

Geographical trends in infant mortality: England and Wales, 1970–2006

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At national level in England and Wales, infant mortality rates fell rapidly from the early 1970s and into the 1980s. Subnational areas have also experienced a reduction in levels of infant mortality. While rates continued to fall to 2006, the rate of reduction has slowed. Although the Government Office Regions Yorkshire and The Humber, the North West and the West Midlands and the Office for National Statistics local authority types Cities and Services and London Cosmopolitan have experienced relatively large absolute reductions in infant mortality, their rates remained high compared with the national average. Within all regions and local authority types, a strong relationship was found between ward level deprivation and infant mortality rates. Nevertheless, levels of infant mortality declined over time even in the most deprived areas with a narrowing of absolute differences in rates between areas. Areas in which the level of deprivation eased have experienced greater than average reductions in levels of infant mortality.

Introduction

The level of infant mortality can be seen as a major indicator of the health of a nation^{1,2} with the focus on infant mortality rates (deaths at ages under one year, per 1,000 live births) remaining high on academic³ and public health and policy agendas^{4,5} within the UK and throughout the world.⁶ Throughout the 20th century, infant mortality rates in England and Wales steadily declined, largely due to ‘improved living conditions, diet and sanitation, birth control, advances in medical science and the availability of healthcare’.⁷ The reduction in infant mortality has been cited as the single greatest factor contributing to increased life expectancy over the past 100 years.^{8,9}

A range of social and biological factors are associated with high infant mortality.^{10,11} These factors include low birthweight, multiple births, marital status, age of mother, country of birth of mother and father’s social class.^{2,12,13,14} Social class differences in infant mortality rates are wider in the postneonatal period (deaths between 28 days and one year) than the neonatal period (deaths under 28 days).¹⁵ Despite reductions in infant mortality over time, health inequalities in infant mortality remain between different social groups.^{4,16,17}

During the 20th century geographical variations in infant mortality have been observed^{18,19} with reductions in rates unevenly distributed,²⁰ although to some extent this is explained by distributions of people by social class. From 1900 up to the 1960s infant mortality rates in Wales were higher than rates for England,²¹ though by the 1990s Wales had lower infant mortality than England. At regional level within England, a north-south divide has existed with higher rates tending to be found in the north.²²

Since the 19th century, the strong tendency has been for infant mortality rates in urban and mining areas to be higher than those in more rural locations, largely due to adverse living conditions and housing density.^{20,23,24,25,26} During 1991–97, high infant mortality rates were concentrated in the major urban areas including London, Birmingham, Sheffield and Manchester.^{15,22} To draw out geographical patterns, and to avoid small number problems, areas can be grouped together using their socio-demographic characteristics. During the 1990s the local authorities classified²⁷ as East Inner London, Ports and Industry and in particular the Manufacturing Centres had the highest infant mortality rates with lower rates for the Most Prosperous, Growth Areas and Rural Amenity locations.²² Consistently over time, the most deprived areas within the countries of the UK have had the highest infant mortality rates and the least deprived areas the lowest rates.^{22,28,29,30,31} Moreover, low birthweight, a risk factor associated with infant mortality,¹⁵ is itself associated with area deprivation.^{14,32} Despite ongoing reductions in infant mortality rates in England and Wales, reports have continued to highlight subnational variations in infant mortality.^{33,34,35}

Recent advances in the development of a time-series of demographic data^{36,37,38} enabled trends in infant mortality to be investigated. Given the previous findings referred to above, the work reported here aimed to investigate whether the reductions in infant mortality rates, observed at national level between 1970 and 2006, were uniform geographically by specific geographies and by area types. This was achieved by:

- the compilation of a database of counts of live births and deaths to infants aged under one year with all data georeferenced to a common small area geography – in this case the Census Area Statistics wards (CAS) as used for the dissemination of the 2001 Census
- the aggregation of these small area statistics into both larger geographies and into different types of areas. After the calculation of rates, this enabled the investigation of regional trends in infant mortality and whether trends varied across different types of area, with a particular focus on the relationship between infant mortality and area deprivation

This paper first reports on the compilation of the database of the relevant vital statistics and defines the geographies and methods used in the analysis. The results section which follows describes national and regional trends in infant mortality between 1970 and 2006 and explores trends by area types.

Data and methods

Compiling a database on a consistent geography at ward level from 1970 onwards

Annual data on live births and deaths of infants aged under one year, collected through the national system of birth and death registration and processed by the Office for National Statistics (ONS), were used for England and Wales from 1970 to 2006. While these were available annually at national level, it was not possible to obtain the relevant subnational vital statistics for 1973 to 1978, and data were therefore analysed only for 1970–72 and 1979 onwards.

The last few decades of the 20th century saw widespread changes in the administrative geographies of England and Wales, particularly at small area level. Taking the census years as examples, in 1971 there were over 16,000 electoral wards nesting into the London, County and Municipal Boroughs and the Urban and Rural Districts which formed the then system of local government in England and Wales. This was subsequently reformed in 1974. In 1981 and 1991 there were 9,289 and 9,527 wards respectively, which nested into 403 local authority districts

and the Registrar General's Standard Regions. Following further local government reorganisation during the 1990s, by 2001 there were 376 local authorities (a mix of London Boroughs, Metropolitan Districts, County Districts and the new Unitary Authorities) which nested within the nine Government Office Regions (GORs) in England, and Wales. For the dissemination of the 2001 Census, 8,850 CAS wards were used, which nested into local authorities and thus GORs, and Wales.

The complexity of geographical changes presents a challenge to the creation of a data time-series so that trends can be analysed.^{36,37,38} To identify change over time, the original births and deaths data were adjusted to a common geography. For the results to have currency, the 2001 CAS wards were used. Geographical consistency was achieved in two ways:

- data for 1970–72 and 1979–89 were apportioned between the geography in which the data exist (the 'source' geography) to the 2001 Census wards (the 'target' geography). This apportionment was computed using a proxy for population distribution – the counts of postcodes (weighted by the number of addresses at each) which fall in the intersections of the source and target geographies. This technique is well-established^{39,40} and is reliable enough that a similar approach is now adopted by the ONS Small Area Population Estimates team to provide mid-year estimates for non-standard areas⁴¹
- data for 1990–2006 were directly allocated by ONS to the 2001 wards using the postcode recorded on the birth or death registration certificate

Geographies used in the analysis

With the time series of births and deaths harmonised to the 2001 wards, the data could be aggregated into higher geographies. For this study, these comprised the Government Office Regions and the National Statistics Area Classification of local authorities.^{42,43} Through these aggregations it was possible to investigate whether changes in infant mortality rates observed at national level occurred evenly for the GORs and across seven different types of areas – the Supergroups known as Cities and Services, London Suburbs, London Centre, London Cosmopolitan, Prospering UK, Coastal and Countryside, and Mining and Manufacturing. Map 1 illustrates the distribution of these area types. The area classification is based on 41 variables from the key statistics tables of the 2001 Census. In this 'geodemographic' scheme areas are grouped together based on similarities in the socio-economic characteristics of their residents, even though like areas may be geographically distant.

