Spatial and temporal variation of mortality and deprivation 1: widening health inequalities

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Abstract. In this paper we examine the relationship between premature mortality and material deprivation both over time (the intercensal period, 1981–91) and over space (for the population in wards and ward groups in Wales). Our focus is on the methods of analysis for small area (ward-based) multiple cross-section mortality data and their application to the substantive issue of the persistent and widening inequalities in Wales. In this paper we examine all-cause deaths and mortality by specific disease classes for groups (quintiles) of wards ranked according to standard measures of material deprivation. Although there have been reductions in premature mortality across all deprivation groups in Wales, over the decade, the gap has widened between the most and least deprived areas. Mortality decline in the largest disease category (circulatory) was found to be significantly lower in the most deprived quintile of wards than in the rest of Wales. Compared with results from the North of England, mortality decline in Wales has been rather greater.

1 Introduction
This is the first of two papers in which we examine the relationship between mortality and deprivation both over time—the intercensal period 1981 to 1991—and, over space—the wards of Wales. The prime focus of our work is an exploration of a range of data analysis and statistical methods for addressing this relationship by using multiple cross sections of mortality data. An important secondary aim is the application of the methods in a substantive context, to seek evidence for widening inequalities in mortality in Wales, an area containing groups suffering some of the worst health in Britain (Charlton et al, 1994; Dorling, 1995; Senior, 1998; Welsh Office, 1997).

1.1 Background
Since 1841 there has been a decline in mortality rates in the United Kingdom, particularly from infectious diseases (Charlton, 1997). However, it is now widely and officially recognised that the rate of decline is far from uniform over population groups. The Black Report (Black et al, 1980; Townsend et al, 1988) gave particular impetus to quantitative investigations of mortality variations within populations, and to discerning differential effects over time. The importance of area of residence for health outcomes has continued to be the focus of much research since the publication of the report (Congdon, 1995; Curtis, 1995). Gradients in mortality rates between groups differentiated by a range of socioeconomic characteristics, ethnicity, and region are now well established and documented (Department of Health, 1996). The importance of prevailing socioeconomic conditions on health outcomes regardless of social grouping has highlighted the potential importance of factors such as housing, employment, and social conditions in determining health status (Bartley et al, 1997; Hunt, 1997). Much of this research is reviewed by MacIntyre (1997); the Department of Health’s (1996) The Health of the Nation: Variations in Health report; and by Drever and Whitehead (1997).

Evidence provided in the Black Report suggests that inequalities in health between social classes and between regions in Britain have grown since the 1930s and that many of the social inequalities were attributable to variations in material
conditions (Townsend et al, 1988; 1992). Further evidence has accumulated over the last five years to suggest that mortality differentials between groups characterised by different levels of material deprivation are persistent and have widened over the 1980s (Fox et al, 1984; Wilkinson, 1992; McCarron et al, 1994; Davey-Smith and Morris, 1994; Phillimore et al, 1994; McLoone and Boddy, 1994; Drever and Whitehead, 1995; Department of Health, 1996; Bartley et al, 1997). Furthermore, these results appear to represent a continuation of the trend of increasing inequalities in mortality identified by Marmot and McDowall (1986) for the previous decade, 1971 to 1981. Other studies indicate that those areas which have the largest variation in socioeconomic circumstances have the worst mortality experience (Ben-Shlomo et al, 1996; Wilkinson, 1992). It increasingly appears that relative, rather than absolute, poverty has a major bearing on differential mortality rates in developed countries (Kawachi and Kennedy, 1997; Wilkinson, 1996; 1997).

It is widely recognised that the determinants of health status and premature death include: general socioeconomic, cultural, and environmental conditions; living and working conditions; social and community influences; individual lifestyle factors; age, sex, and heredity factors (for example, see Benzeval et al, 1995; Dahlgren and Whitehead, 1992). Although the pervasiveness of the influence of material and social circumstances in determining premature death is recognised, the challenge of disentangling causal mechanisms by which the above determinants exert themselves on inequalities is subject to continuing research. Some clarification is in prospect as a result of the recently established Economic and Social Research Council Programme on Health Variations. The public health policy implications of health variations in the United Kingdom have been considered by a Committee chaired by Sir Donald Acheson which is due to report at the end of 1998.

1.2 Methods of analysis

Statistical investigations of the relationship between health status and its determining factors may be broadly distinguished according to the fundamental unit between which variations are sought, and the specification of statistical models linking dependent and explanatory variables (for example, see Barker and Rose, 1990; Jones and Moon, 1987; Maclntyre, 1997). In particular, we can identify the two dominant approaches distinguished by the unit of analysis:

(1) microanalyses applied at the cross section or, more typically in longitudinal studies, in which the health experiences of individuals are related to (changes in) their social and economic circumstances, their individual behaviour, and the environmental conditions to which they are subject; and

(2) aggregate studies, based on one or more cross sections, which focus on the relationship between the numbers of deaths in small geographical areas and a set of associated economic, social, and environment variables for those areas.

The first approach, in the epidemiological tradition, through its focus on individuals, aims to clarify the causal mechanisms influencing their health status and its change over time. Prominent examples of this class are those studies based on the OPCS (Office for Population Census and Surveys) Longitudinal Study (Drever et al, 1996; Filakiti and Fox, 1995; Fox and Goldblatt, 1982; Harding, 1995) and the Whitehall Study of London Civil Servants (Davey-Smith et al, 1990; 1994; Marmot, 1997; Marmot et al, 1991; 1997). Such studies have been concerned with investigating the influence of socioeconomic factors over the lifetime of the individuals under study (Davey-Smith et al, 1997).

The present study is based on the second strategy, that of small area analysis, and draws on the ready availability of large data sets. There are well-known problems of imputing relationships pertaining to individuals from statistical models applied to
aggregated data (for a full discussion of ecological problems, reference may be made to Jones and Moon, 1987; MacIntyre et al, 1993; Openshaw, 1984; Sloggett and Joshi, 1994). Although it cannot establish the causal factors leading to changes in mortality experience, the identification of statistical associations between mortality and deprivation variables at the small area level may be interpreted in conjunction with, and may be suggestive of, epidemiological investigations at the microlevel. In addition, they can be of value for policy formulation and for the targeting of resources (Carstairs, 1995; Thomas, 1990) and, as such, are widely used for interregional and intraregional analyses.

