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Identifying area effects: a comparison of single and multilevel models

Simon Gleave, Richard Wiggins, Heather Joshi and Kevin Lynch,
Centre for Longitudinal Studies,
Institute of Education,
20 Bedford Way,
London WC1 0AL

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1. Introduction

Numerous studies have illustrated geographical differences in health in Britain (Cook et al, 1982; Whitehead, 1987; Eames et al, 1993) while recent research has shown that mortality differences in regions have risen sharply (Dorling 1997). In 1991, the British Census included a question on long term illness for the first time. Analysis of this data has shown sharp regional differences which parallel those for mortality. However, limiting long term illness is more concentrated geographically than mortality (Langford and Bentham, 1996), suggesting that a purely biomedical explanation is inadequate.

These regional differences in health could be due to people with different personal histories and behaviours living in different areas. This is known as a 'compositional effect'. Alternatively, they could be due to 'contextual' effects including climate, industrial structure, history and culture (Macintyre et al, 1993).

Sloggett and Joshi (1998) analysed limiting long-term illness as a function of ward deprivation at two previous censuses, and its individual components. They adjusted for broad region, and whether or nor the person moved between 1971 and 1981. The association between deprivation indicators and illness was positive at the ward level. However, it was stronger at the individual level, and stronger from 1981 than from 1971. Their analysis used conventional regression models where the individual is the sole case of analysis. Any reference to level then refers to the level of aggregation than the unit of analysis. In this chapter, we set out to compare a single level analysis of LLTI, as a function of broadly similar indicators of deprivation to those used by Sloggett and Joshi, to a 2-level multilevel analysis (Goldstein, 1995). In a multilevel framework individuals are nested in higher level, geographical units, namely local authority wards. Our analytical objectives arise from two methodological concerns that could have important consequences for substantive interpretation. Firstly, the opportunity to explore the impact of failing to recognise any clustering in the data structure on the statistical conclusions arising from a single level analysis. Secondly, would a discovery that a positive relationship between area deprivation at the ward level exists in a single level analysis hold in a 2-level analysis and, if so, what would this imply for our understanding of area effect? Both of these questions can be answered by adopting a multilevel analysis, something that simply was not available to Sloggett and Joshi.

Our data is drawn from the 1971, 1981 and 1991 decennial Censuses of England and Wales. Our previous work (Gleave et al., 1998 and Wiggins et al., 1998) pioneered the use of multilevel modelling to examine the relationship between individual reports of LLTI, individual circumstances and histories, as well as the characteristics of the areas in which individuals reside. Broadly, our findings show that individual characteristics do explain a large proportion of the geographical variation in LLTI, but that area still has an important part to play. Other authors, notably, Humphreys and Carr-Hill (1991), Gould and Jones (1996) and Shouls et al. (1996) have used multilevel modelling to address the geography of health related behaviour, but with samples of anonymised records or other secondary sources.

A priori, we expect that any failure to recognise an inherent multilevel structure in our data will present obstacles to the conclusions based on single level analysis. Rowe (1997) lists these obstacles as *aggregation bias, mis-estimating standard errors and the heterogeneity of regression*. Briefly, in our situation aggregation bias occurs when a variable takes on different meanings and therefore may have different effects at different levels. Specifically, an area effect (or D-score) can affect individuals above and beyond their individual circumstances. By separating out the between and within area contribution of area effect, it will be possible to see the extent to which they actually explain any differences in areas once the characteristics of the individuals who reside there have been taken into account. Mis-estimated standard errors occur in clustered data whenever analysts fail to take account of any dependence in outcomes for individuals who live there. In the terminology of survey sampling, multilevel modelling estimates adjust for the intraclass correlation[1] (or design effect, Kish, 1965). Finally, hetrogeneity of regression occurs when the relationship between individual characteristics and outcomes vary across groups or areas. This is also a feature of multilevel analysis, known as random regression coefficient modelling (Longford, 1997). Essentially, this provides further insight as to the stability of a fixed effect or regression coefficient associated with an individual characteristic across different areas.

