Life expectancy: Is the socio-economic gap narrowing?

Longevity Science Panel

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Acknowledgments

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Longevity Science Panel Membership

Dame Karen Dunnell (DCB), Chair of the Longevity Science Panel and formerly National Statistician and Chief Executive of the Office for National Statistics, with experience and understanding of data resources, socio-demographic changes and public policy, is well placed to assess the potential benefits from access to national data by the private sector and the problems that exist in obtaining such access.

Professor Sir Colin Blakemore, Professor of Neuroscience & Philosophy at the University of London, Emeritus Professor at Oxford and former Chief Executive of the Medical Research Council, brings knowledge of the data requirements for medical research.

Professor Steven Haberman, Professor of Actuarial Science at the Cass Business School, is experienced in statistical modelling and mortality research, and has the expertise to consider how to convert research findings into a format for actuarial analysis.

Professor Klim McPherson, a retired public health academic at University of Oxford and Chair of UK Health Forum, is recognised for his work on obesity and the wide ranging detrimental effect this has on the health of the population and particular sub-groups.

Professor Sir John Pattison, formerly Director of Research and Development at the Department of Health in England, is well placed to assess the health services' ability to deliver the changes emerging from health research findings.

Funder: Legal & General.

Life expectancy: is the socio-economic gap narrowing?

Executive Summary

Key messages

- **Differences in life-expectancy between the rich and poor in England have widened between 2001 and 2015.**
    - Sixty-year-old men living in the most advantaged fifth of neighbourhoods could expect to live 4.1 years longer than the most disadvantaged fifth in 2001, increasing to 5.0 years longer in 2015.
    - Sixty-year-old women living in the most advantaged fifth of neighbourhoods could expect to live 3.1 years longer than the most disadvantaged fifth in 2001, increasing to 4.2 years longer in 2015.
- **Death rates have fallen faster for the richer between 2001 and 2015.**
    - Men aged 60-89 years in the most socially advantaged fifth of all men have experienced a 32% fall in the rate of mortality during this period, while the rate has fallen by only 20% for the least affluent fifth.
    - The equivalent figures for women are a 29% fall in death rates for the most affluent fifth and 11% for the least affluent fifth.
    - In 2001, men aged 60 to 89 from the least affluent fifth of the country were 52% more likely to die within a year than the most affluent fifth. By 2015, this figure had climbed to 80%. The equivalent figures for women are 44% in 2001 and 81% in 2015.
- **It's mainly about money.**
    - The Index of Multiple Deprivation takes account of many factors in residential areas including various measures of income, education, crime, health, housing, environment and unemployment. Our analysis shows that income deprivation, as estimated from state benefits and largely associated with unemployment, is the strongest independent predictor of mortality rates in a neighbourhood.

The Longevity Science Panel (LSP) has reviewed mortality trends of people between different socio-economic circumstances and gender in England, concluding that the socio-economic gap in mortality at older ages has persisted and widened between 2001 and 2015. This finding is in agreement with LSP's previous report, which proposed that the powerful forces of socio-economic and behavioural factors that

divide people would lead to a continuing gap in the mortality rates and life expectancy of people in different socio-economic groups. Based on the emerging evidence, the Panel recommends that socio-economic circumstances of the elderly should be considered when forecasting future life expectancy or mortality trends for the purposes of public policy and commercial decisions for the UK's rapidly ageing population.