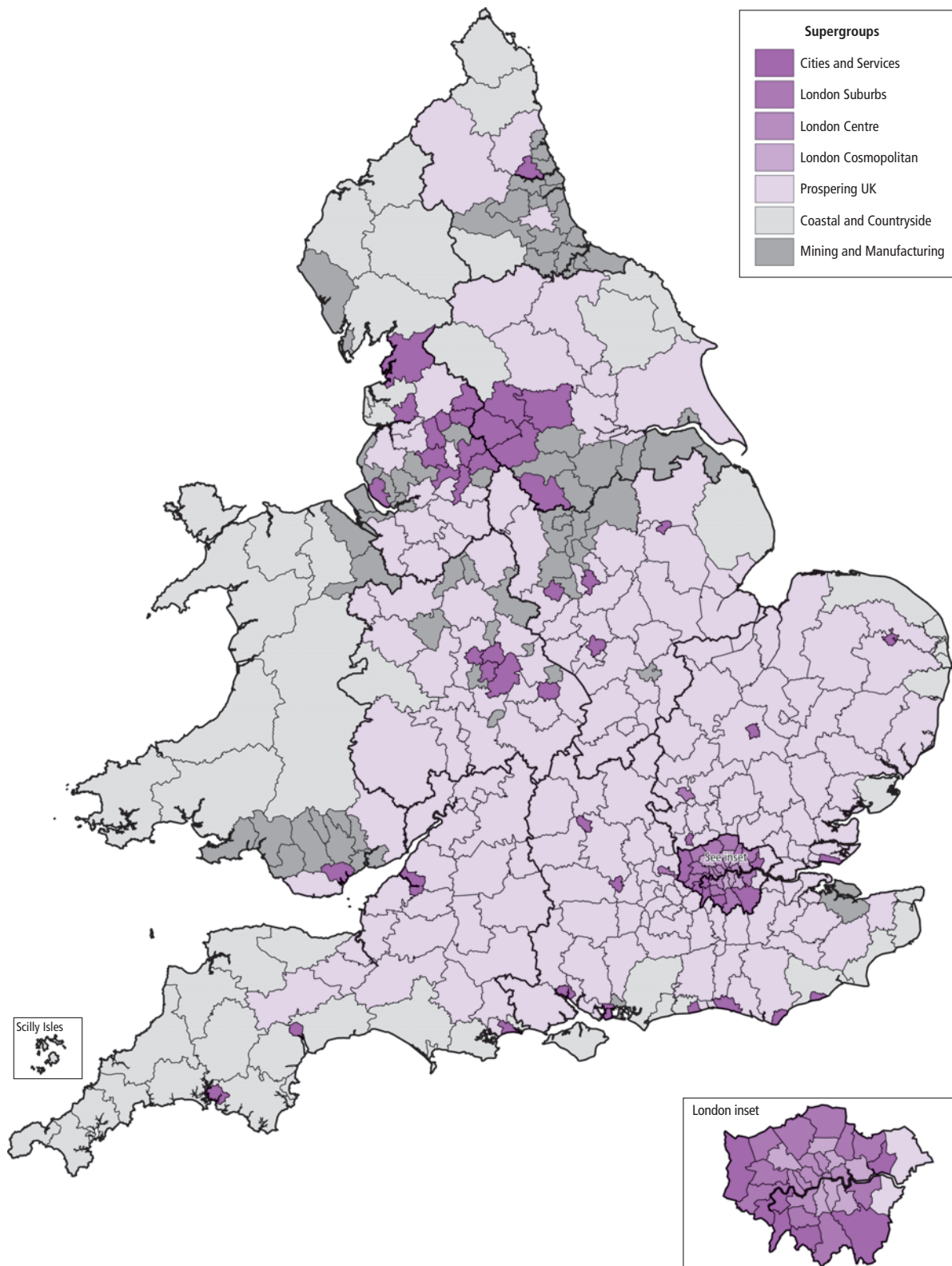
Measuring area deprivation over time

In addition to these local authority area types, the relationship between infant mortality and deprivation over time was also investigated. The Index of Multiple Deprivation (IMD) is the Government's current preferred indicator of deprivation in England. Similar, but not directly comparable, IMDs have been developed for the other constituent countries of the UK. The relative complexity of the IMD, lack of consistency between the index for England compared with the scheme in Wales and a lack of equivalent data over time means that it is not feasible to construct historical datasets.

The Townsend Index of Material Deprivation,⁴⁴ one of the most widely-used indices,^{15,45,46,47,48} was used here since consistent input variables are available for successive censuses. Townsend scores are based on four input variables: unemployed residents as a percentage of all economically active residents; households without access to a car as a percentage of all households; households that are not in owner occupied accommodation as a percentage of all households; and overcrowded households (more than one person per room) as a percentage of all households.

Map 1

National Statistics 2001 Area Classification for Local Authorities, England and Wales



Raw data were available in computerised format at ward level from the 1971, 1981, 1991 and 2001 Censuses so it was possible to calculate Townsend scores for these time points. As with the births and deaths data, the input variables were apportioned from the census geographies for which they were originally disseminated to be consistent with the 2001 Census wards, with deprivation scores then calculated for that geography. To calculate the scores, the unemployment and overcrowding variables were log transformed to produce less skewed distributions and all four variables were standardised as z-scores and summed, with each variable given an equal weight, to give a final deprivation score. The average score for England and Wales is zero, while higher positive scores indicate greater levels of material deprivation and more negative scores indicate less deprived areas. It is common in health studies to summarise results across deprivation quintiles, calculated with each quintile comprising either 20 per cent of the number of areas or 20 per cent of the population distribution. Here deprivation quintiles have been calculated, each with 20 per cent of live births. Quintile 1 contains the least deprived wards, with the most deprived wards in quintile 5. Map 2 illustrates the 2001 distribution of the deprivation quintiles across England and Wales, revealing a strong urban-rural gradient of deprivation.

For the Townsend indicator variables, national levels of non-home ownership, no access to a car and household overcrowding all steadily reduced over time. Contrary to these trends, overall unemployment rose between 1971 and 1981, was still relatively high in 1991, but reduced by 2001. Variations at more local level exist though. As a check on their applicability over time, the Townsend scores were compared with another indicator of deprivation, the Breadline Britain measure.³⁶ This measures relative poverty based on a lack of the perceived necessities of life, using information from poverty surveys. Incorporating more indicators of deprivation than the Townsend index, the Breadline Britain measure has been applied every 10 years since 1970 to produce geographical estimates of the number of 'poor' households. When incorporated into a common geography, a correlation between Townsend scores and the percentage of households which are 'Breadline poor' showed a very strong relationship (significant correlations of 0.88 in 1971 and 0.98 in 1981, 1991 and 2001).

It has been demonstrated that when the deprivation levels of areas change, there is an associated change in the general health of the people who live in those areas.⁴⁹ To investigate this for infant mortality, rates were calculated for those wards which remained in the same deprivation quintile or became more or less deprived over time. Thus, wards which were allocated into the least and most deprived quintiles at each of the 1971, 1981, 1991 and 2001 Censuses were identified, with the remainder classified as changing quintile during the time period. A further classification flagged those wards becoming more deprived or less deprived, and also those experiencing a bigger change by becoming more, or less, deprived by two or more quintiles.

In the results section which follows, this paper reports on a time-series of infant mortality rates for England and Wales, for the regions of England, and Wales, and for local authority area types for the periods 1970–72 and 1979–2001. These rates were calculated using rolling averages of annual births and deaths data. The averages were based on data for three-years, except at the start and end of the two time periods where two years were used (that is 1970–71, 1970–72, 1972–73, 1979–80, 1979–81, 1980–82...2004–06, 2005–06). National infant mortality rates for England and Wales were based on an aggregation of data which had been allocated to the English GORs and Wales. These figures therefore exclude non-residents who are normally included in the routine publication of national infant mortality rates by ONS.

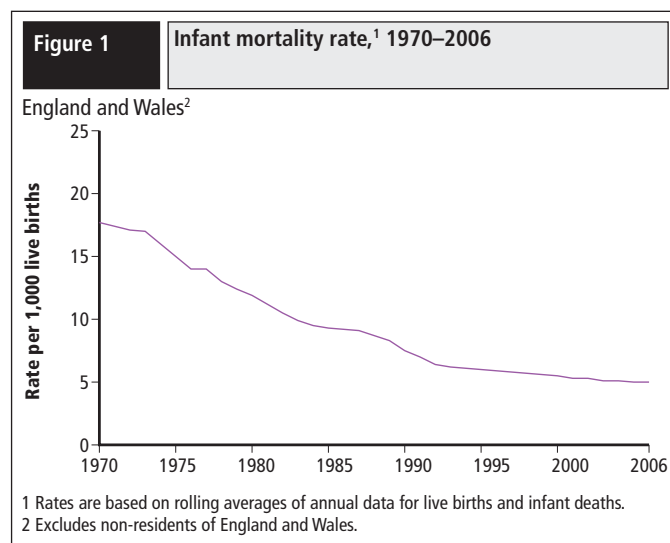
The relationship between infant mortality and deprivation is then investigated by presenting cross-sections of infant mortality rates by deprivation quintile for four periods around the census years from 1971 to 2001, and also for more recent data. These were calculated as an average of the three years surrounding each census and relate therefore to 1970–72, 1980–82, 1990–92 and 2000–02. Infant mortality rates for 2004–06 were calculated in relation

to 2001 deprivation. At each of these time points, to show the relative difference in infant mortality between the most and least deprived areas, rate ratios are used (calculated as the rate in quintile 5 divided by the rate in quintile 1), along with their associated confidence intervals.⁵⁰

Results

National level

For England and Wales, the infant mortality rate fell rapidly from 17.7 infant deaths per 1,000 live births in 1970 to a rate of 11.9 at the start of the 1980s (Figure 1). Rates continued to fall through the 1980s though not so rapidly in the mid-decade. In 1990 the national rate was 7.5. A more modest, but steady, decline continued through the last decade of the 20th century, to a rate of 5.5 in 2000. This decline continued, with the rate for 2006 being at an all time low of 5.0 infant deaths per 1,000 live births.