2. Data source and method

The ONS Longitudinal Study (LS) is a 1% linked sample of individuals from 1971, 1981 and 1991 (Hattersley and Creeser, 1995). The dataset contains census information and a limited health history from the National Health Service Central Register. Our two samples are 94, 618 men and 99, 981 women aged between 10 and 49 in 1971, and with full census records at the three time points. Individuals were excluded if they were recorded as permanently sick in 1971 or 1981. In addition, around 6000 individuals were deleted because of inconsistencies found in the two sources of ward level variables. For the multilevel analysis, there are 9,369 wards with an average of around 10 people per ward for each gender sample.

The outcome variable is the response to a question in the 1991 Census, which asked whether the respondent had a long-term illness that precluded them from working or carrying out their daily activities.

Explanatory variables used are broadly the same as those used in the Sloggett and Joshi (1998) analysis: they represent circumstances which act as markers or proxies for the notion of material deprivation. These circumstances are the absence of the following material or social assets; home ownership, car access, skilled or non-manual occupation, or a job if one is wanted. Other deprivation indices such as those derived by Townsend or Carstairs use similar variables.

These proxies for material deprivation have also been used in the construction of an area deprivation score (or D score) for each of the three Census time points. This index was originally produced by Sloggett and Joshi (1994) and they found that it behaved comparably with the similarly derived Townsend score used by other authors (Eames et al, 1993), at least for mortality analysis. Construction was by summation of normal (Z) scores of four components: the proportions unemployed in the ward's labour force; households with no car access; rented households; and employed men and women in social class 4 or 5. The distribution was highly positively skewed, and therefore the proportions unemployed were log transformed before summation (Townsend et al, 1989). The resulting distributions had means close to zero, and were left as continuous variables for the purposes of the two modelling strategies.

Though Sloggett and Joshi (1998) found a small effect for North-South region, the explicit regional dimension is omitted from both models in this replication to simplify the comparison. Instead, we are simply going to examine the area level residuals at each stage of the multilevel analysis to explore the extent to which the evidence for any North-South divide

[1] In multilevel modelling terminology, this is referred to as the intraunit correlation.

can be explained in terms of the characteristics of the individuals living in our wards and the area deprivation scores alone.

Finally, following Sloggett and Joshi we carry out separate analyses for men and women.

A logistic multilevel regression model can be written algebraically thus:

$$y_{ij} = (\exp(f_{ij} + u_j)/(1+\exp(f_{ij} + u_j))) + e_{ij}$$

where f_{ij} denotes the fixed part of the model, u_j is the random part of the model at ward level, and e_{ij} is the random part of the model at the individual level. The e_{ij} are assumed to be binomially distributed (Goldstein, 1995), while the fixed part of the model contains a linear function of both individual and area level explanatory variables. The random part of the model identifies two components of variance: between area (level 2 variance) and that between individuals within area (level 1 variance). The inclusion of area level characteristics in the model is equivalent to attempting to explain any between area differences in terms of local effects. In this application, the only level 2 characteristic is the ward deprivation score from 1991.

Algebraically, a single level model is equivalent to dropping the subscript j above and the associated error term u_j. We no longer have two components of variance, only a single term e_I associated with individual variation. Thus, all explanatory variables are treated as individual characteristics. This does not deny the inclusion of area effects, but these effects are only specified at the individual level. Thus their contribution to the explanatory power of any model is only witnessed in terms of a reduction in the residual sum of squares. We cannot separate out the relative contribution to individual and area level variation. Put another way, in multilevel modelling the inclusion of area effects is equivalent to modelling random area variation. Algebraically,

$$u_j = \text{area effect (D-score)} + u_j'$$

where u_j' still denotes a random component associated with area. By separating out the components of variation at the area and individual level, we are able, in multilevel analyses, to concentrate on what is actually happening to area specific residuals. This is not possible in ordinary single level analyses. If our measure of area effect is effective, then the resulting variance component associated with random area variation should be reduced accordingly.