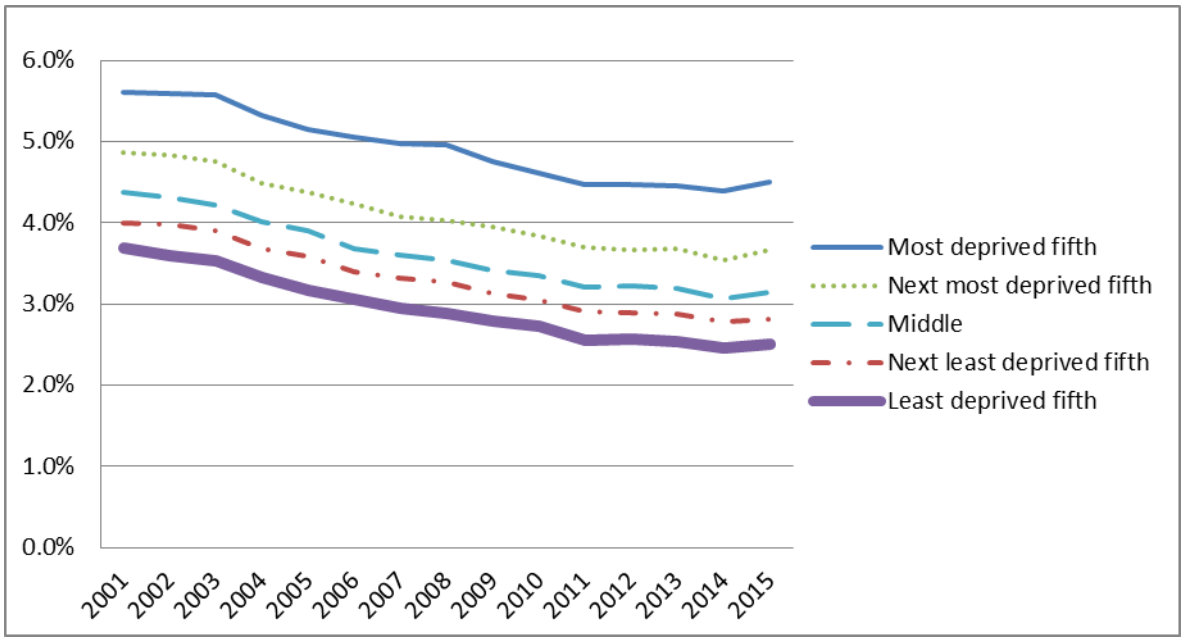

Figure 1 Mortality rates of males age 60-89 in England, standardised to population distribution of European Standard Population 2013.

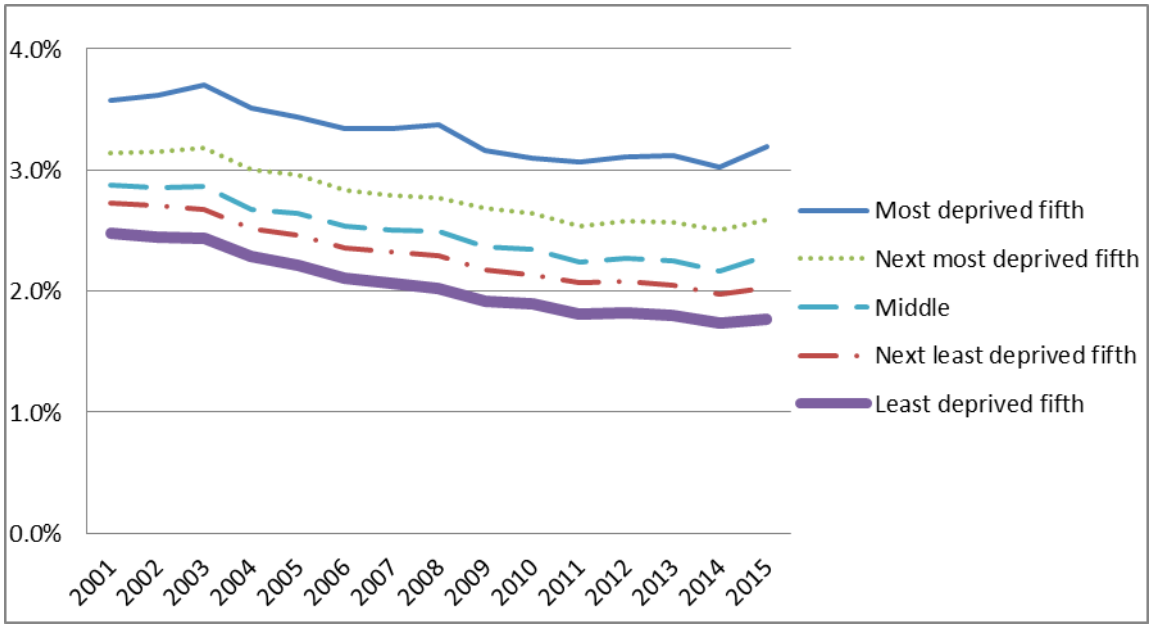

Figure 2 Mortality rates of females age 60-89 in England, standardised to population distribution of European Standard Population 2013.(1)

Widening socio-economic gap in mortality

This report highlights that the relative difference in death rates between the most and least deprived fifth of the population, based on the Index of Multiple Deprivation of where they live, has widened as a proportion of all mortality between 2001 and 2015 (Figure 3 and 4).[1] The average population of the residential areas associated with the Index is about 1,700 people.(2)

- Males aged 60 to 89 years from the most disadvantaged fifth of the country were 52% more likely to die in 2001 than the most advantaged fifth, but the equivalent figure had climbed to 80% in 2015.
- Similarly for females aged 60 to 89 years, the most disadvantaged fifth were 44% more likely to die in 2001 than the most advantaged fifth, but the equivalent figure had risen to 81% in 2015.
- Consequently, the gap in life expectancy has grown. Sixty-year-old men living in the most advantaged fifth of neighbourhoods could expect to live 4.1 years longer than the most disadvantaged fifth in 2001, increasing to 5.0 years

[1] Mortality rates for 5-year age bands were calculated for each socio-economic circumstances quintile for each year and gender. They were then weighted by population profile in the European Standard Population 2013.

longer in 2015. Sixty-year-old women living in the most advantaged fifth of neighbourhoods could expect to live 3.1 years longer than the most disadvantaged fifth in 2001, increasing to 4.2 years longer in 2015.