Government Office Regions, and Wales

There was considerable regional variation between infant mortality rates in 1970, with the lowest at 14.7 per 1,000 live births in the South East and the highest, at 20.3, in the North West. All regions experienced a large reduction in infant mortality rates, through a rapid decline up to the early 1990s, after which the reductions were more modest (Table 1 and Figure 2). Between 1970 and 2006, absolute differences in infant mortality rates between regions narrowed considerably. Despite having the smallest absolute reduction, the South East remained the GOR with the lowest rate (4.0). The West Midlands, with a rate of 6.4, replaced the North West as the region with the highest infant mortality.

While the year-by-year fluctuations create rather 'busy' looking graphs (Figure 3), plotting each region's rate relative to the England and Wales rate each year shows that the relative reductions in infant mortality over the study period were not evenly distributed, neither geographically nor over time. Overall, there was more variation in relative ratios in the 1990s and 2000s than in the early 1980s. Three regions, the East of England, South East and South West, had infant mortality rates which were lower than the national average for England and Wales across the whole period 1970–2006. From 1979 to the late 1980s their rates were more similar to the national average than they had been in 1970–72. From the late 1980s onwards however, their rates were particularly low compared to the England and Wales rate. Yorkshire and The Humber, the North West, and the West Midlands had infant mortality rates which were consistently higher than the national average. Despite the absolute reductions in infant mortality in these regions, from the late 1980s onwards their rates were increasingly high compared to the rate for England and Wales. The

Map 2

Ward-level deprivation, 2001: Townsend scores in quintiles with 20 per cent of live births, England and Wales

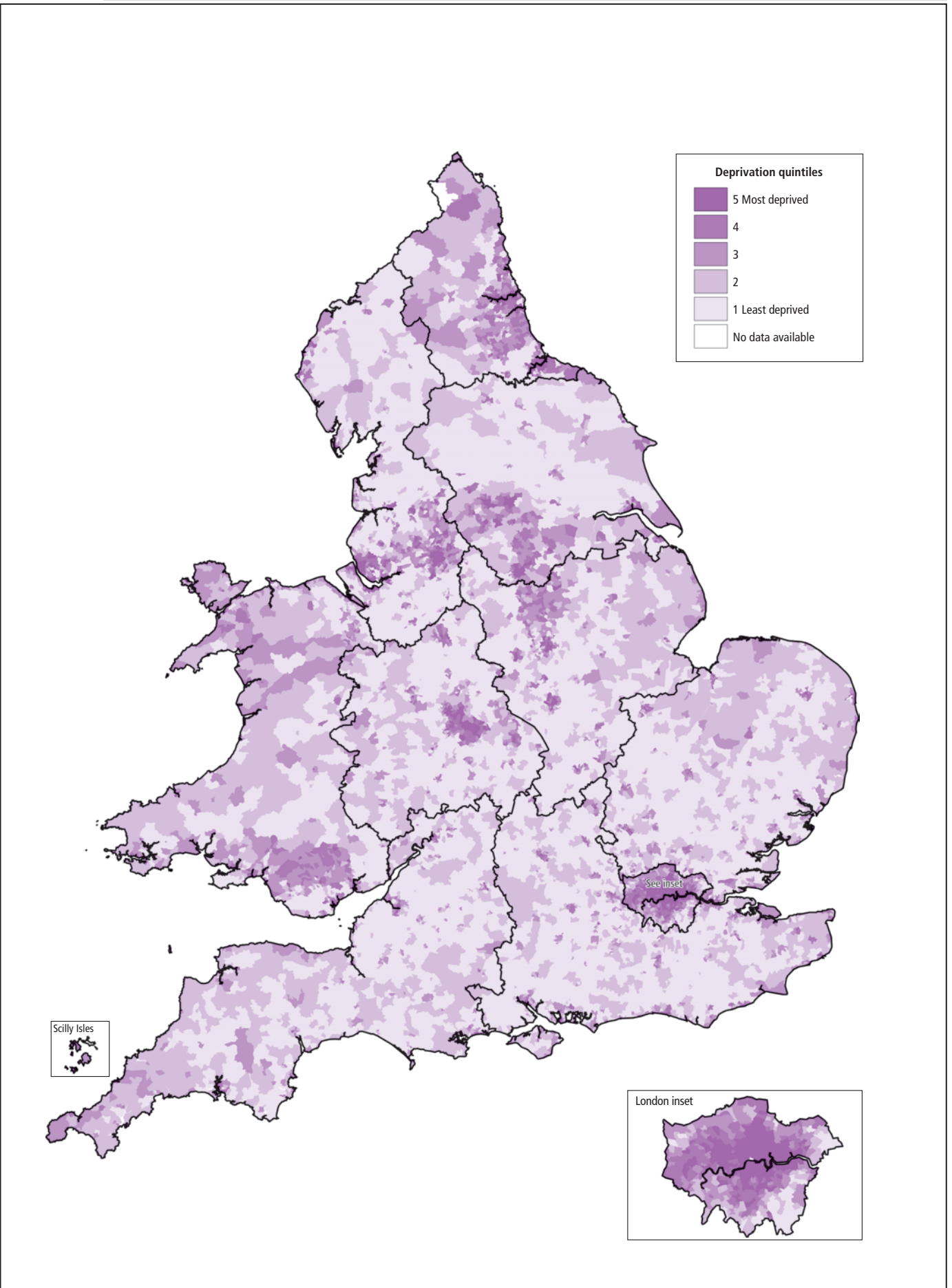


Table 1 Infant mortality rates:¹ Government Office Regions of England, and Wales,² 1970–72, 1979–2006

	Government Office Regions of England, Wales											
	England and Wales	England	North East	North West	Yorkshire and The Humber	East Midlands	West Midlands	East of England	London	South East	South West	Wales
	Rate per 1,000 live births											
1970	17.7	17.5	18.8	20.3	20.2	17.5	18.1	15.0	17.7	14.7	15.6	18.2
1971	17.4	17.4	19.1	19.8	19.7	17.5	18.1	14.6	17.6	14.4	15.6	17.4
1972	17.1	17.1	19.3	19.2	19.3	17.5	17.9	14.3	17.5	14.1	15.3	16.8
1973–78	..	..	..	..	..	..	..	..	..	..	..	..
1979	12.4	12.5	12.9	13.2	13.3	11.3	13.7	11.5	12.7	11.8	11.7	10.6
1980	11.9	11.9	12.1	12.5	12.9	11.1	13.0	10.8	12.0	11.2	11.2	11.1
1981	11.2	11.2	10.9	12.0	12.1	10.6	12.4	10.3	11.2	10.6	10.6	10.9
1982	10.5	10.4	10.1	11.1	11.3	10.6	11.5	9.3	10.1	9.7	10.0	10.8
1983	9.9	10.0	9.7	10.4	10.7	10.0	11.3	8.9	9.7	9.2	9.5	9.5
1984	9.5	9.5	9.7	9.9	10.5	9.8	10.6	8.4	9.2	8.7	9.1	9.1
1985	9.3	9.4	9.4	9.8	10.4	9.6	10.4	8.3	9.1	8.4	8.9	8.6
1986	9.2	9.2	9.0	9.8	10.2	9.7	9.8	8.3	9.2	8.5	8.7	8.8
1987	9.1	9.1	8.7	9.5	9.9	9.7	9.9	8.0	9.2	8.5	8.8	8.3
1988	8.7	8.7	8.4	8.9	9.3	9.1	9.8	7.6	9.1	8.2	8.2	7.8
1989	8.3	8.3	8.3	8.5	9.0	8.6	9.9	6.8	8.6	7.7	7.7	7.0
1990	7.5	7.6	8.1	7.9	8.4	7.6	9.3	6.0	7.8	6.7	6.6	6.6
1991	7.0	7.0	7.6	7.3	7.8	7.2	8.8	5.3	7.2	6.1	6.1	6.1
1992	6.4	6.5	7.3	6.7	7.4	6.8	7.7	5.2	6.8	5.3	5.8	5.8
1993	6.2	6.3	6.7	6.5	7.2	6.6	7.3	5.2	6.5	5.1	5.5	5.7
1994	6.1	6.2	6.6	6.5	7.2	6.3	6.9	5.2	6.3	4.9	5.4	5.9
1995	6.0	6.1	6.4	6.4	6.8	6.0	7.0	5.2	6.2	5.2	5.5	6.1
1996	5.9	5.9	6.2	6.4	6.7	5.8	6.9	5.1	6.1	5.0	5.4	5.7
1997	5.8	5.8	5.7	6.3	6.6	5.8	6.9	5.0	6.0	4.9	5.2	5.7
1998	5.7	5.7	5.5	6.4	6.8	5.6	6.7	4.7	5.9	4.6	4.8	5.5
1999	5.6	5.6	5.6	6.3	6.6	5.6	6.7	4.6	5.8	4.6	4.8	5.7
2000	5.5	5.5	5.5	6.1	6.3	5.5	6.5	4.5	5.8	4.4	4.8	5.4
2001	5.3	5.4	5.2	5.7	6.0	5.5	6.5	4.4	5.7	4.4	4.7	5.0
2002	5.3	5.3	4.8	5.7	5.8	5.7	6.7	4.5	5.6	4.4	4.4	4.6
2003	5.1	5.2	4.7	5.6	5.9	5.5	6.8	4.3	5.4	4.2	4.3	4.6
2004	5.1	5.1	4.7	5.6	5.8	5.2	6.8	4.2	5.3	4.0	4.4	4.4
2005	5.0	5.0	4.9	5.5	5.8	5.0	6.4	4.1	5.0	4.0	4.4	4.4
2006	5.0	5.0	5.0	5.5	5.8	5.1	6.4	4.1	5.0	4.0	4.3	4.1