Although applications of cross-sectional analyses between mortality, morbidity (typically using limiting long-term illness as a proxy variable), and indicators of material deprivation at the small area level, are widespread, there have been relatively few studies exploiting multiple cross sections to consider temporal changes of mortality variations (for example, see Drever and Whitehead, 1995; McLoone and Boddy, 1994; Phillimore et al, 1994; Shouls et al, 1996; Staines, 1994). Of particular relevance to the present paper are the ward-based analyses of mortality variations in the Northern region of England by Phillimore et al (1994) and a similar study of Scotland at the postcode-sector level by McLoone and Boddy (1994). By grouping spatial units ranked according to standard measures of material deprivation, both studies show that mortality differentials have persisted and widened over the 1980s.

In this paper we employ a similar method to that of Phillimore et al (1994), McLoone and Boddy (1994), and Drever and Whitehead (1995) to examine the relationship between premature mortality and deprivation in Wales for different age–sex groups and diseases. The approach has been adopted to allow comparisons with these other studies, in particular that of Phillimore et al (1994). It is then used for methodological exploration in paper 2 (Senior et al, 1998).

1.3 Objectives and contents
The substantive aims of the paper are threefold:
1. to confirm for Wales the existence of mortality gradients with respect to material deprivation at the cross sections around the census years 1981 and 1991 for a number of disease groups;
2. to examine changes in mortality over time and seek evidence for widening differentials of mortality experience over the intercensal period;
3. to compare the mortality experience in Wales over the 1980s with that of the Northern region of England.

Additionally, the paper serves the important role of providing the context, data, and results for the exploration of the relationship between deprivation and mortality with more formal and systematic statistical methods discussed in paper 2, in which the generalised linear model serves as an integrating framework.

In section 2 we establish the modelling framework for relating premature mortality to indicators of material deprivation at the level of wards grouped into quintiles. This grouping allows comparison with previous work in the North of England (Phillimore et al, 1994). In section 3 the distribution of deprivation in Wales is examined and quintile groups which provide the geographical units of analysis in this paper are established. In section 4 gradients in mortality over the deprivation groups are established at the 1981 and 1991 cross sections and, by standardising mortality to 1981 we consider the temporal change for age–sex groups over the decade. In section 5 this analysis is repeated for four causes of death. In section 6, we compare the mortality variation in Wales with that in the Northern region of England, the study area adopted by Phillimore et al (1994). The contributions of the paper are summarised in section 7.
2 Methodology

2.1 Relating premature mortality and deprivation at the small area level

The statistical methodology adopted addresses the objectives of, first, determining the variation of premature mortality over groups of individuals subject to different levels of material deprivation at the cross sections in 1981–83 and 1990–92 and, second, analysing the variation in the change in mortality between 1981–83 and 1990–92 over groups of individuals subject to different levels of material deprivation. The electoral ward has been chosen as the areal unit of analysis as it represents a compromise between the requirements for relatively homogenous spatial units and the accuracy of the assignment of deaths from postcoded data. Although a postcode directory exists which allows accurate linkage between postcodes and enumeration districts, this facility has only been available since 1991. The choice of 1981 wards as the units of analysis was conditioned by the need to compare the results in 1981 and 1991.

Underpinning our analysis are the hypotheses that the number of premature deaths in a ward at the 1981–83 and 1990–92 cross sections, and the change in this number over the decade are dependent on the age–sex distribution in the ward, the average measure of material deprivation of the ward, and a variety of unmeasured factors (including the effects of heterogeneity of the ward populations) which are absorbed into random error terms.

Various measures may be used to denote the extent of premature death in a population, including the number of years of life lost, and the number of deaths in specific age ranges. A full review of these procedures and their implications for study results have been examined by Wagstaff et al (1991) and by MacIntyre (1997, page 734). In order to compare our research with previous studies, we have concentrated on the use of age/sex standardised mortality ratios in order to investigate the magnitude of class differences as hypothesised from area deprivation measures. To accommodate different definitions of premature death, the temporal and spatial variation in mortality ratios have been computed for the 0–64 and 0–74 age categories. The first age range implies particularly premature death, whereas the latter corresponds more closely with the average life expectancy. Also, the greater number of deaths in the 0–74 age range provides finer confidence intervals for mortality ratios. Additionally, we include an analysis of mortality differentials by sex in the age ranges 0–14, 15–44, 45–54, 55–64, and 65–74. Although a finer age classification distinguishing infant, child, and young adult (15–24) mortality, was contemplated, sample sizes and the resultant confidence intervals for mortality changes in deprivation groups precluded such analysis.

The standardised mortality ratio SMR, for ward j, is calculated as the number of deaths, D, in ward j as a percentage of the deaths, E, which would have been expected if the local people had experienced the age–sex specific mortality rates observed in England and Wales as a whole in that year. That is

\[ \text{SMR}_j = \frac{D_j}{E_j} \times 100. \]  

(1)

In lower case smr will refer to the ratio of observed to expected deaths (that is, \( \text{SMR} = \frac{\text{smr}}{100} \)).

If we define a set of age–sex groups, \( \{as\} \subset AS \), the expected deaths \( E_j \) calculated from the local population in conjunction with the England and Wales age–sex-specific mortality rates \( r_{as} \) is given at time \( t \) by

\[ E_j(t) = \sum_{\{as\} \subset AS} r_{as}(t)P_{j}^{as}(t). \]  

(2)
Here, $P_{j}^{as}(t)$ is the population in ward $j$ in the age-sex group $\{as\}$, at time $t$. The expressions for the standardised mortality ratio may be readily extended to arbitrary age-sex groupings and to specific disease classes.