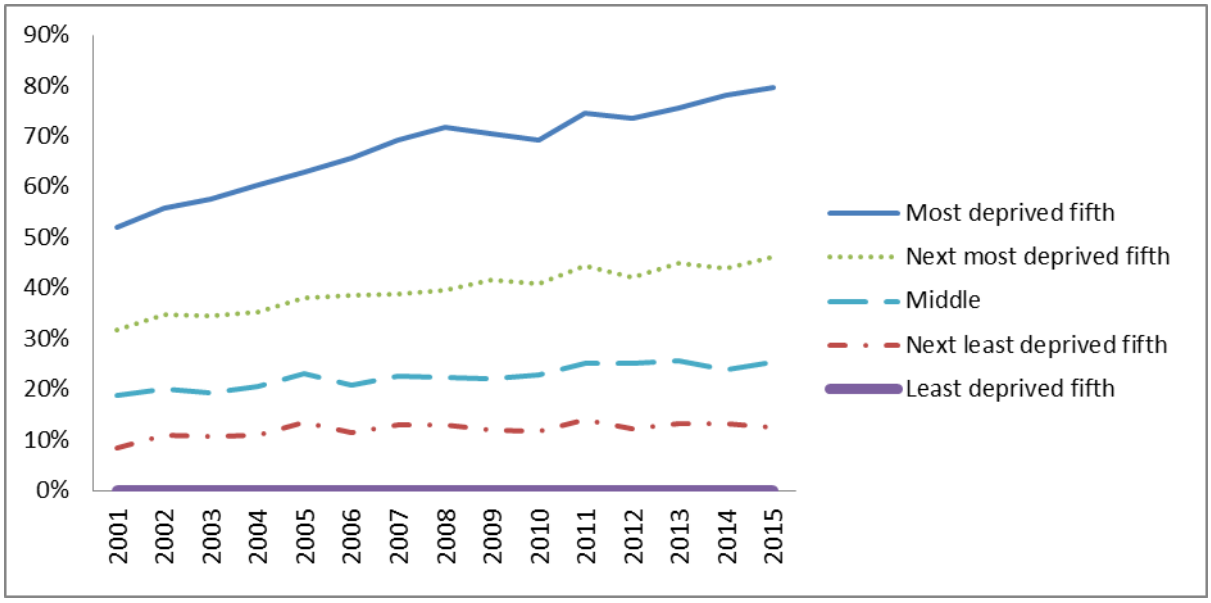

Figure 3 Percentage difference in death rates relative to the least deprived fifth Males aged 60-89 in England.

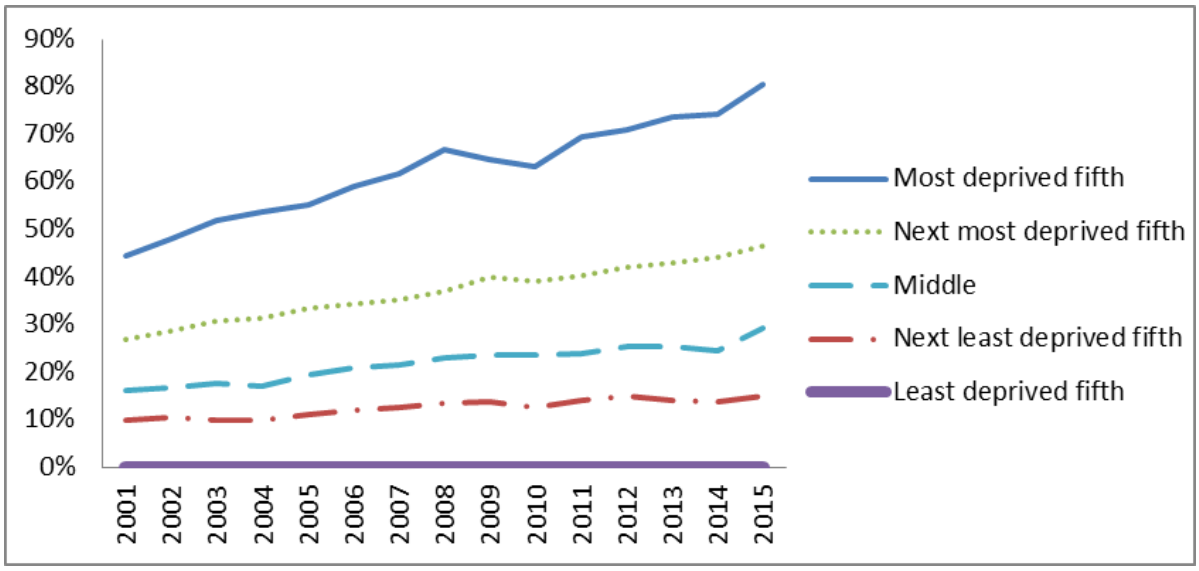

Figure 4 Percentage difference in death rates relative to the least deprived fifth Females age 60-89 in England. [2]

[2] Ratio of age standardised mortality rates of the four least advantaged quintiles to the most advantaged fifth quintile in each calendar year. Figure 3 numbers are calculated from age standardised mortality rates in Figure 1, and Figure 4 from Figure 2.