1 Rates are based on rolling averages of annual data for live births and infant deaths (see Methods section).

2 Excludes non-residents of England and Wales.

.. Not available

West Midlands, which had a similar rate to that of England and Wales in 1970–72, tended to have the highest rate from 1979 onwards, with relative ratios to the national average increasing over time. The infant mortality rate in Wales was higher than that in England in 1970, but after that was mostly consistently lower. By 2006 the rate in Wales was only 4.1 infant deaths per 1,000 live births, compared with 5.0 in England.

Local authority types

Infant mortality rates for all the National Statistics Area Classification Supergroups also showed a rapid decline from 1970 (lowest rate in Coastal and Countryside at 15.0; highest rate in London Cosmopolitan at 20.9) to the early 1990s (Table 2 and Figure 4). The falls in infant mortality rates were then more modest so that in 2001 the lowest rate again occurred in areas classified as Coastal and Countryside (4.2), with the highest rate again in London Cosmopolitan (7.6). In 2006, however, the lowest rate was in Prospering UK (4.0) with Cities and Services experiencing the highest rate (5.9).

Plotting the rates for each Supergroup relative to the national level in each year (Figure 5) shows a clearer difference in infant mortality between area

types. Compared to the early 1970s, in the early 1980s there was a reduction in the amount of relative difference from national rates. From the early 1990s to the turn of the century, the difference in rates between Supergroups increased markedly, though by 2006 this had reduced somewhat. Throughout the study period (1970–2006), the strong tendencies were that Cities and Services and London Cosmopolitan had high infant mortality rates relative to the national level while Coastal and Countryside and Prospering UK had relatively low rates. The London Centre area had the most volatile relative ratios. This could be a ‘small number’ problem since this area had around 400 infant deaths per year in the early 1970s, which reduced to less than 100 per year in recent years. The counts of live births used as the denominators were also relatively small.

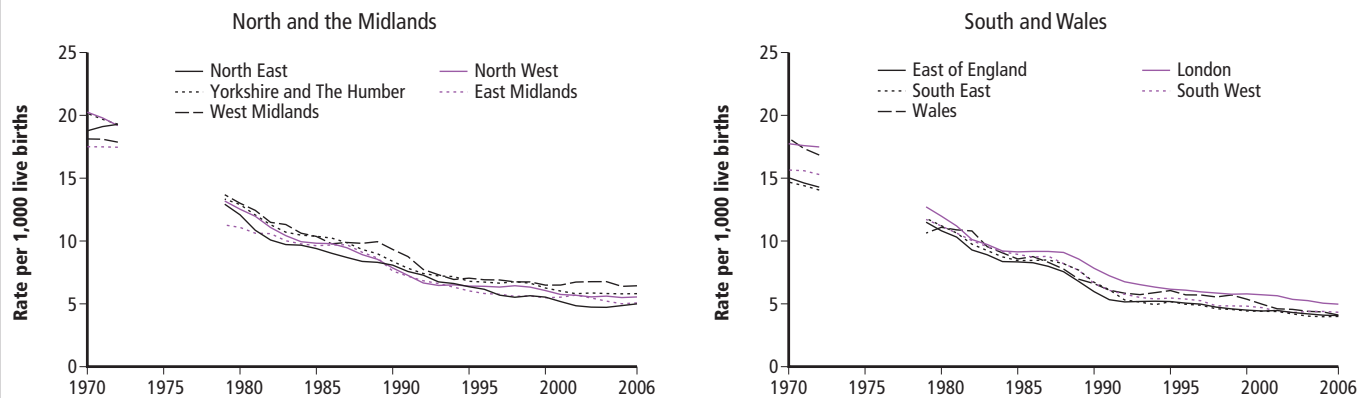
Ward level deprivation

Infant mortality rates around each census year from 1971 to 2001 (Table 3 and Figure 6), showed a strong, positive relationship with deprivation, with significant differences between quintiles (except between quintiles 1 and 2 in 1981 and 1991 when the confidence intervals overlap). The 2004–06 rates, centred around 2005, also showed the same relationship. Such is the reduction over time in levels of infant mortality that the rates in all deprivation quintiles in 1981 were below even the least deprived

Figure 2

Infant mortality rates,¹ Government Office Regions of England, and Wales,² 1970–72, 1979–2006

Government Office Regions of England, Wales

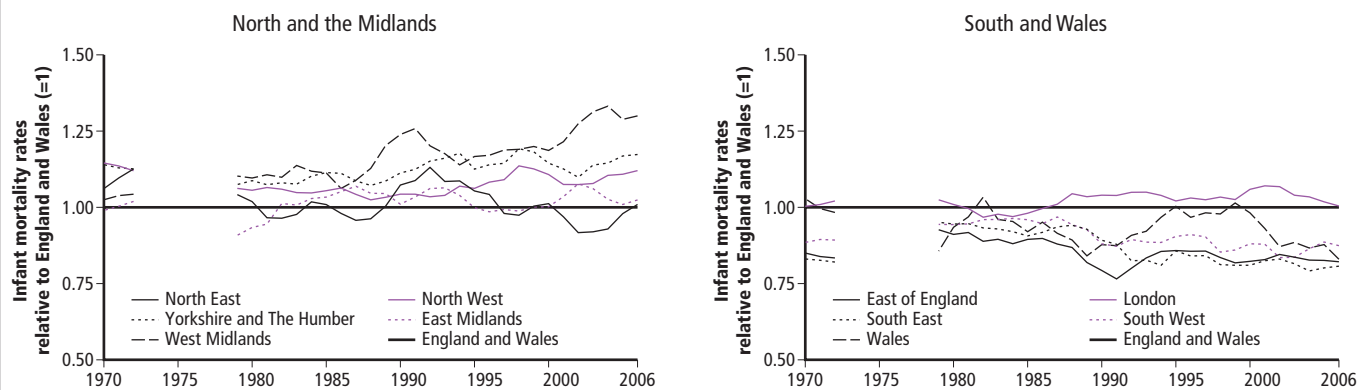


1 Rates are based on rolling averages of annual data for live births and infant deaths.
2 Excludes non-residents of England and Wales.

Figure 3

Infant mortality rates¹ for Government Office Regions, and Wales, relative to England and Wales,² 1970–72, 1979–2006

Government Office Regions of England, Wales



1 Rates are based on rolling averages of annual data for live births and infant deaths.
2 Excludes non-residents of England and Wales.

areas in 1971, a pattern which was repeated in 1991. This was no longer the case by 2001 when reductions in rates had slowed down, but all 2001 quintiles had significantly lower rates than their equivalents in 1991. By 2005, the only quintile with rates which were significantly lower than its counterpart in 2001, was quintile 5, containing the most deprived areas.

Inequalities between differently deprived areas are highlighted more clearly in Figure 7 which illustrates the ratio of infant mortality rates in the most to least deprived areas. Rate ratios above one occur when rates in quintile 5 are higher than those in quintile 1. Over the study period, although the ratio of rates in the most and least deprived areas narrowed between 1971 and 1981 from 1.40 to 1.26, it widened to 1.59 in 1991 and 2.19 in 2001. By 2005, the relative inequality reduced to 1.87. The 95 per cent confidence intervals, illustrated in Figure 7, show that the ratios at each time point were statistically significantly different from each other.

Of the wards which remained in the same deprivation quintile in all four censuses, 15 per cent were in quintile 1 (least deprived) and five per cent were in quintile 5 (most deprived). For the wards that remained in quintile 1 the infant mortality rate in 1971 was 14.0 and in 2005 was 3.5. The wards which remained in quintile 5 had significantly higher rates

compared to the wards that remained in quintile 1 in both 1971 (20.8) and 2005 (6.6), but the absolute reduction was larger (10.5 reduction in quintile 1; 14.2 reduction in quintile 5). The rates for wards remaining in the most and least deprived quintiles were only marginally different to the rates calculated for all wards in quintiles 1 and 5 in 1971 and 2005. This suggests that current area deprivation is influential on mortality outcomes rather than there being a cumulative advantage or disadvantage.