All analyses are carried out on individual data downloaded from the ONS computer. Single level analyses were conducted using SPSS (SPSS INC., 1997) and two level analyses using MLn (Woodhouse, 1996).

Multilevel analysis is carried out in three distinct stages. Firstly, age terms will be introduced, then all individual characteristics in an interim model. Finally, area effects are included in a final model which is compared directly with the single level model fitted earlier. In the multilevel analysis, we will examine the residuals at each stage which will allow us to see the extent to which an area has an excess or deficit of ill health. We attempt to explain the influence that area may have on an individual's chance of reporting LLTI, once we have taken their individual circumstances into account by modelling area variation in terms of area deprivation scores.

This type of analysis on the ONS Longitudinal Study represents a breakthrough. Previously, multivariate analysis was only feasible on a dataset of limited complexity extracted as a machine readable table. Such was the regime in which Sloggett and Joshi's work was done. In the last two years, ONS has allowed us the opportunity to download individual level data (under strict supervision) onto a standalone PC (within ONS), where multilevel analysis can be carried out on larger and more interesting datasets.

3. Descriptive statistics

The samples under investigation, aged 10-49 in 1971, all occupied or passed into labour-force ages during the period of study, 1971-1991. The 1971 labour force variables are not applicable to the youngest members of our cohort, but household based ones are. The individuals in these younger age groups were classified into a 'catch-all' other category for the labour force variables whose coefficients for this category are not explicitly reported. LS members who were in communal establishments at any of the relevant census time points, along with those who were classified as permanently sick in 1971 or 1981, were excluded from the analysis. Those who were permanently sick were excluded because they were known to be in a poor health state already. The model is attempting to predict limiting long term illness in 1991 for those in good health at earlier censuses. Table 5.1 shows the rates of experiencing the different states of deprivation. Unemployment rates are generally quite low with the highest figure being 7.8% for men in 1981. However, in contrast, the other three index states of deprivation were each at least 13.5% (females in social class 4 or 5 in 1971) and rising as high as 48.2% for females who were tenants in 1971. The rise in owner occupation over time and over the lifecycle is illustrated as both genders experience a greater than 50% reduction in tenancy over the 20 year period. The same sort of pattern (although not quite as marked) applies to car ownership. The generally lower rates of disadvantage for females across the labour market indicators reflect the fact that we include the economically inactive in the analysis as ‘others’.

Around 9% of both gender samples experience multiple (2+) deprivation at every census, but only 2% of men and ½% of women experience three or more states of deprivation at every census. However, far fewer experience this ‘constant’ deprivation than those who pass in and out of the deprivation states, as around 4 out of 10 had experienced 2 or more deprivation states in at least one of the three censuses. This pattern of mobility has been seen before in studies of low income (Jarvis and Jenkins, 1996).

Table 5.1 Percentage of cohort aged 10-49 experiencing given state of disadvantage

Index state	1971 %	1981 %	1991 %	At every Census	At any Census
Low skill					
Male	17.4	20.2	18.7	5.7	34.2
Female	13.5	18.1	21.0	3.9	34.7
No car					
Male	31.6	19.3	15.0	8.6	38.8
Female	34.4	23.2	20.7	10.4	45.6
Tenant					
Male	47.8	34.4	20.4	15.2	54.9
Female	48.2	35.7	22.7	17.3	55.4
Unemployed					
Male	2.6	7.8	6.9	0.29	14.4
Female	1.6	3.1	2.4	0.02	6.7
2+ states					
Male	29.0	22.6	15.2	8.5	38.9
Female	29.9	22.9	17.9	9.1	41.0
3+ states					
Male	7.4	7.6	4.9	2.21	13.7
Female	5.1	4.8	3.8	0.52	10.6

Note: Cohort size = 94 618 (male), 99 981 (female).

Figure 5.1 shows histograms of the 3 deprivation scores, each for males and females. The 1971 scores are very close to normality, but the 1981 and 1991 scores still have some positive skewness. However, their distributions are reasonably good approximations of normality.