Death rates have fallen more for the most advantaged

Mortality rates have fallen since 2001 for all groups. However, the most advantaged fifth have experienced a greater fall in death rates than their more deprived counterparts (Figure 5 and 6).[3] Pension plans, government bodies and insurers tend to set assumptions for future mortality trends using data of the total population, giving results for the average population. However, most pension commitments are associated with the more advantaged because they have larger pensions and tend to live longer. So, forecasts for longevity should take account of the differences between people in different socio-economic circumstances.

There has been a slow-down in the fall in mortality rates for all groups since 2011, potentially linked to austerity measures on the National Health Service and social services in response to the 2008 economic crisis. This implies that people in all socio-economic circumstances have been affected by austerity, including the most advantaged fifth. The LSP recommends more research into establishing the cause of the slow-down.

However, we expect the more self-sufficient and the more advantaged would be less likely to be affected by cut-backs on social services in the future. We expect the advantaged-disadvantaged mortality gap to persist, if not widen, if austerity continues.

[3] Ratio of age standardised mortality rate of various calendar years to that in 2001 within each socio-economic circumstances quintile. Figure 5 numbers are calculated from age standardised mortality rates in Figure 1, and Figure 6 from Figure 2.

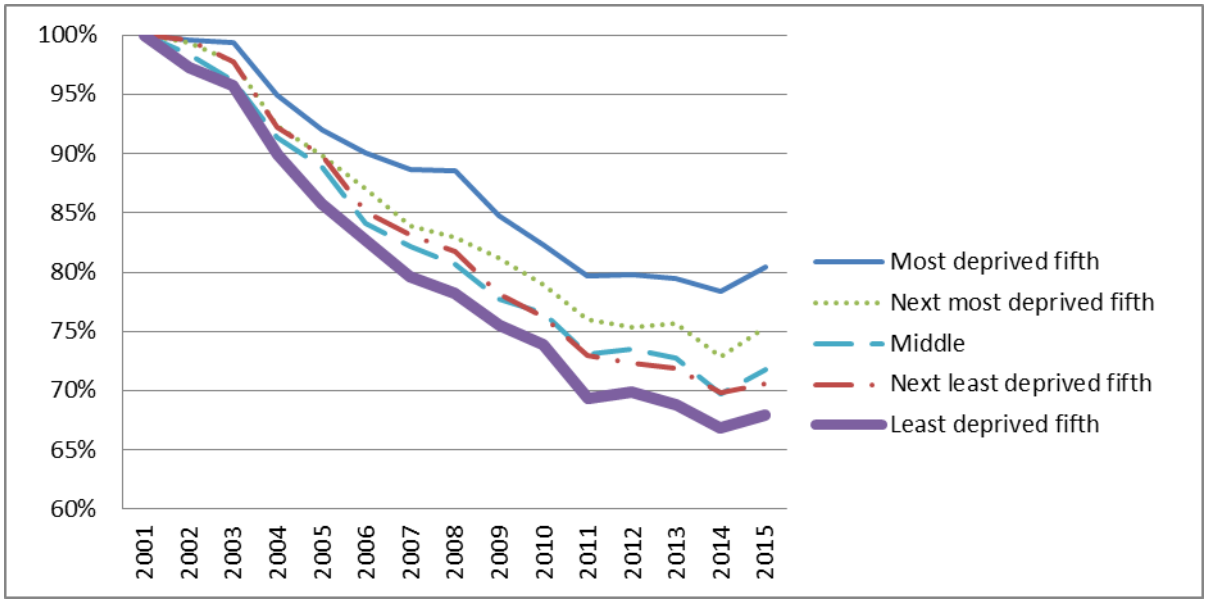

Figure 5 Progression of male death rates for those aged 60-89 of each socio-economic circumstances quintile in England, relative to their levels in 2001. For each quintile, the value of mortality is given as a percentage of the mortality rate in 2001.