Previous studies have drawn attention to the potential use of unidimensional deprivation indicators such as the Townsend and Carstairs indicators (Carstairs, 1981) and the Jarman scores (Jarman, 1983; 1984) as well as multidimensional demographic profiles such as the use of the ACORN (Langford and Bentham, 1996; Morgan and Chinn, 1983) and Super Profile (Reading et al, 1994) classifications in order to examine the association between area deprivation and various measures of mortality and morbidity. In this paper, the first approach is adopted and the spatial and temporal dependency of mortality ratios and deprivation has been investigated by relating the number of deaths (mortality ratios) in groups of wards ranked according to a composite measure of material deprivation.

The research strategy may now be expressed in terms of establishing the strength of the dependency of the standardised mortality ratios on a set of variables $X$ describing material deprivation in the wards, $d_j$. For the cross-sectional analysis, 1981–83 and 1990–92 the relationship between mortality ratios and deprivation scores (or variables) at times $t = 1981$ and $t = 1991$ is expressed as

$$smr_j(t) = G_j[d_j\{X(t)\}],$$

in which standardisation is to 1981 and 1991, respectively.

The analysis over the period 1981–91 examines the (proportional) change in the mortality ratio $\Delta smr_j$ over the decade as a function of deprivation, in which standardisation is performed with reference to a common date, here taken as 1981

$$\frac{\Delta smr_j}{smr_j(81)} = H[d_j\{X(81)\}].$$

$G$ and $H$ represent functional dependencies which may be assessed through categorical description for selected ranges of deprivation, or more formal statistical analysis based on specific functional forms. For comparison with previous work, expressions (3) and (4) are specified in terms of composite deprivation indexes which are given a priori. In paper 2 (Senior et al, 1998) we also explore the significance of individual deprivation variables through statistical analysis.

2.4 Variation of mortality over deprivation groups

Over the last fifteen years many deprivation indicators have been proposed and applied for needs assessment and resource allocation across the health and other service sectors. It is not the purpose of this paper to describe the advantages and disadvantages of applying these indicators in such areas (for fuller reviews see Carstairs, 1995; Coombes et al, 1995). The Townsend index of material deprivation is particularly widely adopted in academic studies and public health reports and will provide the basic indicator in the present study.

The approach adopted in this paper involves the grouping of the wards into deprivation categories. Throughout this study we have used the Townsend score as a measure of material deprivation not only because of its use in previous studies [permitting comparisons, for example, with the work of Phillimore et al (1994)] but also because of its widespread applicability in a range of socioeconomic contexts as a general measure of deprivation. The index is based on rates of unemployment, levels of car and home ownership, and household overcrowding (Townsend et al, 1988). As the ranking of wards, and therefore the spatial distribution of the quintiles, will depend on the deprivation measure selected, an important component of our analysis has been
to use alternative indicators in order to test the robustness of our conclusions to possible variation of this indicator. Thus the Carstairs (Carstairs and Morris, 1989) and Jarman (Jarman, 1983; 1984) measures have been used at various stages of our analysis (see section 6). Inequalities and the widening or narrowing of mortality differentials are then analysed in terms of the mortality ratios in these ward groups and in particular the difference between the most and least deprived groups of wards.

To this end, the set of wards $J$, of which an arbitrary member is $j$, is ranked on the basis of a deprivation index, $d_j$, and divided into $M$ equal groups. Let $J(m, M)$ denote the $m$th such group, with $m = 1, \ldots, M$. If $M = 5$ the groups are referred to as quintiles, each with 160 wards, and $M = 10$ defines a set of deciles each with 80 wards. The set of wards $j \in J(m, M)$ associated with the $m$th group is a specific geographical area of, in general, noncontiguous wards which will be considered in the next section.

Three points should be made with regard to this grouping. First, the ranking of wards and therefore the spatial distribution of the quintiles will depend on the deprivation measure selected. It is therefore important to establish the robustness of our conclusions to possible variation of this indicator. Second, the ranking of wards in 1981–83 will be different from that in 1990–92 and it will be necessary to specify which ward quintiles are used in any particular analysis. Third, the most deprived wards have, on average, larger populations as they tend to be in nonrural areas. The converse is true for the least deprived wards. (The most deprived quintile of wards in Wales in 1981 and 1991 has approximately 30% of the population, and the least deprived has about 15.5%). Had, therefore, wards been grouped so as to produce equal population quintiles, then the mortality ratios would likely be greater for every quintile. However, it is difficult to say a priori whether the inequality in mortality between most and least deprived population quintiles will be greater than that for the corresponding ward quintiles, as this will depend on the functional form of the relationship between mortality and deprivation.

The mortality ratios for the groups of wards are computed according to a straightforward extension of formula (1). Confidence intervals are derived from the assumption that the observed deaths are Poisson-distributed variables, as discussed by Gardner and Altman (1989). The analysis has established, both for all causes of death and for specific disease groups, the variation of SMR over the wards of Wales in 1981–83 and 1990–92, standardised, respectively, to 1981 and 1991; the variation of SMR over the decile and quintile groups in 1981–83 and 1990–92 and the absolute change in SMR by age-sex categories for a variety of diseases in which standardisation is to the common base year 1981.

2.5 Implementing the research strategy

The integration of the OPCS postcoded mortality data and the census-based measures has been performed using the Arc/Info geographical information system (ESRI, 1993). The results for both 1981–83 and 1990–92 have been calculated with reference to the 800 ward boundaries in 1981. The mortality data supplied by OPCS were in the form of anonymised postcoded records containing the age of death, the sex of the deceased, the postcode of the residence or the institution (if residence has exceeded six months) in which the person died, and the cause of death [by International Classification of Diseases (ICD) number]. To avoid spatial bias at the small area level, institutional deaths have been removed from the analysis. Deaths occurring in the periods 1981–83 and 1990–92 are separately grouped in order to mitigate the small number problem. In addition to the analysis of the relationship of mortality by all causes and deprivation within these periods, the following specific causes of death were analysed separately: all cancers (140–239); breast cancer (174); circulatory diseases (390–459); and deaths
from suicides (E950–E959) and injury undetermined (E980–E989), where the ICD code (ninth revision) is included in brackets. Respiratory diseases are not considered because of the effects of changes in classification in 1983 (Rooney and Devis, 1996).