4. Results

4.1 Single Level Model

Estimates of the single level model in table 5.2 show that the chance of reporting long term illness rises strongly with age, but at a diminishing rate. Our deprivation indicators at the individual level are generally significant and positive (ie detrimental to health). We can see, for example, that for males, being unemployed in 1971 and 1981 respectively increase the odds of having a limiting long-term illness in 1991 by 44% and 61%, relative to an employed member of the cohort. The three area based variables appear to have limited predictive power, in comparison to the individual level variables. However, this tells us very little about area effects. The ward deprivation scores are all significant at the 95% level, except the 1971 deprivation score for males, but they are of small magnitude, with generally only a 1 or 2% increase in odds for a unit increase in deprivation (about 1/3 of the standard deviation). Therefore, the results of using these variables may just illustrate that we need to find other, more predictive, variables at an area level. Changing address between 1971 and 1981 has no significant effect for men, but for women, their chances of becoming long-term ill are increased by around 8% over those that have not moved in this period.

Table 5.2 Single level models (odds ratios, standard errors of raw coefficients and p values)

Model	Males Odds ratio	Raw SE	P	Females Odds ratio	Raw SE	P
Constant	0.0856	0.0248	<0.001	0.0669	0.0295	<0.001
Age in 1971	1.0893	0.0018	<0.001	1.0790	0.0019	<0.001
Age^2 1971	0.9995	0.0001	<0.001	0.9992	0.0001	<0.001
1971 Personal Characteristics						
Unemployed*	1.4449	0.0556	<0.001	1.2765	0.0727	0.008
Low Skill**	1.1235	0.0273	<0.001	1.0948	0.0320	0.005
Tenant	0.9927	0.0268	0.783	1.0610	0.0277	0.032
No Car Access	1.0691	0.0259	0.010	1.1328	0.0248	<0.001
1981 Personal Characteristics						
Unemployed*	1.6097	0.0354	<0.001	1.5857	0.0540	<0.001
Low Skill**	1.2682	0.0264	<0.001	1.1333	0.0299	<0.001
Tenant	1.2487	0.0276	<0.001	1.2483	0.0283	<0.001
No Car Access	1.2970	0.0284	<0.001	1.3067	0.0263	<0.001
Moved 71-81	0.9990	0.0213	0.963	1.0803	0.0219	<0.001
D Score 1971	1.0065	0.0044	0.145	1.0105	0.0045	0.020
D Score 1981	1.0135	0.0047	0.004	1.0287	0.0047	<0.001
D Score 1991	1.0497	0.0043	<0.001	1.0287	0.0044	<0.001
Log likelihood	66 490.7			66413.1		

* Vs Employed. Unemployed wasn't the only category here as there was also a catch-all 'other' category. In both models, this was positively significant in 1971 but not 1981.

** Vs Skilled or non-manual. Again there was an 'other' category here, for the same reason as above which is not reported. This time, the category is not significant in 1971, but is positively significant in 1981 in the model for males. For females, the 'other' category is positively significant for both census points.

4.2 Hierarchical model

The hierarchical modelling takes place in stages; firstly, the base model of age terms is fitted, followed by an interim model of all individual characteristics, and finally a model including both individual and area based characteristics. For males, the base model confirms an age effect indicating that the probability of reporting a limiting long-term illness increases with age. The significance of the quadratic term suggests that the age effect is stronger at older ages, though this feature disappeared with the inclusion of more variables and the quadratic term's odds fell to below 1, as seen in the single level model. There was no evidence for the presence of any extra binomial variation (Woodhouse, 1996). The base model also reveals between area differences (level 2 variance of 0.2184).

By including individual characteristics, we begin to explain these area differences. This variation reduces by nearly half to 0.1136 in the interim model. This suggests that area differences decrease, once the characteristics of the local population are taken account of.

Once the area level characteristics are added in to produce the final model, a further reduction of around 30% is achieved, to leave the unexplained area variation at just 0.0793. As in the single level model for males, being a tenant in 1971 and moving between 1971 and 1981 are not statistically significant. At the area level, the D score for 1971 is also not significant and the other coefficients on area score are near identical. Again, this ties in with the single level model for males.