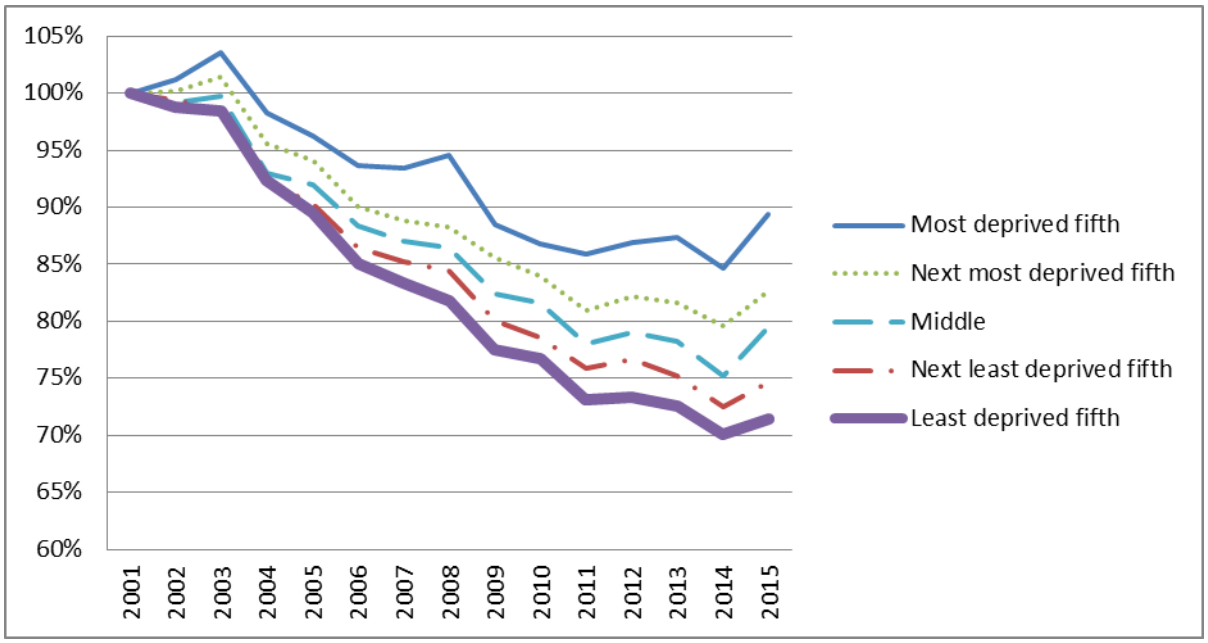

Figure 6 Progression of female death rates for those aged 60-89 of each socio-economic circumstances quintile in England, relative to their levels in 2001. For each quintile, the value of mortality is given as a percentage of the mortality rate in 2001.

It's mainly about money

The Index of Multiple Deprivation takes account of many factors in residential areas including various measures of income, education, crime, health, housing, environment and unemployment. We have studied how each of the factors is linked to mortality and how they interact with each other to influence mortality. Our analysis shows that income levels of their neighbourhood, as estimated from state benefits and largely associated with unemployment, have the most powerful influence over their mortality rates.

We recommend that any public policies that seek to reduce mortality inequality should consider income deprivation.

Introduction

How long we can all expect to live has a major impact not only on ourselves but also on financial institutions and national and local government budgets, as it determines the expenditure that will be needed for pensions, health and social care. The Longevity Science Panel recognised the importance of this issue in its first two reports, *Life expectancy. Past and future variations by socio-economic group in England and Wales*, published in January 2012,(3) and *Life expectancy: past and future variations by gender in England & Wales*, published in January 2013.(4)

At the time that our previous reports were written, around 5 years ago, life expectancy had been increasing for many years in England and Wales, with an annual increase of 2.1% for the 25 years up to 2004, compared with an annual rate of improvement of 0.5% for the 125 years before that. However, the improvements had not been spread equally across the population. The gap between life expectancy between genders at age 65 grew at the start of the 20th century, when the increases in women's life expectancy exceeded the increase in men, but the gap started to narrow again from the 1990s. [*Life expectancy. Past and future variations by socio-economic group in England and Wales*, Figure 2]

There was also a difference in longevity benefit across different socio-economic groups. Not only was life expectancy greater in people in higher socio-economic groups than lower, the *rate* of mortality improvement in men was also greatest in the higher social classes I, II and IIIN than in classes IIIM, IV or V at all ages under 85 years, meaning that the gap was widening. The pattern in women showed less of an influence of socio-economic class, but increases in life expectancy were generally also greater in higher than lower classes at all ages. [*Life expectancy. Past and future variations by socio-economic group in England and Wales*, Figures 8 and 9].

There are now suggestions that the trend of increasing life expectancy may be levelling out. The Continuous Mortality Investigation (CMI) Mortality Projections Model has found that the rate at which mortality is improving has been slower since 2011 than in previous years. As a consequence, the 2016 CMI model reduced life expectancy for a 65 year-old man by 1.3% compared with its 2015 version, a fall of nearly 4 months, and reduced that of a 65 year-old woman by 2%, a fall of nearly 6 months.(5)

If the overall improvements in life expectancy are now reaching a plateau, what does this mean for inequalities in life expectancy across the genders or socio-economic group? A 2015 bulletin from the Office for National Statistics found that the gap between life expectancy between men and women was narrowing, with 65-year-old women living 3.8 years longer than 65-year-old men in 1991 to 1993, but only 2.4 years longer in 2012 to 2014. (6) However, the trend in terms of geographical inequalities is less clear.