Postcoded data for the two time periods have been assigned to ward boundaries by using the Central Postcode Directory available at the University of Manchester Computer Centre. Some depletion of the mortality records occurred in this assignment because of invalid codes or a matching failure with the postcode directory but this accounts for less than 0.2% of the yearly mortality records.

Because of the changes in ward boundaries in the intercensal period, data from the 1991 Census have been recalculated on the basis of 1981 Census geography, allowing consistency in the analysis of change. This attribution of the 1991 Census variables to the 1981 ward boundaries was undertaken by Atkins et al (1993) and the data made available to the academic community through the Census Dissemination Unit at the University of Manchester.

Figure 1. Ward-deprivation groups for 1981 Census data on 1981 ward base.
3 Deprivation in Wales

Figure 1 shows the distribution of wards in the least and most deprived quintiles at the time of the 1981 Census showing a familiar pattern of poorer areas in the old industrial settlements of the South Wales valleys and those of the industrial areas of the northeast fringe, together with the poorer areas of Cardiff, Swansea, Newport, and Wrexham, and parts of the coastal towns of North and South Wales. The rural areas are, on the whole, among the least deprived areas on this measure, with exceptions in some of the free-standing small towns of North and Mid Wales. It can also be seen that, although these extreme quintiles are not self-contained areas and are composed of wards which are dispersed throughout Wales, they do tend to form clusters of contiguous areas. In particular, the South Wales valleys are widely represented in the most deprived quintile.

Figure 2 shows the distribution of wards in the most affluent and deprived quintiles on the Townsend measure for the 1991 Census data based on the 1981 ward base. The patterns of deprivation in 1981 and 1991 are very similar and have a rank correlation of...
0.88 although it should be noted that this high degree of correlation can be consistent with marked changes in the ranking of some individual wards. Over the whole ward system, however, the changes in the ranking between 1981 and 1991 are relatively small and result in the large majority of wards remaining in the same quintile groups. Analysis, not presented here (see Williams et al, 1997), has illustrated the similarity between the spatial patterns of deprivation as measured using the Townsend and Carstairs indicators. However, maps of wards by deprivation quintiles for the Jarman index, which was originally constructed as the basis for workload payments for general practitioners (Jarman, 1983; 1984), suggests that the valleys in South Wales are less represented in the most deprived quintile than are the rural areas of North Wales and Anglesey. We will return to the need for sensitivity analysis with respect to variation of deprivation measures in section 6.

4 Mortality gradients and temporal changes—all causes

4.1 Cross-sectional results for 1981 and 1991

A comparison has been made between the all-cause SMR for 1981–83 and 1990–92, standardised respectively to 1981 and 1991, for the wards of Wales grouped into quintiles and deciles for age groups 0—64 and 0–74 (table 1). For both age ranges Wales exhibited a fall in SMR over this period towards the average for England and Wales, from 108 to 100 for 0–64, and from 109 to 101 for the wider age range 0–74.

Table 1. Standardised mortality ratios, SMRs (all causes), for (a) 0–64 years, and (b) 0–74 years, for grouping of wards by deprivation category (Townsend index) in Wales, 1981–83 and 1990–92 (standardisation in 1981 and 1991 to their respective years).

| Grouping                    | 1981–83 |          | 1990–92 |          |
|-----------------------------|---------|----------|---------|----------|
|                             | SMR     | number of deaths | SMR     | number of deaths |
| **(a) 0–64 years**          |         |          |         |          |
| Most deprived tenth         | 126     | 4292     | 129     | 3245     |
| Most deprived fifth         | 123     | 7976     | 120     | 5972     |
| Second fifth                | 113     | 5060     | 105     | 3966     |
| Third fifth                 | 106     | 4133     | 94      | 3372     |
| Fourth fifth                | 97      | 3464     | 87      | 2609     |
| Least deprived fifth        | 87      | 2898     | 80      | 2238     |
| Least deprived tenth        | 85      | 1259     | 76      | 960      |
| All Wales                   | 108     | 23531    | 100     | 18157    |
| **Ratio of SMR for most to least deprived tenth** |         |          | 1.48  |          |
| (95% confidence interval)   | (1.39 to 1.58) |          | (1.58 to 1.82) | |

| **(b) 0–74 years**          |         |          |         |          |
| Most deprived tenth         | 125     | 8609     | 126     | 7203     |
| Most deprived fifth         | 123     | 16382    | 119     | 13532    |
| Second fifth                | 113     | 11152    | 108     | 9512     |
| Third fifth                 | 106     | 9355     | 101     | 8207     |
| Fourth fifth                | 100     | 7823     | 89      | 6499     |
| Least deprived fifth        | 90      | 6544     | 76      | 5209     |
| Least deprived tenth        | 89      | 2789     | 76      | 2161     |
| All Wales                   | 109     | 51256    | 101     | 42959    |
| **Ratio of SMR for most to least deprived tenth** |         |          | 1.41  |          |
| (95% confidence interval)   | (1.35 to 1.47) |          | (1.58 to 1.74) | |
Comparison of premature mortality between 1981–83 and 1990–92 revealed that, in both periods, significant gradients in mortality existed over the deprivation quintiles. In 1981–83 the mortality rate for the most deprived tenth of the wards in Wales was 48% higher than that for the least deprived tenth for the 0–64 age group. By 1991, the corresponding excess for the 0–64 group was 69%, indicating that mortality differentials between deprivation groups had widened over the decade. Confidence intervals around these values suggest that the change is just significant at the 95% level. Table 1(b) which gives similar information for the 0–74 age group, provides clearer evidence for a widening in inequality with the ratio of SMR for the most to least deprived tenth increasing from 1.41 in 1981–83 to 1.66 in 1990–92.

4.2 Absolute changes in mortality: 1981–83 to 1990–92

In order to investigate absolute changes in mortality we have standardised mortality ratios to 1981 and computed the age and sex variation of mortality experiences in the two periods 1981–83 and 1990–92 (table 2). For the age range 0–64, the mortality ratios for the most and least deprived quintile of wards decreased by 19% and 26%, respectively. The change in mortality for residents in the most deprived group is significantly different from the rest of the Welsh population taken together.