The model for females also confirms similar age effects, but at the base model stage, there are smaller area differences than were seen in the model for males (level 2 variation of 0.1604). Once individual level characteristics are included, the area differences reduce by more than half, again implying that area differences decrease after taking account of the characteristics of the individuals who make up the area. Inclusion of the 3 deprivation scores again brings this area difference down, this time by a further 40.5%. In the female model, all of the variables that enter the model are statistically significant, and very similar to the single level estimates, therefore mirroring the experience of the single level model.

Allowing the 'fixed effects' to vary across areas revealed little evidence of variability, with all of these random regression coefficients showing up as very small and insignificant at the 5% level.

Table 5.3 Base, interim and final multilevel models (odds ratios and standard errors of raw coefficients) for males

	Base model	**Base model S.E.**	**Interim model**	**Interim model S.E.**	**Final model**	**Final Model S.E.**
Fixed effects						
(Level 1)						
Constant	0.1114	0.0165	0.0782	0.0250	0.0822	0.0255
Age	1.0784	0.0012	1.0908	0.0018	1.0902	0.0018
Age^2	1.0003	0.0001	0.9995	0.0001	0.9996	0.0001
Unemployed 1971			1.4859	0.0563	1.4411	0.0563
Low Skill 1971			1.1494	0.0277	1.1269	0.0276
Tenant 1971			1.0369	0.0268 NS	0.9933	0.0272 NS
No Car Access 1971			1.1468	0.0260	1.0689	0.0263
Unemployed 1981			1.6945	0.0358	1.6135	0.0358
Low Skill 1981			1.2993	0.0268	1.2720	0.0268
Tenant 1981			1.3559	0.0278	1.2582	0.0280
No Car Access 1981			1.3946	0.0287	1.2982	0.0288
Moved 71-81			0.9923	0.0216	1.0024	0.0216 NS
Level 2						
D Score 1971					1.0063	0.0045 NS
D Score 1981					1.0128	0.0048
D Score 1991					1.0519	0.0045
Random Effects						
Level 1	1		1		1	
Level 2 (ward)	0.2184		0.1136		0.0793	
Log likelihood	33 687.2		29 163.1		28 911.7	

5. Discussion

5.1 Comparison of single level and multilevel modelling

The reason for multilevel modelling is that we should be modelling a hierarchical structure if one is present. In order to illustrate the possible consequence of ignoring a hierarchy, consider a study of primary schoolchildren in the 1970s (Bennett, 1976), which claimed that formal styles of teaching reading produced greater progress amongst pupils than other methods. This study ignored the pupils' groupings within teachers and classes. When re-analysed by Aitkin et al (1981), who took these groupings into account, the significant differences between styles disappeared. Therefore the formally taught children could not be shown to differ from the others.

Table 5.4 Base, interim and final multilevel models (odds ratios and standard errors of raw coefficients) for females

	Base model	**Base Model S.E.**	**Interim model**	**Interim Model S.E.**	**Final Model**	**Final model S.E.**
Fixed effects						
(Level 1)						
Constant	0.1054	0.0163	0.0615	0.0296	0.0655	0.0299
Age	1.0685	0.0012	1.0790	0.0019	1.0795	0.0019
Age^2	1.0001	0.0001	0.9992	0.0001	0.9992	0.0001
Unemployed 1971			1.2962	0.0735	1.2802	0.0733
Low Skill 1971			1.1224	0.0323	1.0941	0.0323
Tenant 1971			1.1142	0.0275	1.0615	0.0280
No Car Access 1971			1.2079	0.0248	1.1303	0.0250
Unemployed 1981			1.6374	0.0545	1.5872	0.0544
Low Skill 1981			1.1708	0.0301	1.1335	0.0301
Tenant 1981			1.3584	0.0282	1.2538	0.0285
No Car Access 1981			1.4117	0.0263	1.3097	0.0265
Moved 71-81			1.0718	0.0221	1.0818	0.0221
(Level 2)						
D Score 1971					1.0104	0.0045
D Score 1981					1.0282	0.0048
D Score 1991					1.0299	0.0045
Random Effects						
Level 1	1		1		1	
Level 2 (ward)	0.1604		0.0739		0.0439	
Log likelihood	31 698.5		29 277.3		29 274.4	