A King's Fund report '*Inequalities in life expectancy. Changes over time and implications for policy'* found that the social gradient in life expectancy improved between 1999-2003 and 2006-2010, showing that income-related inequalities in life expectancy had improved between these two periods.(7) The report updated an analysis of life expectancy against neighbourhood income deprivation percentiles from the Marmot report of 2010.(8) A key visualisation used is the 'Marmot Curve'. This is a plot of life expectancy at birth (y-axis) against the percentile of the IMD score for neighbourhoods (Figure 7).

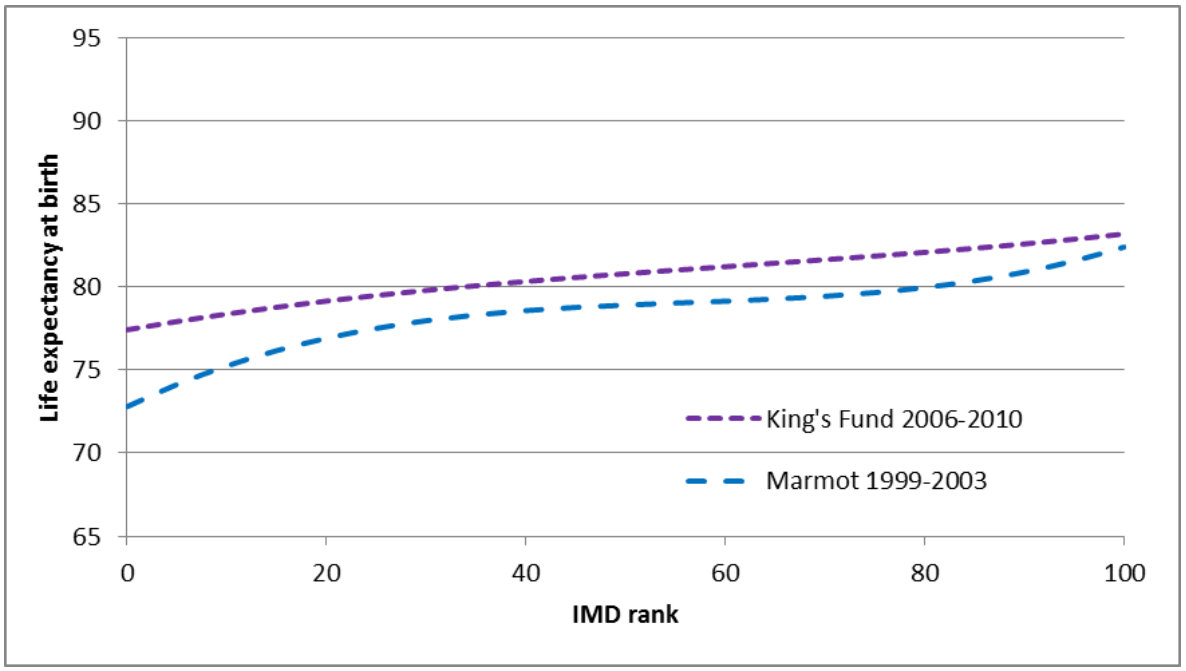

Figure 7 Marmot curves comparing the original analysis in the 2010 Marmot Review and the King's Fund update.

The King's Fund analysis found that the curve had both shifted upwards and had flattened in 2006-2010 compared with the original data from 1999-2003.(8) Not only had life expectancy increased, the gap in life expectancy between the bottom and top 10% of deprivation had decreased from 6.9 years in 1999-2003 to 4.4 years in

2006-2010. However, employment, housing and older people's deprivation all contributed to health inequalities, and austerity could be expected to have an impact on inequalities.

The 2015 Office for National Statistics bulletin also found that regional differences in life expectancy at birth had reduced over the past two decades in males and females.(6) However, the report found that the gap in life expectancy at age 65 had widened between adults in England compared with those in Wales. The difference in life expectancy at age 65 in 2012-14 between the local areas of England and Wales with highest longevity compared with the local areas with the lowest longevity was similar in both genders, at 5.7 years in men and 5.8 years in women. This suggests that where a 65-year-old lives in England and Wales has double the impact on how much longer they might be expected to live than does their gender.

In this report, we aim to address the question of what is happening to inequalities in life expectancy in older adults in England by conducting a detailed analysis of the most up-to-date available data on mortality rates at age 65 across England. We have analysed the mortality data available for each Lower Super Output Area (LSOA) to see how life expectancy varies according to Index of Multiple Deprivation (IMD 2015) scores for each LSOA. We have compared the results with data from previous years to explore how the trend might be changing.