In wards which became less deprived, infant mortality rates decreased from 17.5 in 1971 to 4.5 in 2005, a reduction of 13.0. Wards which became relatively more deprived experienced less of a decrease since rates in these locations were 17.1 in 1971 and 5.2 in 2005, a reduction of 11.9. A slightly bigger disparity exists for those wards which became less deprived by two or more quintiles over time since areas with particularly reduced deprivation had a rate of 4.0 in 2005 compared with 17.3 in 1971, a decrease in the infant mortality rate of 13.3. While the rate in wards which became much more deprived by two or more quintiles was not as high in 1971 (16.8) as in other areas, the rate in 2006 (5.4) was relatively high, compared with wards which became less deprived. Wards which became relatively less deprived experienced a reduction in infant mortality rates greater than that for national rates in England and Wales.

Table 2

National Statistics 2001 Area Classification for local authorities: infant mortality rates¹ for Supergroups, England and Wales,² 1970–72, 1979–2006

Supergroups	Rate per 1,000 live births						
	Cities and Services	London Suburbs	London Centre	London Cosmopolitan	Prospering UK	Coastal and Countryside	Mining and Manufacturing
1970	19.6	16.5	18.9	20.9	15.4	15.0	19.5
1971	19.6	16.1	19.2	20.6	15.1	14.4	19.1
1972	19.4	15.7	19.0	20.6	14.9	13.8	18.6
1973–78	..	..	..	..	..	..	..
1979	13.8	13.3	12.7	13.6	11.6	9.5	12.7
1980	13.0	12.2	11.9	12.9	11.0	9.9	12.3
1981	12.4	11.0	11.6	12.2	10.5	9.7	11.5
1982	11.5	9.9	11.0	10.9	9.6	10.2	10.7
1983	11.0	9.4	10.5	10.7	9.1	9.8	10.0
1984	10.6	9.2	9.3	10.5	8.6	9.4	9.6
1985	10.6	9.1	8.4	10.6	8.4	9.0	9.3
1986	10.4	9.2	8.8	10.7	8.4	8.8	9.1
1987	10.1	9.2	8.9	10.6	8.3	8.7	9.0
1988	9.5	9.0	9.4	10.2	8.0	8.1	8.7
1989	9.2	8.5	8.9	9.3	7.5	7.7	8.5
1990	8.5	7.6	8.3	8.7	6.6	6.8	7.9
1991	8.0	7.0	7.5	8.3	6.0	6.3	7.2
1992	7.5	6.3	6.9	8.2	5.5	5.6	6.7
1993	7.2	5.9	6.7	8.2	5.4	5.6	6.4
1994	7.0	6.0	6.1	8.0	5.2	5.6	6.5
1995	6.8	6.1	5.6	7.9	5.2	5.7	6.4
1996	6.8	6.1	5.4	7.6	5.0	5.4	6.3
1997	6.8	5.9	5.3	7.7	4.9	5.2	6.1
1998	6.7	5.9	5.8	7.3	4.7	4.9	5.9
1999	6.7	5.9	5.3	7.3	4.6	4.6	6.0
2000	6.7	5.8	5.4	7.4	4.4	4.4	5.7
2001	6.8	5.6	4.8	7.6	4.4	4.2	5.2
2002	6.7	5.4	4.9	7.5	4.3	4.4	5.0
2003	6.4	5.2	4.6	6.9	4.3	4.3	5.1
2004	6.2	5.5	4.6	6.1	4.2	4.4	5.1
2005	6.0	5.5	4.3	5.8	4.0	4.6	5.2
2006	5.9	5.6	4.2	5.7	4.0	4.7	5.2

1 Rates are based on rolling averages of annual data for live births and infant deaths (see Methods section).

2 Excludes non-residents of England and Wales.

.. Not available

Table 3

Infant mortality rates: Townsend deprivation quintiles, England and Wales, 1970–72 to 2004–06

Deprivation quintile	Rate per 1,000 live births				
	1970–72	1980–82	1990–92	2000–02	2004–06
Q1: Least deprived	14.5	10.0	5.7	3.5	3.5
Q2	15.8	10.5	6.0	4.4	4.1
Q3	17.2	11.1	6.6	5.0	4.9
Q4	19.3	11.9	7.5	6.1	5.7
Q5: Most deprived	20.4	12.6	9.0	7.7	6.5
England and Wales	17.4	11.2	7.0	5.3	5.0

Wards which became relatively more deprived had lower infant mortality rates than the national average in 1971, but higher rates by 2005.

Ward level deprivation within Government Office Regions

It was noted above that levels of infant mortality vary between GORs and also by ward level of deprivation. To investigate whether the relationship

with ward deprivation is evident within regions, results are presented here for East of England and for the West Midlands – regions which generally have relatively low and high infant mortality rates respectively. Note that the deprivation quintiles are relative to the national distribution so the number of live births in each quintile within GORs may not be equal.

Figure 8 shows that in both East of England and the West Midlands there was evidence of increasing infant mortality with increasing deprivation, as noted above for all wards in England and Wales. The differences in rates between adjacent deprivation quintiles in each year and GOR were not necessarily significant (given small numbers), but the overall pattern is clear and the differences between quintiles 1 and 5 were significant. In both the East of England and the West Midlands, the infant mortality rates progressively decreased across the deprivation gradient from one census time point to the next. Reflecting the generally advantageous infant mortality position in East of England, levels of infant mortality were consistently lower compared with the West Midlands. Nevertheless, even in East of England inequalities between the most and least deprived areas were evident. For example, in 2001, the ratio between rates in the most and least deprived wards was 2.73, a slightly greater disparity than in West Midlands where the rate ratio was significantly lower (2.50), even though the rates in the East of England were lower. Similar situations exist within all the other GORs, with levels of infant mortality increasing with deprivation but reducing in each deprivation quintile overall over time.

Ward level deprivation within local authority types

Similarly, to identify whether the relationship between infant mortality and deprivation existed within local authority area types, rates were calculated for the Prospering UK and Cities and Services Supergroups – area types which were shown above to experience relatively low and high infant mortality respectively. The deprivation quintiles are relative to the national distribution so the number of live births in each quintile within Supergroups may not be equal.

Figure 9 shows that the relationship between infant mortality and deprivation observed for all wards also exists within area type. Over time, rates declined in all deprivation quintiles by area type with rates in Prospering UK consistently below those in City and Services, reflecting the overall differences between the area types. Despite the classification label of Prospering UK, local authorities of this type still contain relatively deprived areas and inequalities exist between the most and least deprived areas. In Prospering UK areas, rate ratios increased significantly from the situation in the early 1970s when rates in quintile 5 were 1.34 times those in quintile 1, to 2.11 around 2001, but reduced a little by 2004–06 to 1.99. A similar pattern exists for wards in Cities and Services areas in which the quintile 5 to quintile 1 inequalities increased significantly from 1.28 around 1971 to 2.29 at the start of the 21st century but levelled off to 2.26 by 2004–06. In other area types, the relationship with deprivation described here is also found with similar reductions over time.

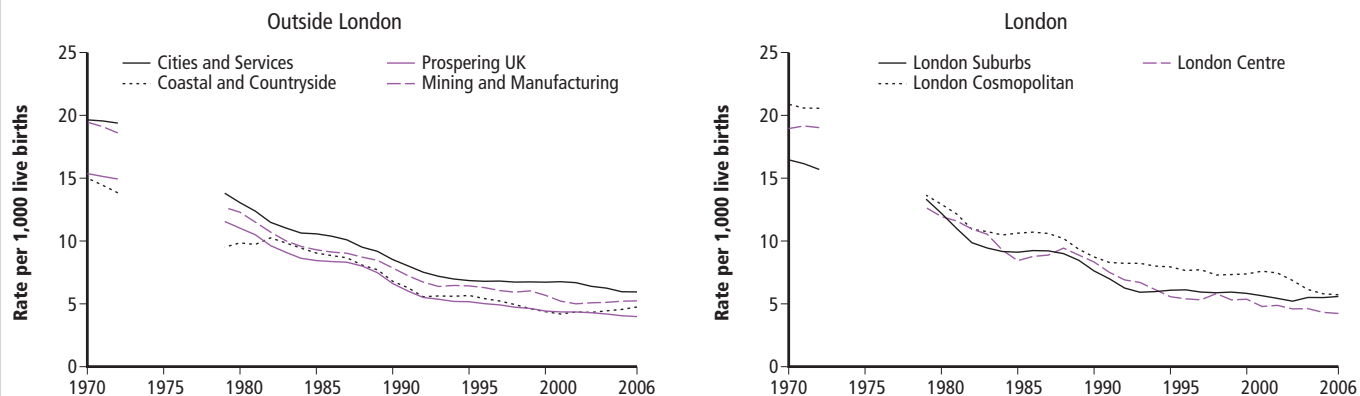
Discussion

Examining trends in population health for subnational geographies can be severely hampered when data are released over time in different formats, especially when the areas for which data are disseminated change. To investigate trends in infant mortality, an annual time-series of vital statistics data from the early 1970s to 2006 was assembled, harmonised to the ward geography used for the 2001 Census. Unfortunately, the subnational time-series was incomplete between 1973 and 1978.