The situation above happened because failure to take account of the data hierarchy tends to underestimate the size of the standard errors of the explanatory variables. Looking at a comparison of the single level and multilevel models in this chapter reveals the same problem, as almost all of the standard errors are larger in the multilevel models. Admittedly, there is little difference between them (often only around 1% here), but the standard error for having no car access in 1971 in the female model is 7% larger in the multilevel model. A differential of this magnitude could produce a significant result in a single level model when, in fact, none is present.

Another advantage of multilevel modelling is that we have a measure of variance at the different levels. In our single level models, the area level variables are generally significant, but this doesn't reveal any great magnitude in the area differences that are present. By implementing the hierarchy in our model, it is possible to not only produce a measure of the area differences, but also to see what effect the addition of both individual level and area level variables have on the size of these effects. So, we find that there are marginally higher area differences for males than females in the base model (0.2184 as against 0.1604), and the explanatory variables explain a higher percentage in the model for females. The area effects reduce by around 64% between base and final model for males, whereas this reduction is around 73% in the female models. In other words, around 36% and 27% of the age adjusted limiting long term illness remains unexplained by the variables included, which suggests area effects exist, but are not dominant.

Other advantages of multilevel modelling over single level include the opportunity to allow the fixed effects to vary across the higher levels of the hierarchy. So, for example, the impact of unemployment on health could depend on where the individual lives. Living in an area of very low unemployment might produce a real stigma to being unemployed and this may have a more pronounced detrimental effect on health than being unemployed in an area of high unemployment. However, to keep this chapter relatively simple, this area of multilevel modelling is not explored here.

Finally, residual analysis can be produced at any of the levels of the hierarchy in a multilevel model and therefore, we can examine the ward residuals in the multilevel models to find the pattern of areas with an excess or deficit of ill health. In previous work (Wiggins et al 1998), significant residuals have been examined at county district level, but when we include ward in the hierarchy, it is not possible, as the number of individuals within each area are too small to yield well determined residuals at the ward level. However, we can examine the distribution of residuals that are produced, in order to show how the distribution changes as we step through the stages of the modelling process. Therefore, as an illustration, maps have been produced which show the distribution of these residuals across the wards, and how this distribution changes across the three steps of the multilevel modelling process.

The maps (figures 5.2-5.7 in Appendix 1) are dark when there is an excess of limiting long-term illness, graduating to light shades when there is a deficit. The white patches are areas in

England and Wales that are uninhabited by LS members in our sample. For each base model (fig 5.2 and fig 5.5), the residuals have been split into 7 groups of approximately equal size. The boundaries of each of these groups have then been kept constant for the subsequent model iterations, and therefore the shading of the maps progressively moves towards the middle more neutral shading. It is clear in the base model for males that there are excesses of limiting long-term illness in the North East of England, the North West, parts of Yorkshire and South Wales. The female base model exhibits a similar pattern of residuals. There is also clear evidence from these maps that the South suffers less from limiting long-term illness than the North of the country. Moving to the interim models (fig 5.3 and fig 5.6) after the individual characteristics have been allowed for and we find that the residual pattern is moving away from the extremes, and more into the neutral shading. This illustrates how successful the individual characteristics have been at explaining the apparent excess and deficit of limiting long-term illness for both genders. Once the ward level deprivation scores have been included (fig 5.4 and fig 5.6), there is practically no evidence of areas with a deficit of limiting long-term illness, and only a small number of wards scattered around the country which still exhibit an excess of limiting long-term illness.

This analysis has been carried out because the census question on limiting long-term illness revealed marked geographical variations in this measure across England and Wales (Charlton and Wallace, 1994; Gould and Jones, 1996). In this chapter, we have looked at a comparison between single level and multilevel models in trying to explain these area differences in limiting long-term illness.