Methods

This analysis is based on data from the Office for National Statistics for death counts in England by gender, single year of age between 0 and 89 years, then all aged 90 and older, and by single calendar year between 2001 and 2015; mid-year population estimates for the same categories; and Index of Multiple Deprivation (IMD 2015) scores by Lower Super Output Area (LSOA).

The IMD 2015 combines information from seven domains to give an aggregated relative measure of deprivation.(9) The seven domains are officially described as follows:

Income Deprivation Domain. The Income Deprivation Domain measures the proportion of the population experiencing deprivation relating to low income. The definition of low income used includes both those people that are out of work, and those who are in work but have low earnings (and who satisfy the respective means tests).

Employment Deprivation Domain. The Employment Deprivation Domain measures the proportion of the working age population in an area involuntarily excluded from the labour market. This includes people who would like to work but are unable to do so due to unemployment, sickness or disability, or caring responsibilities.

Education, Skills and Training Deprivation Domain. The Education, Skills and Training Deprivation Domain measures the lack of attainment and skills in the local population. The indicators fall into two sub-domains: one relating to children and young people and one relating to adult skills.

Health Deprivation and Disability Domain. The Health Deprivation and Disability Domain measures the risk of premature death and the impairment of quality of life through poor physical or mental health. The domain measures morbidity, disability and premature mortality but not aspects of behaviour or environment that may be predictive of future health deprivation.

Crime Domain. The Crime Domain measures the risk of personal and material victimisation at local level.

Barriers to Housing and Services Domain. The Barriers to Housing and Services Domain measures the physical and financial accessibility of housing and local

services. The indicators fall into two sub-domains: 'geographical barriers', which relate to the physical proximity of local services, and 'wider barriers', which includes issues relating to access to housing such as affordability and homelessness.

Living Environment Deprivation Domain. The Living Environment Deprivation Domain measures the quality of the local environment. The indicators fall into two sub-domains. The 'indoors' living environment measures the quality of housing; while the 'outdoors' living environment contains measures of air quality and road traffic accidents.

Mapping mortality rates to deprivation quintiles

The tables of deaths and mid-year population estimates were sorted by the 2015 IMD scoring and the LSOAs falling into to each of the five IMD quintiles were identified. The five quintiles ranged from 1 being the least deprived to 5 being most deprived.

Death counts and mid-year population estimates for the five IMD quintiles were calculated by summing the death counts and mid-year population estimates for each single year of age and calendar year. The category of 90+ was dropped as it is not possible to know the indicative bin size for this category, leaving the ages 0-89 years in the analysis.

The central mortality rate was calculated by dividing the death counts for each IMD quintile by the population in each quintile by age and gender. The central mortality for the data set as a whole was calculated by age and gender.

Smoothed mortality rates were calculated using two-dimensional penalised tensor splines with single year of age and calendar year as the 'x' and 'z' axes, and the unsmoothed log central mortality rates as the y-axis. The 'mgcv' package in R was used with tensor psplines and a cubic spline basis, four knot points across the 15 calendar years and 25 knot points across the ages '0' to '89'.

Calculation of a 'difference ratio' to identify trends

In order to examine any trend in inequality in mortality rates between SEC groups, we generated a metric we have called the 'difference ratio'. The mortality difference ratio is calculated as the central mortality rates in the 5th quintile minus that of the 1st quintile, divided by the overall average rate for that age and gender. This gives a

measure of the scale of the difference in mortality as a percentage of all mortality. A similar metric is calculated for life expectancy.

In young people, the difference in mortality between IMD quintiles is relatively large, and the average mortality is relatively low. This means that in younger people, the inequality between IMD quintiles is a more significant driver of mortality in disadvantaged people than it is in the elderly, where the difference in mortality between IMD quintiles is relatively small, and the average mortality is relatively high. This is reflected in the scale of the difference ratio.

In order to examine trends in the difference ratio for a particular age, another metric referred to as the 'mortality difference ratio relative to 2001' was calculated. This standardises the difference ratio to the value in the calendar year 2001, which was the earliest year for which we had comparable data for this analysis. This makes it easier to observe the relative trends in inequality for a given age, regardless of scale.

Regression analysis of IMD domains

The aim of the multiple linear regression was to gain insight into how the various components of the Index of Multiple Deprivation (IMD) relate to mortality and hence longevity. Initial analysis revealed that using the log of the standardised mortality ratio (ln(SMR)) as the dependent variable provided a better fit than using the untransformed SMR.

The average age in the LSOA was included as an independent variable as it varies considerably across LSOAs and may not be sufficiently controlled for across the calculation of the deprivation indices.

About 23% of the health deprivation index component is derived from the Years of Potential Lives Lost (YPLL)(9) and there is intuitively a close connection between measures of poor health and mortality. This accounts for the high correlation between the health deprivation index and ln(SMR) as shown in Table 6.