Table 2. Absolute change in mortality (all causes, 0–64 years) for grouping of wards by deprivation category (Townsend index), in Wales, 1981–83 to 1990–92 (standardisation to a 1981 base).

| Grouping          | 1981–83 | 1990–92 | Percentage change | 95% confidence interval |
|-------------------|---------|---------|------------------|-------------------------|
|                   | SMR     | number of deaths | SMR     | number of deaths |              |                  |
| Most deprived fifth | 123     | 7976    | 99    | 6106    | −19          | −22 to −17    |
| Second fifth       | 113     | 5060    | 85    | 3716    | −25          | −28 to −22    |
| Third fifth        | 106     | 4133    | 80    | 3153    | −25          | −29 to −22    |
| Fourth fifth       | 97      | 3464    | 73    | 2782    | −25          | −28 to −21    |
| Least deprived fifth | 87     | 2898    | 65    | 2400    | −26          | −30 to −22    |
| All Wales          | 108     | 23531   | 83    | 18157   | −24          | −25 to −22    |

^SMR, standardised mortality ratio.

Figure 3 shows the absolute changes in mortality for different gender and age groups in the least and most deprived quintiles. Again, all mortality ratios are standardised to 1981. With the exception of the male 15–44 age group, all age–sex groups show a significant improvement in mortality and this is particularly marked in the age range 0–14 for all deprivation groupings. For the latter age group, the mortality ratio for the most deprived quintile decreased by 32% compared with 50% for the more affluent quintile. In the most and least deprived fifth of wards in Wales there has been no significant improvement (or worsening) in mortality in the 15–44 age group. Indeed, it is officially recognised that the 15–44 age group has not shared in the “general reduction in death rates which have benefited the rest of the population” (Welsh Office, 1995, page 14).

For females in the least deprived quintile the reduction in mortality for all age groups above 15 years was approximately 25%. For the most deprived group the decline in any age group is somewhat smaller and is significantly smaller for the age range 65–74. Mortality amongst the most deprived groups improved less than amongst the least deprived groups across all age and sex bands (although the differences were generally not significant at the 95% level). Analysis of the sensitivity of the results to the choice of deprivation indicator between the Carstairs and Jarman indicators, not presented here (see Williams, et al, 1997), has shown that the difference between the changes in the
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Figure 3. Mortality changes in the most and least deprived Welsh quintiles, 1981 to 1991.

standardised mortality ratios arising from the three deprivation indicators is not statistically significant, suggesting that the results are robust with respect to this source of variation.

5 Mortality gradients and temporal changes—by disease class

5.1 Introduction

Charlton and Murphy (1997) have described the variations in mortality by cause in the period 1841 and 1994 and noted the decline in the importance of death by infectious disease in the overall mortality totals for England and Wales. Conversely, there has been a greater proportion of deaths from circulatory diseases and cancers, especially in men. Presently almost a third of deaths of people in Wales are caused by heart disease and nearly a quarter by cancer (Welsh Office, 1997). Hidden within these figures are variations both by gender and by age group. For males between the ages of 15 and 34 years, for example, the major causes of death are accidents and suicide. Furthermore this cause of death amongst men in this age group is actually rising and is five times the rate for women in the equivalent age group. In the 35–44 age group heart disease is a significant cause of death amongst men as compared with women (three times the rate) but conversely cancer-related deaths are twice as likely for women in this age group as for men.

We now consider the changes in mortality due to all cancers, breast cancer, circulatory diseases, and suicide for different quintile groups.

5.2 Mortality (cancers) and deprivation: 1981–83 to 1990–92

In the age range 0–64, mortality due to cancer decreased by 12% over 1981–83 to 1990–92 compared with a 24% decrease for all causes (table 3, over). A mortality gradient existed in 1981–83 with the mortality rate for the most deprived fifth of wards in Wales over 25% higher than that for the least deprived fifth for the age group 0—64. The reductions in cancer mortality rates over the decade were similar across the different deprivation groups. In the 0–74 age range, a much smaller decline in mortality (4%) over the decade was largely attributable to the significant improvement in mortality for the least deprived quintile of wards.
Table 3. Change in standardised mortality ratio, SMR (all cancers, 0–64 years), for grouping of wards by deprivation category (Townsend index) in Wales, 1981–83 to 1990–92 (standardisation to a 1981 base).

| Grouping            | 1981–83 | 1990–92 | Percentage change | 95% confidence interval |
|---------------------|---------|---------|-------------------|-------------------------|
| SMR                 | number  | SMR     | number of deaths  | number of deaths         |
| Most deprived fifth | 113     | 102     | 2366              | 1994                    | -10                      | -15 to -4                |
| Second fifth        | 107     | 92      | 1569              | 1297                    | -14                      | -20 to -8                |
| Third fifth         | 103     | 90      | 1316              | 1160                    | -13                      | -19 to -6                |
| Fourth fifth        | 96      | 86      | 1132              | 1074                    | -11                      | -18 to -3                |
| Least deprived fifth| 89      | 78      | 973               | 950                     | -13                      | -20 to -5                |
| All Wales           | 104     | 91      | 7356              | 6475                    | -12                      | -15 to -9                |

5.3 Mortality (breast cancer) and deprivation: 1981–83 to 1990–92

A breakdown of causes of cancer has revealed that in the case of female breast cancer (ICD 174) a reversal in trends is apparent with mortality from breast cancer in 1981 being 24% higher in the most affluent fifth of wards compared with the most deprived fifth (table 4).

Similar trends of an inverse relationship of breast cancer with deprivation were found in Scotland for 1980–85 by MacIntyre (1994) and for 1990–92 by McLoone and Boddy (1994). Temporal analysis for Wales has revealed that over the decade 1981–91, there was an overall improvement in the mortality rate of 18% in the age range 0–64, with the two most deprived and the least deprived quintiles showing significant improvements (19%, 18%, and 30%, respectively).