At national level in England and Wales, infant mortality rates fell rapidly from the early 1970s and into the 1980s. While rates then continued to fall, the reduction slowed. Nevertheless, in 2006 the national rate of infant mortality was at an all time low of 5.0 deaths to infants aged under one year per 1,000 live births. Broadly, this pattern was also seen when the ward level data were aggregated into Government Office Regions, local

Figure 4 Infant mortality rates¹ by Supergroups, 1970–72, 1979–2006

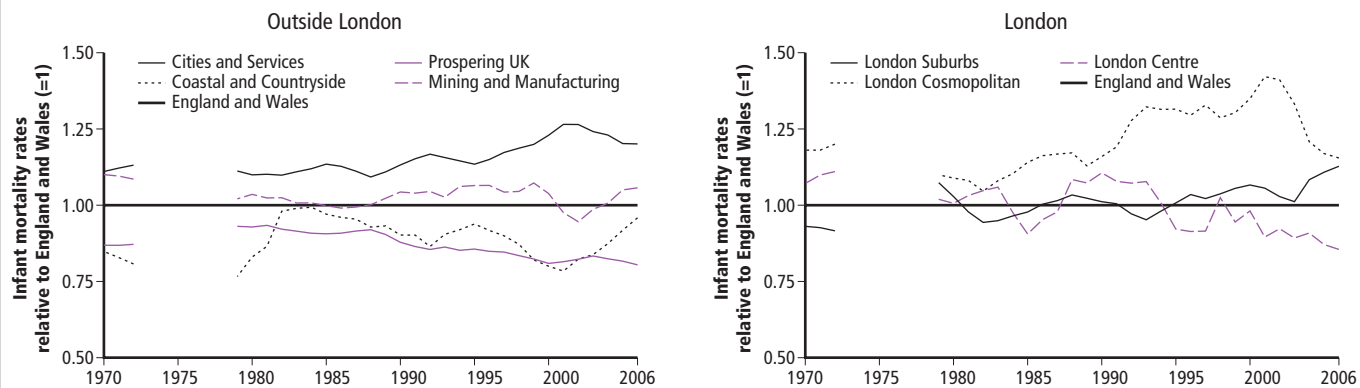
England and Wales²



1 Rates are based on rolling averages of annual data for live births and infant deaths.
2 Excludes non-residents of England and Wales.

Figure 5 Infant mortality rates¹ for Supergroups, relative to England and Wales,² 1970–72, 1979–2006

England and Wales²



1 Rates are based on rolling averages of annual data for live births and infant deaths.
2 Excludes non-residents of England and Wales.

Figure 6 Infant mortality rates by deprivation quintile, 1970–72 to 2004–06

England and Wales

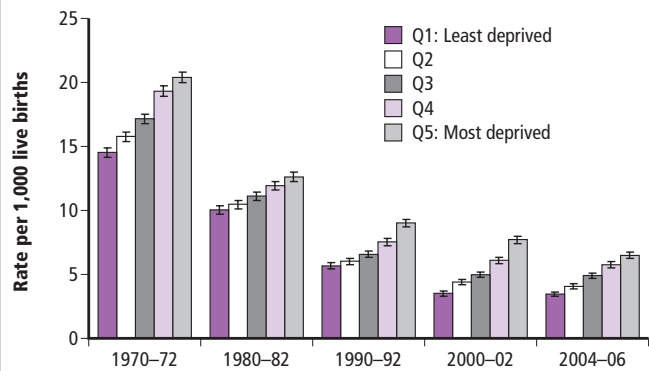


Figure 7 Rate ratios of infant mortality rates: most to least deprived areas, England and Wales, 1970–72 to 2004–06

England and Wales

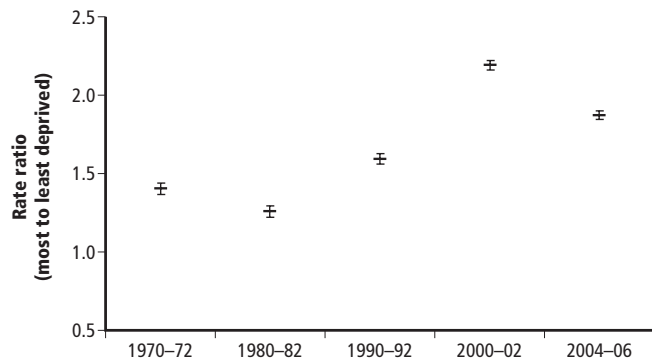


Figure 8

Infant mortality rates by deprivation quintile and Government Office Region, 1970–72 to 2004–06

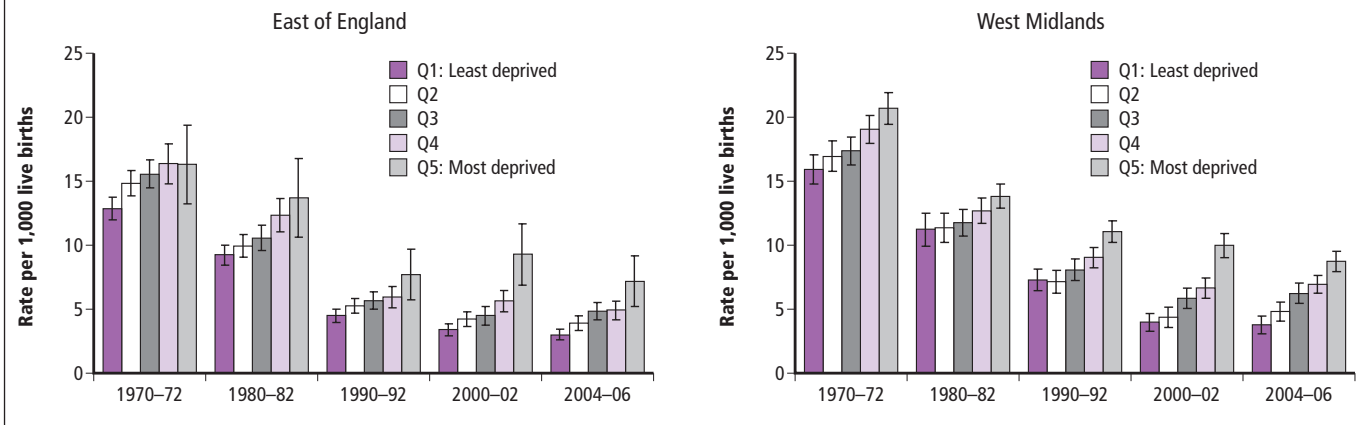
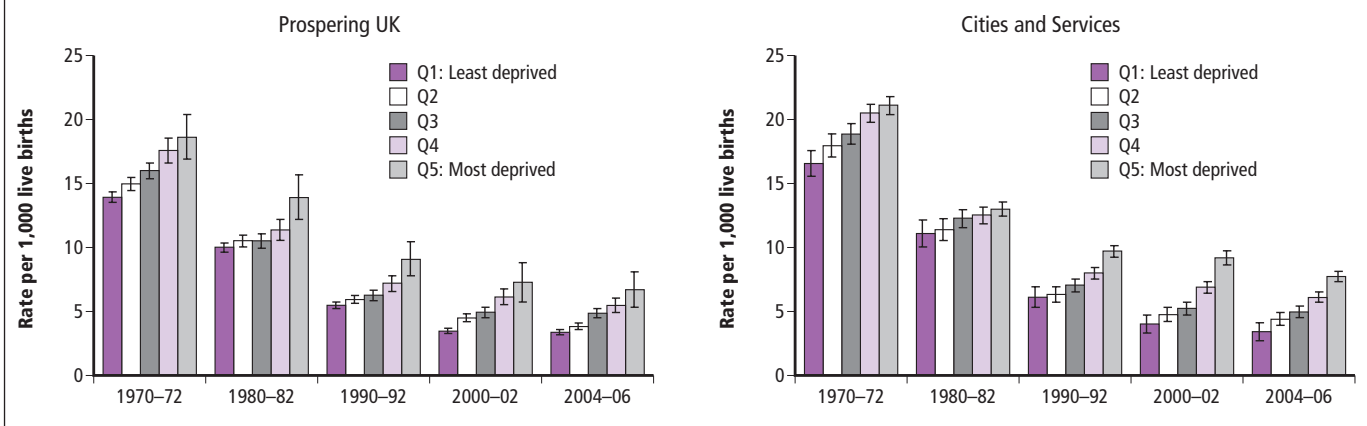


