, the second is the across practice variance and the last line is the within practice variance.

In section 4.1 we use the practice level data set to show the bias in neglecting within area inequalities in the even simpler case where access costs are zero so that (5) reduces to the first and fourth terms. Section 4.2 illustrates the effects of positive access costs by simulating (5) with positive t_i.

2. Data

The data used for analysing the geographical distribution of GPs were collected by Family Health Service Authorities and collated by the STATS Division of the NHS Executive. Information was collected on all qualified GPs practicing in the NHS in England and Wales. We use a subset of the data for April 1995 which contains data on: list-size, patients by their capitation payment categories, GP time commitment, FHSA area in which the majority of the GP's patients reside, and whether the GP provides a full range of services. Because GPs within the same practice are known to share patients, we aggregate the data to practice level. GPs are assigned to the FHSA responsible for paying their fees and allowances. This is normally the FHSA containing the majority of the patients of the practice to which the GP belongs. We have calculated the numbers of whole-time equivalent GPs and patients in each practice. Only GPs who are unrestricted principals providing the full range of services are included in the analysis.

The data set contains a number of anomalies which we are still in the process of resolving. For example, even after aggregation of GPs to practices, there are practices with zero patients and others with over 5600 patients per GP. In order to illustrate the points we make in earlier sections we have excluded the practices in the top and bottom 1% of the list size distribution. This leaves us with 9408 practices.

GP lists are known to be inaccurate. On average there are more patients registered with GPs at any one time in an area than the population estimated from the population census. List inflation varies and is greater in more deprived areas. The effect of list inflation is therefore to somewhat overstate inequality. We feel that this disadvantage of using practice level information is outweighed by its merits in terms of providing estimates of inequality at lower and more appropriate levels of aggregation, compared with the use of FHSA level data which has better population estimates.

3. Aggregation and measured inequality

Previous studies have examined the distribution of GPs by comparing average levels of provision across FHSAs. The use of FHSA level data is likely to underestimate inequality. First, there are variations in practice list sizes so that equivalised resources per head of practice populations vary within each FHSA. Given that a typical FHSA contains around 100 practices, aggregation to FHSA level is likely to substantially underestimate the total level of geographical inequality. Second, patients within a given practice have different access costs and so derive different benefits from the practice. Since there are on average over 1800 patients per GP, neglect of within practice variations may also substantially underestimate inequality.

3.1. Inequality at practice, area and regional level

We use the practice level data set to illustrate the implications of different levels of aggregation. Table 1 compares a variety of inequality measures (Cowel, 1995) calculated at practice level with those calculated by aggregating the practice level information to FHSA and Regional Health Authority level. The populations are adjusted for need by the share of total of age and deprivation related capitation payments accruing to the population. As would be expected the level of aggregation has a marked effect. For example, the Gini coefficient doubles in moving from RHA to FHSA level and again in moving from FHSA to practice level. The effect of disaggregation on other measures is even more marked. By contrast the effect of the need adjustment was to increase the inequality measures by between 0.4% to 13.7%. Clearly comparisons across areas considerably understates inequality in GP provision

3.2. Simulation of decomposition to individual level

Decomposition to practices implicitly assumes that individual within practices receive the same level of equivalised resources. However, the evidence on the effect of distance on GP consultation rates (Parkin, 1979; Whitehouse, 1985; Carr-Hill, Rice and Roland, 1994) suggests strongly that the value placed on the practice by its patients varies with their distance from the practice. In section 2.4 we used a simplified spatial model of the value of GPs to illustrate the additional inequality which results from differential access costs.

Table 2 shows simulation results based on the simple spatial model which gave rise to (5). The results are somewhat unexpected in two respects. First inequality falls as the distance cost parameter increases. Increasing the time cost parameter in principle can have ambiguous effects on the level of inequality. The covariance of practice list sizes and the practice areas (the third row of the table) is positive and since this term enters negatively into (5) and is mutliplied by t increases in t have both negative and positive effects on the total variance of equivalised resources. In the current case measured inequality falls as t increases. Second, the effect of a positive distance cost parameter on inequality is quite small.

We suspect that these results may be a result of the use of the variance as the measure of inquality. The variance is not scale invariant and this means that the choice of units in the simulation matters. For example, we measured n_i in units of 10,000. The choice of units for n_i also in part determines the magnitude of the distance cost parameter *t* since we imposed the restriction that no individual patient had a negative net benefit from their practice. We intend to repeat the simulation using the generalised entropy measure of inequality since it can be decomposed in a way similar to the variance but is scale invariant.

Conclusions

Since this is work in progress we summarise our conclusions briefly :

- the measurement of equivalised resources per head at an area level as the ratio of GPs per head of need adjusted population requires very strong assumptions about the form of true individual level equivalised resource function,
- need adjustement of populations increases GP inquality measures but the effect is relatively small for most of the inequality measures we considered,
- aggregating resources to area or regional level grossly understates the amount of inequality compared with practice level estimates,
- simulation of the effect of distance costs indicates that inequality falls as distance costs are allowed for but the effect is smaller than the effect of need adjustment.

Table 1: Inequality measures at different levels of aggregation

	RHA	FHSA	Practice
Number	9	98	9408
Range	0.644	13.05	73.81
Variance	0.055	0.270	1.595
Coeff of var.	0.046	0.101	0.245
Relative mean deviation	0.041	0.063	0.157
Logarithmic variance	0.0021	0.0075	0.0471
Variance of logarithms	0.0021	0.0075	0.0465
Gini	0.0255	0.0458	0.1151
Atkinson	0.0005	0.0021	0.0121
Dalton	0.0003	0.0010	0.0061
Theil	0.0010	0.0044	0.0251
Entropy	0.0010	0.0042	0.0242
Herfindahl	1.81E-08	1.82E-08	1.91E-08

Table 2: The effect of distance costs on inequality at different levels of aggregation

Distance costs	None (t=0)	Low (t=0.0125)	Medium (t=0.025)	High (t=0.05)
Between areas:				
Var (r_i/n_i)	0.2559	0.2559	0.2559	0.2559
Var ($t_iK_i/4^*\rho_i$)	0	0.0015	0.0060	0.0239
Cov (r_i/n_i, $t_iK_i/4^*\rho_i$)	0	0.0084	0.0169	0.0338
Total	**0.256**	**0.240**	**0.228**	**0.212**
Between practices within areas	**1.302**	**1.302**	**1.302**	**1.302**
Within practices	**0**	**0.001**	**0.005**	**0.017**
TOTAL	**1.558**	**1.543**	**1.535**	**1.531**

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