In the age range 0–74, the overall improvement of 11% was largely attributable to the most and least deprived quintiles which both showed significant improvements, of 15% and 26%, respectively. The Scottish study points to a higher survival rate amongst more affluent social groups, although the incidence of this form of cancer is higher in such groups. MacIntyre (1994, page 461) suggests that “the better survival rates for breast cancer among women from more affluent social groups do not appear to be attributable to later presentation among the poorer groups” and that social class variations in outcomes are the result of other, unspecified, processes. However, there is local evidence to suggest that the use of preventive screening services is greater amongst the least deprived groups of women (Bro Taf Health Authority, 1996).

Table 4. Change in standardised mortality ratio, SMR (breast cancer, 0–64 years), for grouping of wards by deprivation category (Townsend index) in Wales, 1981–83 to 1990–92 (standardisation to a 1981 base).

| Grouping            | 1981–83 | 1990–92 | Percentage change | 95% confidence interval |
|---------------------|---------|---------|-------------------|-------------------------|
| SMR                 | number  | SMR     | number of deaths  | number of deaths         |
| Most deprived fifth | 99      | 80      | 273               | 207                     | -19                      | -33 to -3                |
| Second fifth        | 116     | 94      | 224               | 178                     | -18                      | -33 to -1                |
| Third fifth         | 105     | 90      | 178               | 156                     | -14                      | -31 to +7                |
| Fourth fifth        | 105     | 95      | 165               | 159                     | -10                      | -28 to +12               |
| Least deprived fifth| 123     | 87      | 180               | 143                     | -30                      | -44 to -12               |
| All Wales           | 108     | 89      | 1020              | 843                     | -18                      | -25 to -11               |
5.4 Mortality (circulatory diseases) and deprivation: 1981–83 to 1990–92
In the 1981–83 period there were large differences in the death rate from circulatory diseases between the most and least deprived people in Wales. Premature mortality from the poorest fifth of wards was nearly 50% higher than that for the most affluent fifth of wards. By 1990–92 this difference had widened to 71%.

Over all deprivation classes there was a large decrease in mortality for this cause, with an all-Wales average decline of 35% in premature death (table 5). There is also evidence of a gradient in the rate of change, with the reduction in SMR for the least and most deprived wards amounting to 39% and 29%, respectively. In the 0–64 age group the mortality decline of the most deprived quintile was significantly lower than for the other 80% of wards. For the 0–74 age group the overall decline in mortality over the decade is 29%, with the least deprived wards experiencing a 34% fall and the most deprived a 25% decline. Similar trends were found in Scotland (McLoone and Boddy, 1994) where the differential between the most affluent and deprived categories increased for the rates of death from ischaemic heart disease. In the case of Wales, it is evident that the increasing differentials in the mortality attributed to the large class of circulatory diseases contributed most to the corresponding results for all cause mortality.

Table 5. Change in standardised mortality ratio, SMR (circulatory diseases), (a) 0–64 years, (b) 0–74 years for grouping of wards by deprivation category (Townsend index) in Wales, 1981–83 to 1990–92 (standardisation to a 1981 base).

| Grouping               | 1981–83 | 1990–92 | Percentage change | 95% confidence interval |
|------------------------|---------|---------|-------------------|-------------------------|
|                        | SMR     | number of deaths | SMR   | number of deaths |                      |                      |
| (a) 0–64 years         |         |         |                   |                         |                      |                      |
| Most deprived fifth    | 133     | 3236    | 94                | 2145                    | −29                   | −33 to −25           |
| Second fifth           | 123     | 2096    | 79                | 1299                    | −36                   | −40 to −31           |
| Third fifth            | 108     | 1598    | 68                | 1014                    | −37                   | −42 to −32           |
| Fourth fifth           | 99      | 1345    | 62                | 906                     | −37                   | −42 to −31           |
| Least deprived fifth   | 90      | 1137    | 55                | 777                     | −39                   | −45 to −34           |
| All Wales              | 114     | 9412    | 74                | 6141                    | −35                   | −37 to −33           |
| (b) 0–74 years         |         |         |                   |                         |                      |                      |
| Most deprived fifth    | 129     | 7615    | 97                | 5744                    | −25                   | −27 to −22           |
| Second fifth           | 119     | 5295    | 86                | 3886                    | −27                   | −30 to −24           |
| Third fifth            | 111     | 4425    | 77                | 3165                    | −31                   | −34 to −27           |
| Fourth fifth           | 105     | 3697    | 71                | 2768                    | −32                   | −36 to −29           |
| Least deprived fifth   | 94      | 3058    | 62                | 2319                    | −34                   | −37 to −30           |
| All Wales              | 114     | 24090   | 81                | 17882                   | −29                   | −31 to −28           |

5.5 Mortality (suicides and injury undetermined) and deprivation: 1981–83 to 1990–92
To compare trends for Wales with those of the McLoone and Boddy (1994) study for Scotland, we have explored the significance of deaths from suicide (ICD E950–E959) and injury undetermined (accidentally or purposely self-inflicted) (ICD E980–E989). In table 6(a) (over) we record the variation of mortality from suicides over the five deprivation groups for males aged 15–44. There has been a significant increase of suicides in this age group for the whole of Wales and for the two most deprived quintiles. Because of the relatively small numbers the confidence intervals are wide.

A clearer picture of the changes for different quintiles emerges when suicides are combined with deaths from undetermined injuries, some of which are likely to be
Table 6. Change in standardised mortality ratio, SMR, (a) suicides, (b) suicides and injury undetermined (male 15–44 years) for grouping of wards by deprivation category (Townsend index) in Wales, 1981–83 to 1990–92 (standardisation to a 1981 base).