Figure 9

Infant mortality rates by deprivation quintile and Supergroup, 1970–72 to 2004–06



authority area types and quintiles of deprivation. However, while all areas experienced a decrease in levels of infant mortality, different locations and area types did not see the same pace of reduction. For example, relative to the national level, infant mortality in Yorkshire and The Humber, the North West and the West Midlands or the area types Cities and Services and London Cosmopolitan remained high. Southern regions and non-urban area types had relatively low infant mortality rates. Disparities between both regions and area types reduced a little between 2001 and more recent data for 2004–06, but there was more difference in infant mortality by local authority type than by region. Although the geographies and area types are defined differently, the regional north-south differentials and urban-rural area type variations are consistent with infant mortality rates previously reported for the 1970s, 1980s,⁵¹ and 1990s.²²

Between the early 1970s and 2006 levels of infant mortality reduced for all quintiles of deprivation over time but the relationship between infant mortality and deprivation was essentially consistent with more deprived areas having relatively high rates compared to the least deprived areas. This relationship holds for deprivation quintiles within regions and across local authority area types. What is particularly telling is that deprived wards had relatively poor infant mortality rates even within larger areas with apparently advantageous rates. Similarly, the least deprived wards within regions and area types with relatively poor infant mortality experienced lower rates. Generally, the infant mortality/deprivation gradient existed across all areas, but at a level tempered up or down in relation to the larger area geography. These infant mortality-deprivation relationships are in

line with previous studies^{28,29,30,31} especially that this relationship persists within regions.²² At national level, recent infant mortality rates are at a similar level to the Netherlands (4.7 per 1,000 live births), Canada (4.8), New Zealand (5.0) and Italy (5.0). At 3.5 per 1,000 live births, the infant mortality rate in the least deprived areas of England and Wales (wards in quintile 1 using the Townsend index) are lower than national rates in France (4.2) and Germany (4.3) but not as low as Norway (3.3), Japan (3.2) and Iceland (2.9). The most deprived areas in England and Wales (wards in quintile 5) have rates (6.5) similar to Croatia (6.4) and Malta (6.5).⁵² Note that these international comparisons must be interpreted with care due to potential differences in data quality, definitions and time periods.

Researchers and policy makers have tended to focus on the social and biological factors which are associated with high infant mortality.^{10,12,13,14,15,53,54} The research reported here has shown that small area deprivation is more strongly related to levels of infant mortality than larger area geography and that a reduction in disparities between the most and least deprived areas between the early 1970s and 1980s was paralleled by rapid reductions in infant mortality. When ward level inequalities increased during the 1990s, the reductions in rates for regions and local authority types slowed down and the relative differences increased. From 2001 to 2004–06, when inequalities in infant mortality by deprivation narrowed again, there was a similar reduction in rate differences between larger geographic regions. It should be acknowledged that the most recent rates have been related to deprivation calculated for 2001 and that any changes in the geography of deprivation in the intervening period are not accounted for.

Higher rates of infant mortality in more deprived communities may be the result of many factors.²² For example, more deprived areas tend to have much higher rates of teenage pregnancies, babies born with a low birthweight and people of low social class (and therefore on low income); all of which are associated with higher risk of infant mortality. For the general population, during the latter part of the 20th century, health has become more strongly aligned with deprivation than in the mid-century, due in part to both health-selective migration and to long-term immobility in deprived places.^{55,56}

On both conceptual and technical levels, the choice of which deprivation index and indicator variables to use has been subject to wide debate.^{47,57,58} However, it is worth noting that the various commonly-used deprivation measures tend to correlate closely^{59,60} and that a strong relationship between deprivation and health is consistently found, however measured. The reasons for this relationship existing and persisting are complex but include that health and health-related behaviours tend to be poorer in more disadvantaged areas and that the range of resources and facilities which might promote health are less common in poorer areas.⁶¹

Deaths during the first year of life tend to be concentrated in the first week (early neonatal) or month (neonatal) and, during this period, causes of infant deaths tend to be different from those occurring later. The infant mortality rate can therefore be broken down into the early and late neonatal rates and the postneonatal mortality rate (deaths after 28 days). During the late 20th century the declines in neonatal mortality rates were relatively steady at national level but the decline in postneonatal rates was much smaller. As noted before, social class differences in infant mortality rates have been found to be wider in the postneonatal than the neonatal period.¹⁵ Given changes in the major causes of infant deaths over time, an examination of the association between socio-economic and health care factors (such as the fall in sudden infant deaths) may be informative.

Previous research has found that when small areas become more or less deprived over time the health experience of the population responds accordingly.⁴⁹ Although infant mortality reduced even in areas where relative deprivation worsened, the biggest reductions were found for those areas where deprivation eased. Even in relatively advantaged regions and area types, to complement policy aimed at addressing social inequalities, resources targeted at relatively deprived areas may help reduce infant mortality.

Key findings

- Infant mortality rates for England and Wales fell rapidly from the early 1970s and into the 1980s and then slowed to 2006
- Infant mortality fell in subnational areas, but this was not evenly distributed. The Government Office Regions of Yorkshire and The Humber, the North West and the West Midlands and the ONS local authority types Cities and Services and London Cosmopolitan experienced relatively large absolute reductions in infant mortality but their rates remained high compared with the national average
- Within all Government Office Regions and local authority types a strong relationship existed between ward level deprivation and infant mortality rates, with highest rates in the most deprived areas
- Infant mortality reduced over time, even in the most deprived areas, with a narrowing of absolute differences in rates between areas
- Wards which became relatively less deprived experienced a reduction in infant mortality rates greater than that for national rates in England and Wales

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References

- 1 Blaxter M (1981) *The health of children: a review of research on the place of health in cycles of disadvantage*, Heinemann Educational: London.
- 2 Botting B (1997) 'Mortality in childhood', in Drever F and Whitehead M (eds), *Health Inequalities: Decennial Supplement*, Series DS no.15, The Stationery Office: London.
- 3 Garrett E, Galley C, Shelton N and Woods R (eds) (2006), *Infant Mortality: A Continuing Social Problem*, Ashgate: Aldershot.
- 4 Department of Health (2007) 'Review of the Health Inequalities Infant Mortality PSA Target' accessed 22 October 2008, available at: www.dh.gov.uk/en/Publicationsandstatistics/Publications/PublicationsPolicyAndGuidance/DH_065544
- 5 Freemantle J and Read A (2008) 'Preventing child deaths', *British Medical Journal* **336**, 1083–84.
- 6 Storeygard A, Balk D, Levy M and Deane G (2008) 'The global distribution of infant mortality: a subnational spatial view', *Population, Space and Place* **14**, 209–29.
- 7 Woodroffe C, Glickman M, Barker M and Power C (1993) *Children, Teenagers and Health: the Key Data*, Open University Press: Milton, Buckingham.
- 8 Bongaarts J (2006) 'How long will we live?', *Population and Development Review* **32**, 605–28.
- 9 Riley J C (2005) 'Estimates of regional and global life expectancy, 1800–2001', *Population and Development Review* **31**, 537–43.
- 10 Hobcraft J, McDonald J and Rutstein S O (1984) 'Socioeconomic factors in infant and child mortality: a cross-national perspective', *Population Studies* **38**, 193–223.
- 11 Office for National Statistics (2005) *Mortality statistics: Childhood, infant and perinatal. Review of the Registrar General on deaths in England and Wales*, Series DH3 no.38, Her Majesty's Stationery Office: London. Available on the Office for National Statistics website at: www.statistics.gov.uk/statbase/Product.asp?vlnk=6305
- 12 Cooper N (2001) 'Analysis of infant mortality by risk factors and by cause of death, in England and Wales', in Griffiths C and Fitzpatrick J (eds), *Geographic variations in health. Decennial supplement*. Series DS no.16, The Stationery Office: London.
- 13 Schuman J (1998) 'Childhood, infant and perinatal mortality, 1996: social and biological factors in deaths of children aged under 3', *Population Trends* **92**, 5–14. Available on the Office for National Statistics website at: www.statistics.gov.uk/statbase/Product.asp?vlnk=6303
- 14 Spencer N J, Logan S and Gill L (1999) 'Trends and social patterning of birthweight in Sheffield, 1985–94', *Archives of Disease in Childhood Fetal & Neonatal Edition* **81**, F138–40.
- 15 Maher J and Macfarlane A (2004) 'Inequalities in infant mortality: trends by social class, registration status, mother's age and birthweight, England and Wales, 1976–2000', *Health Statistics Quarterly* **24**, 14–22. Available on the Office for National Statistics website at: www.statistics.gov.uk/statbase/Product.asp?vlnk=6725
- 16 Hargreaves S (2007) 'Gaps between UK social groups in infant mortality are widening', *British Medical Journal* **334**, 335.
- 17 Marmot M G (2003) 'Understanding Social Inequalities in Health', *Perspectives in Biology and Medicine* **46(3)**, S9–S23.
- 18 Botting B and Macfarlane A (1990) 'Geographic variation in infant mortality in relation to birthweight 1983–85 in Britton M (ed), *Mortality and Geography*, Series DS no.9, Her Majesty's Stationery Office: London.