We have shown effects of individual characteristics, and of area deprivation, on the likelihood of reporting a limiting long-term illness in 1991. We have also illustrated that using a multilevel model reveals how the addition of these characteristics affects the area level variation.

It seems that being in any of the disadvantageous states (except being a male tenant in 1971) at any time is, all being equal, associated with higher rates of limiting long-term illness. This applies even if this state is not repeated, but repetition of these states hugely increases the odds of a limiting long-term illness by 1991.

The importance of the social composition of the area within a hierarchy has been highlighted by the significance of the majority of the area level deprivation scores, and their resultant effect on the area level variation. This is on the same lines as Wiggins et al (1998), who used the ONS classification of county districts as area level variables, and found a significant effect of four of these types of areas. Both that approach and this one find a significant amount of variation between areas and, even after accounting for individual characteristics, a significant amount of this variation can be explained by area level characteristics. This emerges far more clearly using a multilevel approach than a single level one.

However, the single level approach detected the same fixed effects, including the same area effects which were captured by the deprivation index, as the multilevel model. The comparison of the two modelling strategies does not reveal any bias in the single level estimates, but area clustering was not detected in the residuals. Multilevel modelling also revealed that the area level variables were still leaving some area variation unexplained. Better information about places should pick up and identify more of this area variation than the fixed terms in either of these models reveal. It would be preferable to introduce more area specific information in the hierarchical model, particularly allowing the individual level variables to vary at the area level.

It should be acknowledged that the four variable index is limited in attempting to reflect area characteristics or, indeed, as the only area level variables in our multilevel models. In both cases we might consider using more variables, in order to more effectively describe an area's make up.

Finally, we should mention the modifiable areal unit problem (Openshaw, 1994), which has not been addressed here. This says that the results of statistical analyses can be sensitive to the number and boundaries of geographic areas used. It is possible that a redrawing of the ward map to maximise the social homogeneity of an area might change our results, but if the higher risks of deprived wards are mainly accounted for by individual characteristics, the redrawing of boundaries is likely to make little differences to the conclusions.

6. Conclusion

Sloggett and Joshi (1998) found area effects, as measured by a 4 variable index of the composition of a ward's population, to be minor (though not insignificant as they had been with mortality and some other outcomes). Our updating of a single level approach reaches similar conclusions. We also included the ward deprivation index for 1991 (not previously available), which has another small significant effect. To this extent at least, we can demonstrate that Sloggett and Joshi (1998) understated ‘area’ influences on limiting long-term illness by omitting information on ward deprivation in 1991. However, the omitted effect has not proved to be very big. It can also be suggested, from comparison with research which has found area influences for Census data over a wider spatial network (Wiggins et al, 1998; Shouls et al, 1996), that richer geographical information at the higher levels would reveal more of a systematic association with place of residence. Thus, one reason the early results seem incompatible with later findings is indeed that area effects have become apparent as more information was used, though they have not obliterated the individual level relationships.

The answer to our question as to whether single level methodology was suppressing area effects is both yes and no. No, because the close correspondence of our single level parameter (and standard errors) estimates with those obtained in the multilevel context suggest that, in this case, single level estimates of those parameters were not particularly biased or misleading. We suspect that had the data had a different structure, with rather more individuals per ward, there could have been a difference. The answer is also yes, because the single level model is misleading, in that it does not generate area specific residuals. These reveal which places have the unusual characteristics, which emerge in our mapping exercise. The single level methodology can only reveal spatial effects to the extent that they are associated with included variables. The multilevel approach reveals area variation in unmeasured heterogeneity as well.