| Grouping                  | 1981–83 | 1990–92 | Percentage change | 95% confidence interval |
|---------------------------|---------|---------|------------------|-------------------------|
|                           | SMR     | number  | SMR              | number                  |                         |
| (a) Suicides              |         |         |                  |                         |                         |
| Most deprived fifth       | 120     | 73      | 160              | 100                     | +34                      | 0 to +83                 |
| Second fifth              | 92      | 37      | 155              | 67                      | +69                      | +15 to +161              |
| Third fifth               | 109     | 38      | 142              | 54                      | +31                      | −15 to +104              |
| Fourth fifth              | 99      | 33      | 108              | 39                      | +9                       | −33 to +79               |
| Least deprived fifth      | 79      | 24      | 120              | 40                      | +53                      | −9 to +165               |
| All Wales                 | 102     | 205     | 141              | 300                     | +38                      | +16 to +65               |
| (b) Suicides and injury undetermined |        |         |                  |                         |                         |
| Most deprived fifth       | 105     | 90      | 185              | 161                     | +76                      | +37 to +131              |
| Second fifth              | 96      | 54      | 148              | 89                      | +55                      | +12 to +121              |
| Third fifth               | 96      | 47      | 147              | 78                      | +53                      | +8 to +125               |
| Fourth fifth              | 97      | 45      | 108              | 54                      | +11                      | −27 to +69               |
| Least deprived fifth      | 63      | 27      | 128              | 59                      | +101                     | +26 to +230              |
| All Wales                 | 94      | 263     | 149              | 441                     | +59                      | +36 to +85               |

suicides [table 6(b)]. All quintiles, except the fourth, experience significant increases in mortality over the decade, although there is no systematic trend over the quintiles.

The above results are consistent with those from the Scottish study which found that suicide death rates for the 20–29 age group, especially for males, increased in every deprivation category.

6 Variations in mortality: a comparison of Wales with the Northern region of England

6.1 Introduction

In this section we compare the relationship between the all-cause premature mortality experience and deprivation in Wales with that for the Northern region recently studied using the same methodology by Phillimore et al (1994). We would note that, in aggregate terms, in the intercensal period, 1981–91, the all-ages SMR for Wales improved from 105 to 101, signifying a move towards the average conditions in England and Wales taken as a whole. Among the regions, Wales improved its position from ninth to seventh. We should, however, regard this improvement with some caution in view of the volatility of yearly mortality ratios, and we would note that in the years 1993–95, Wales has apparently lost ground, the SMR rising back to levels experienced in the early 1980s. In contrast, the Northern region retained its bottom position in the regional ranking, and stands out as having a lesser mortality decline than other regions (Drever and Whitehead, 1995).

Phillimore et al (1994) published for the Northern region of England tables of mortality ratios disaggregated by sex and age for the most and least deprived quintiles of wards, similar to those we have produced for Wales in sections 4 and 5. Although the calculation of mortality changes in ward quintiles over the 1980s was made with respect to slightly different year groups (1981–83 to 1990–92 for Wales and 1981–83 to 1989–91 for the North) they are otherwise similar and provide the basis for a comparison. (We would note that the proportional distribution of population over the quintiles of the Northern region is very similar to that for Wales, suggesting that the influence of different ward geographies is probably very small). A comparison of the
cross-sectional gradients and the relative changes of mortality for the most and least deprived quintiles in the two regions may be achieved through consulting these tables. They are inappropriate, however, for the absolute comparison of mortality changes because the use of quintiles to define spatial units, through reference to the ranking of wards, allows only internal comparisons. In order to test for significant differences between the mortality in the two regions it is necessary to identify similarly deprived or affluent groups of wards.

Although it would be desirable to adopt a comparison based on a research design of matched pairs of similarly deprived wards in the two regions, the comparison is constrained by the available published information for the Northern region, specifically the mortality changes for the quintiles, and by the deprivation characteristics in the two areas. We undertake the comparison with reference to the distribution of ward-deprivation scores in the two regions.

6.2 Mortality and deprivation in the Northern region

Figure 4 shows the change in mortality over the period 1981–83 to 1989–91 as published by Phillimore et al (1994, table V). The authors noted a widening mortality differential between the most affluent and deprived quintiles in all age categories under 75 years. It was also shown that, in absolute terms, there were improvements in mortality in all age groups in the most affluent areas. In the poorest areas improvements in the 55–64 age group were balanced by increased mortality among men aged 15–44, a slight rise among women aged 65–74, and static rates among men aged 45–54.

Comparing this with figure 3 it is possible to deduce that for the 0–64 age group the excess mortality of the most deprived compared with the most affluent quintile in 1981–83 is rather greater in the North (56%) compared with that in Wales (41%). The larger disparity between deprivation groups in the North was also evident when comparing changes over time. In the North, the decline in the 0–64 year mortality for the most affluent and the most deprived ward groups is 20% and 9%, respectively. In Wales the corresponding figures are 26% and 19%.
6.3 Identification of ward groups for interregional comparisons

In order to assess the absolute differences in mortality experience between the regions, it is necessary to select those wards in Wales which are comparable in deprivation with the most and least deprived quintiles in the Northern region. The method for their selection is based on an analysis of the distributions of the respective deprivation scores in the two areas. These are shown in figure 5 which also shows the distribution of the Townsend scores for the 9264 wards (plus the City of London) in England and Wales in 1981.

![Histograms of Townsend scores for 1981](image)

**Figure 5.** Histograms of Townsend scores for 1981 for (a) all English and Welsh wards, (b) Welsh wards, (c) Northern wards.

With reference to the Townsend index, the distribution of deprivation in Wales is similar to that for England, but without the extremes of high and low deprivation. Conversely, the Northern region has a flatter distribution with a greater occurrence of the most deprived and least deprived wards. The North has considerably more wards than Wales which are deemed to be highly deprived (according to the Townsend measure). This is evident from the distributions and reflects the difference between the mean Townsend scores for the most deprived quintiles in Wales and the North, which are 4.74 and 7.94, respectively.
The initial criterion for selection involved the identification of those groups of wards in Wales which have similar mean Townsend scores to the means for the most and least deprived quintiles in the Northern region. Applying this criterion resulted in the selection of the 16 most deprived wards in Wales which had a mean Townsend score equal to that of the Northern quintile. In contrast, the 88 least deprived wards in Wales had a mean value equal to that of the most affluent Northern quintile. The problem therefore is of a disparity in the number of wards in the most deprived groupings—16 in Wales and 135 in the Northern quintile—with implications for the size of the confidence intervals associated with a relatively small number of deaths in Welsh wards. It is, however, possible to consider the mortality decline for the 0—64 age range for the deprived groups in the regions.