- 19 Office for Population Censuses and Surveys (1978) *Occupational mortality. The Registrar General Decennial Supplement for England and Wales 1970–1972*, Series DS no.1, Her Majesty's Stationery Office: London.
- 20 Lee C (1991) 'Regional inequalities in infant mortality in Britain, 1861–1971: patterns and hypotheses', *Population Studies* **45**, 55–65.
- 21 Marsh D C (1965) *The Changing Social Structure of England and Wales 1871–1961*, Routledge and Kegan Paul: London.
- 22 Fitzpatrick J and Cooper N (2001) 'Patterns and trends in stillbirths and infant mortality', in Griffiths C and Fitzpatrick J (eds), *Geographic Variations in Health*, Series DS no.16, The Stationery Office: London, 161–90.
- 23 Guildea Z E S, Fone D L, Dunstan F D and Cartlidge P H T (2005) 'Differences in risk of mortality under 1 year of age between rural and urban areas: an ecological study', *Public Health* **119**, 442–47.
- 24 Haines M (1995) 'Socio-economic Differentials in Infant and Child Mortality during Mortality Decline: England and Wales 1890–1911', *Population Studies* **49** (2), 297–315.
- 25 Webster C (1985) 'Health, welfare and unemployment during the depression', *Past and Present* **109**, 204–29.
- 26 Woods R (2003) 'Urban-rural mortality differentials: an unresolved debate', *Population and Development Review* **29**, 29–46.
- 27 Wallace M, Charlton J and Denham C (1995) 'The new OPCS area classifications', *Population Trends* **79**, 15–30.
- 28 Carstairs V (1981) 'Small area analysis and health service research', *Community Medicine* **3**, 131–39.
- 29 Hirst K, Butler N and Dawkins M (1968) 'Infant and Perinatal Mortality in England and Wales', *National Centre for Health Statistics, Vital and Health Statistics* **3**(12).
- 30 Kmietowicz Z (2001) 'Health gap between rich and poor in London widens', *British Medical Journal* **323**, 828.
- 31 Marr T (1978) 'Infant mortality mirrors deprivation', *Health & Social Service Journal*, 750.
- 32 Dibben C, Sigala M and Macfarlane A (2006) 'Area deprivation, individual factors and low birth weight in England: is there evidence of an "area effect"?'', *Journal of Epidemiology and Community Health* **60**, 1053–59.
- 33 Collis D and Hooper J (2008) *Infant deaths in north Kirklees*, Kirklees Primary Care Trust, Huddersfield. Accessed 23 October 2008, available at: www.kirklees.nhs.uk/public-information/publications/infant-deaths-in-north-kirklees/
- 34 Dyer O (2008) 'Neonatal service reorganisation fails to iron out regional variation in death rates', *British Medical Journal* **336**, 1393.
- 35 Evans S (2005) *Mortality in children and young people in the East of England*, Eastern Region Public Health Observatory. Accessed 23 October 2008, available at: www.erpho.org.uk/viewResource.aspx?id=12553
- 36 Dorling D, Rigby J, Wheeler B *et al* (2007) *Poverty, wealth and place in Britain, 1968 to 2005*, Policy Press: Bristol.
- 37 Gregory I N and Ell P S (2005) 'Breaking the boundaries: Integrating 200 years of the Census using GIS', *Journal of the Royal Statistical Society A, Statistics in Society* **168**, 419–37.
- 38 Norman P (2006) 'Sociodemographic spatial change in the UK: data and computational issues and solutions', *GIS Development special issue Maps & Census* **10**(12), 30–34.
- 39 Norman P, Rees P and Boyle P (2003) 'Achieving data compatibility over space and time: creating consistent geographical zones', *International Journal of Population Geography* **9**(5), 365–86.
- 40 Simpson L (2002) 'Geography conversion tables: a framework for conversion of data between geographical units', *International Journal of Population Geography* **8**, 69–82.
- 41 Bates A (2008) 'The development of a postcode best fit methodology for producing population estimates for different geographies', *Population Trends* **133**, 28–34. Available on the Office for National Statistics website at: www.statistics.gov.uk/statbase/Product.asp?vlnk=6303
- 42 Office for National Statistics (2004) *National Statistics 2001 Area Classification*. Available on the Office for National Statistics website at: www.statistics.gov.uk/about/methodology_by_theme/area_classification/default.asp
- 43 Vickers D and Rees P (2006) 'Introducing the Area Classification of Output Areas', *Population Trends* **125**, 15–29. Available on the Office for National Statistics website at: www.statistics.gov.uk/statbase/Product.asp?vlnk=6303
- 44 Townsend P, Phillimore P and Beattie A (1988) *Health and deprivation: inequality and the north*, Croom Helm: London.
- 45 Gordon D (1995) 'Census Based Deprivation Indices: Their Weighting and Validation', *Journal of Epidemiology and Community Health* **49** (Suppl 2), S39–S44.
- 46 Bradford M G, Robson B T and Tye R (1995) 'Constructing an urban deprivation index: a way of meeting the need for flexibility', *Environment and Planning A* **27**, 519–33.
- 47 Senior M L (2002) 'Deprivation indicators', in Rees P, Martin D and Williamson P (eds), *The Census Data System*, John Wiley: Chichester, 123–37.
- 48 Eroğlu S (2007) 'Developing an index of deprivation which integrates objective and subjective dimensions: extending the work of Townsend, Mack and Lansley, and Halleröd', *Social Indicators Research* **80**, 493–510.
- 49 Boyle P, Norman P and Rees P (2004) 'Changing places: do changes in the relative deprivation of areas influence limiting long-term illness and mortality among non-migrant people living in non-deprived households?', *Social Science & Medicine* **58**, 2459–71.
- 50 Bland M (2000) *An introduction to medical statistics*, Oxford University Press: Oxford.
- 51 Coleman D and Salt J (1992) *The British Population: Patterns, Trends and Processes*, Oxford University Press: Oxford.
- 52 United Nations (2007) *World Population Prospects. The 2006 Revision*, Department of Economic and Social Affairs, Population Division, United Nations.
- 53 Shelton N (2006) 'Conclusion: the social dimension to infant well-being', in Garrett E, Galley C, Shelton N and Woods R (eds), *Infant mortality: a Continuing Social Problem*, Ashgate: Aldershot, 249–60.
- 54 Whitehead M and Drever F (1999) 'Narrowing social inequalities in health? Analysis of trends in mortality among babies of lone mothers', *British Medical Journal* **318**, 908–14.
- 55 Norman P, Boyle P and Rees P (2005) 'Selective migration, health and deprivation: a longitudinal analysis', *Social Science & Medicine* **60**(12), 2755–71.
- 56 Brimblecombe N, Dorling D and Shaw M (2000) 'Migration and geographical inequalities in health in Britain', *Social Science & Medicine* **50**, 861–78.
- 57 Mackenzie I F, Nelder R, Maconachie M and Radford G (1998) 'My ward is more deprived than yours', *Journal of Public Health Medicine* **20**, 186–90.
- 58 Davey Smith G, Whitley E, Dorling D and Gunnell D (2001) 'Area based measures of social and economic circumstances: cause specific mortality patterns depend on the choice of index', *Journal of Epidemiology and Community Health* **55**, 149–50.
- 59 Morris R and Carstairs V (1991) 'Which deprivation? A comparison of selected deprivation indexes', *Journal of Public Health Medicine* **13**(4), 318–26.
- 60 Hoare J (2003) 'Comparison of area-based inequality measures and disease morbidity in England, 1994–98', *Health Statistics Quarterly* **18**, 18–24. Available on the Office for National Statistics website at: www.statistics.gov.uk/statbase/Product.asp?vlnk=6725
- 61 Macintyre S, Macdonald L and Ellaway A (2008) 'Do poorer people have poorer access to local resources and facilities? The distribution of local resources by area deprivation in Glasgow, Scotland', *Social Science & Medicine* **67**, 900–14.