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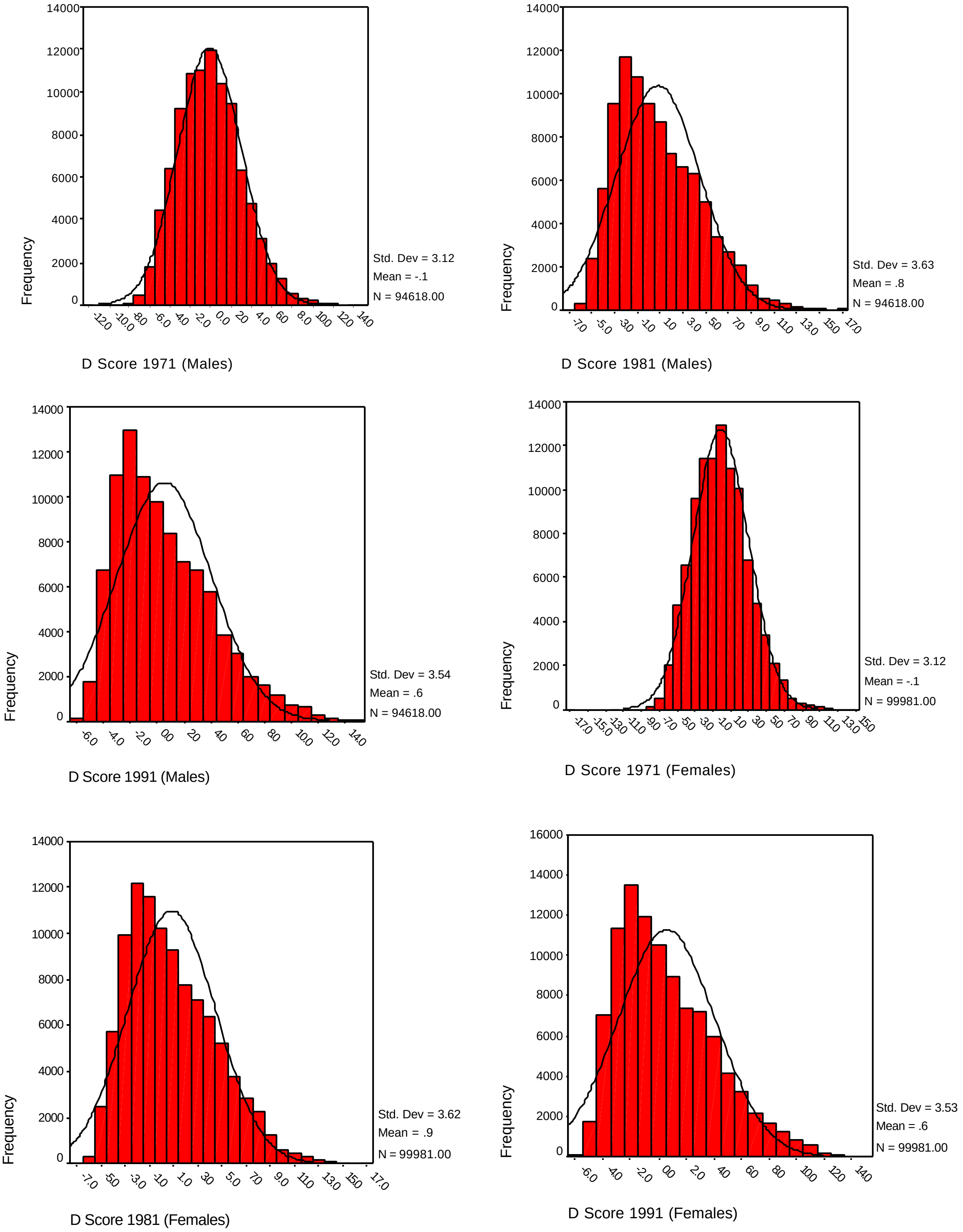
Appendix 1

Figure 5.1 Distributions of D scores for males and females



WORKING PAPERS USING THE ONS LONGITUDINAL STUDY

*We do not supply copies of papers that have been subsequently published, or for various other reasons have been discontinued. Working paper numbers not shown have been withdrawn.

*1 Dawkins, D. (1982) Migration and Health of the Elderly.

*2 Leon, D. (1983) Housing tenure: an example of using record linkage to study differentials in cancer incidence, survival and mortality.

*3 E. Hoinville (1983) A review of the literature on migration in England and Wales.

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