In 1981–83 the SMR for age group 0—64 for the most deprived 16 wards in Wales was 138 and in 1990–92 the value (standardised to 1981) had fallen to 109, representing a 21% decrease, with a 95% confidence interval of —28 to —12, reflecting the relatively low number of deaths in this group. The comparable SMR values for the most deprived Northern quintile are 136 reducing to 124, representing a 9% decline with a confidence interval of —12 to —7. We can conclude that the overall decline in premature mortality for this deprived group in Wales is significantly greater than that for the Northern quintile.

Because the confidence intervals around the change in mortality for different age—sex groups for the 16 wards are too wide to yield meaningful comparisons, we have relaxed the requirement that the mean values of the groups of wards should be equal. Instead we have used the threshold Townsend scores which define the most and least deprived quintiles in the North to identify comparable groups of wards. This results in the selection of 46 wards in the most deprived and 142 wards in the least deprived groups in Wales. The change in mortality across age—sex groups for the 46 most and 142 least deprived ward groups in Wales is shown in figure 6 (see over). Comparing this with figure 4 for the Northern quintiles, even accounting for the fact that we have wider confidence intervals associated with the results for the most deprived group in Wales, a number of trends can be discerned. First, there has been an improvement in mortality in the least deprived wards in both regions in most age groups for males and females, and the improvement appears greater in Wales. Among the most deprived wards the mortality decline in Wales appears greater than that in the North. The large improvement in mortality in the male 45—54 age group and in the female 55—64 age group experienced in Wales is not evident in the North. For males aged 15—44 there is a significant improvement in the mortality in the least deprived area of the North and a significant deterioration in that of the most deprived. By contrast, in Wales, there is no significant change in the mortality in the most or least deprived areas. Among females in the most deprived wards, in both regions, no significant change is observed in the mortality of the 15—44 or the 65—74 age groups.

Thus, although there is difficulty in establishing precise conclusions because of the relatively low number of wards involved in the comparison, the above analysis suggests that, for similarly deprived areas, the contrasts in mortality at the cross section and differential changes in mortality decline over the extreme deprivation groups are rather greater in the Northern region than in Wales. We would note, however, the possible confounding effect of selective migration by health status, as Wales has experienced a net in-migration of relatively healthy people, whereas the Northern region has experienced the opposite.

The next stage in our analysis has been to determine to what extent the mortality differences are a function of the particular deprivation index applied.
6.4 Sensitivity analysis with respect to variation of deprivation measure

It is evident that the most deprived quintiles in the two regions had very different mean values for the Townsend score. This difference in the quintile scores can be traced to the differences in the mean values of the component census variables. Although these variables are subject to transformations before entry into the Townsend deprivation measure, it was evident that the most deprived quintile in Wales has a considerably higher level of owner-occupation than the corresponding quintile in the North (37% compared with 17%), and it is partly as a result of this that there is apparently less deprivation in this group of wards in Wales.

For historical and cultural reasons Wales, and particularly the valley communities in South Wales, are characterised by relatively high levels of owner-occupation. However, as significant parts of this housing stock are in poor condition, inclusion of this census variable in a deprivation index may confound the interregional analysis of deprivation. We have, therefore, undertaken a sensitivity analysis of the above interregional comparison with the Carstairs and Jarman indicators—neither of which contain the owner-occupier variable. We have simply selected the 46 most deprived wards according to the Carstairs and Jarman scores and undertaken the above comparison of the mortality changes with the most deprived Northern (Townsend) quintile. This procedure seeks to establish whether an alternative cluster of deprived wards, which are free from the potential distorting influence of the owner-occupier variable, is characterised by more extreme mortality gradients. We found that the differences in the changes in mortality over the decade arising from the different deprivation indicators were considerably smaller than the confidence intervals around the mortality changes themselves. Again, it was therefore concluded that the trends identified in the previous section are robust with respect to variation in the deprivation measure.
7 Conclusions
This study has quantified the relationship between mortality and deprivation in Wales over the intercensal period, 1981–91. Tabular methods have been used based on quintile groups formed from wards ranked according to standard measures of material deprivation. We have also sought to compare the experience of Wales with that of the Northern region of England for which similar results are available for all-cause mortality.

We have established the existence of gradients in premature mortality over the deprivation quintiles at the 1981 and 1991 cross sections. At the first, mortality of the under-65 year-olds in the most deprived fifth of wards was about half as much again as in the least deprived wards. Although there have been reductions in premature mortality across all deprivation groups in Wales, over the decade the gap has widened between the most and least deprived areas. The 48% excess mortality in the most deprived wards increased to 69% compared with the least deprived wards.

Between 1981–83 and 1990–92, deaths of under-65 year-olds in Wales reduced by 24% with considerable differences between age–sex groups. The 35% reduction in circulatory disease deaths contributed most to the reduction in all-cause deaths. Cancer has proved less amenable to prevention and treatment—premature deaths reduced by 12%. Premature deaths from suicides showed a significant increase. The differences between circulatory disease mortality rates in the most and least deprived fifth of wards was larger than for other disease groups and larger than for all-cause deaths. The decline in mortality in this large disease category was significantly lower in the most deprived 20% of wards than in the rest of Wales.

Although both Wales and the Northern region exhibit significant reductions in mortality, referred to a 1981 base, the improvement in Wales is, on the whole, rather greater than that in the North and this is consistent with the regional mortality trends. Although both regions exhibit widening differences between their most and least deprived quintiles, mortality ratios in most age–sex groups are rather less in Wales than in the North. Our substantive conclusions are robust with respect to variation of the deprivation measure chosen. A full review of the policy implications of this work is available in Williams et al (1997).

The study has shown that small area approaches can provide important insights into systematic variations in mortality rates between different population groups within and between regions and over time, and such approaches have an important role to play in exploring the relationship between material deprivation and changing health differentials. This has been demonstrated in this paper through the use of tabular data analysis based on deprivation groups. In the second paper (Senior et al, 1998), we explore the use of statistical models to provide further insights into these trends and more specifically, show how the generalised linear model may be used as an integrating framework.

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