The partial correlation between employment deprivation and income deprivation is very high (81%) as seen in Table 6. The partial correlations between employment deprivation and health deprivation or average age in the LSOA are also high (38% and 40% respectively). The correlation with health deprivation is explained by the contribution of ill-health-related unemployment benefit rates (Incapacity Benefit, Employment Support Allowance, Severe Disablement Allowance and Carer's

Allowance) to both the employment and health deprivation indices. The age correlation is explained by the limitation of the employment deprivation metrics to those of working age (<65 years old).

Both the health and employment deprivation indices were omitted from the regression analysis as they were insufficiently distinct from both the dependent variable (log(SMR)) and income deprivation, and their inclusion makes interpretation of the results difficult.

Mortality rates for ages 60-89 years standardised by the European Standard Population

An additional analysis using deaths and population in 5-year age bins was carried out to enable weighting by the European Standard Population (ESP) 2013.(1) Both deaths and mid-year population counts by 5-year age bins from 60-64 years to 85-89 years were summed for each quintile of IMD from single-year of age data, and the central mortality rates by the same 5-year bins were calculated. The age standardised mortality rate for ages 60 to 89 years was then calculated using the ESP weightings (Table 1).

In order to visualise the relative trends in mortality rates by IMD quintile, the mortality rate from age 60 to 89 years was indexed first to the most advantaged quintile of IMD. To visualise the time trend in mortality rates across the IMD quintiles, the mortality rate was separately indexed to the rates for the year 2001.

Table 1. European Standard Population between the ages of 60 and 89 years with the proportional breakdown by the 5-year age bins.

ESP 2013	Number	Proportion
60-64	6,000	24%
65-69	5,500	22%
70-74	5,000	20%
75-79	4,000	16%
80-84	2,500	10%
85-89	1,500	6%
Total	24,500	100%

Results

The results are shown in the tables and figures below.

Figure 8 shows the smoothed log-mortality rates in 2013 for men and women from the age of 50 years, with the different lines showing the results for each IMD quintile. As expected, mortality rates are higher in infants and the elderly, and lowest in children and adolescents. The gap between the highest and lowest deprivation quintiles is greatest in middle-aged adults (35-55) and narrows with age, with a similar shape for men and women.

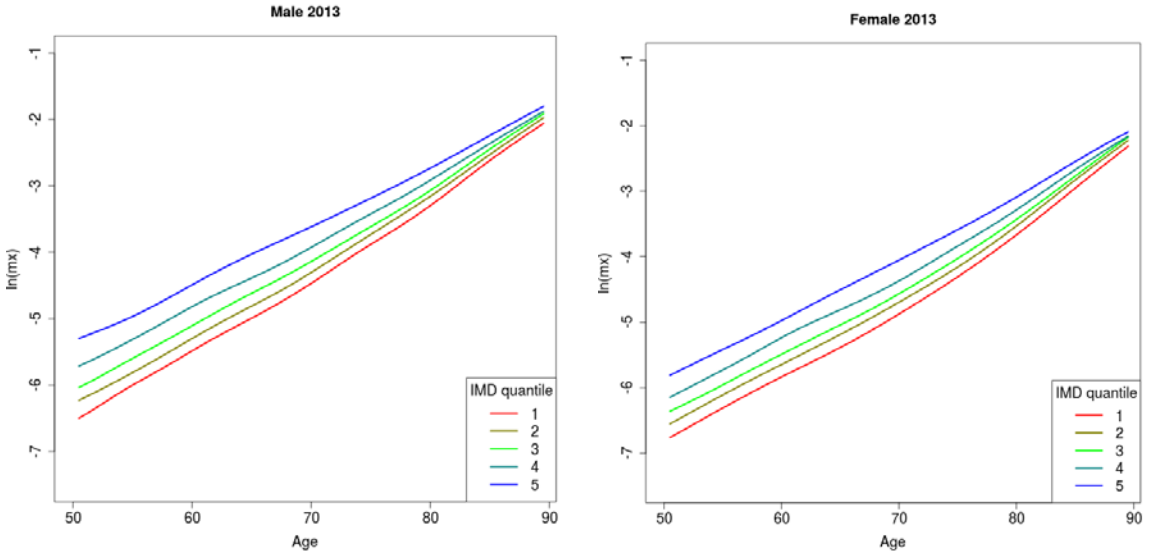

Figure 8 Smoothed log-mortality rates 2013 for males and females showing the different rates by IMD quintile by age from 50 years to 90 years.

Looking at the age range from 60 to 89 years in males (Figure 9), it is clear that there has been a substantial reduction in mortality rates in all areas regardless of deprivation, but the difference in mortality between the most and least deprived neighbourhoods has changed very little. The relative degree of inequality is therefore greater.

Examination of the differences by single year of age reveals different patterns and scale to the trends.

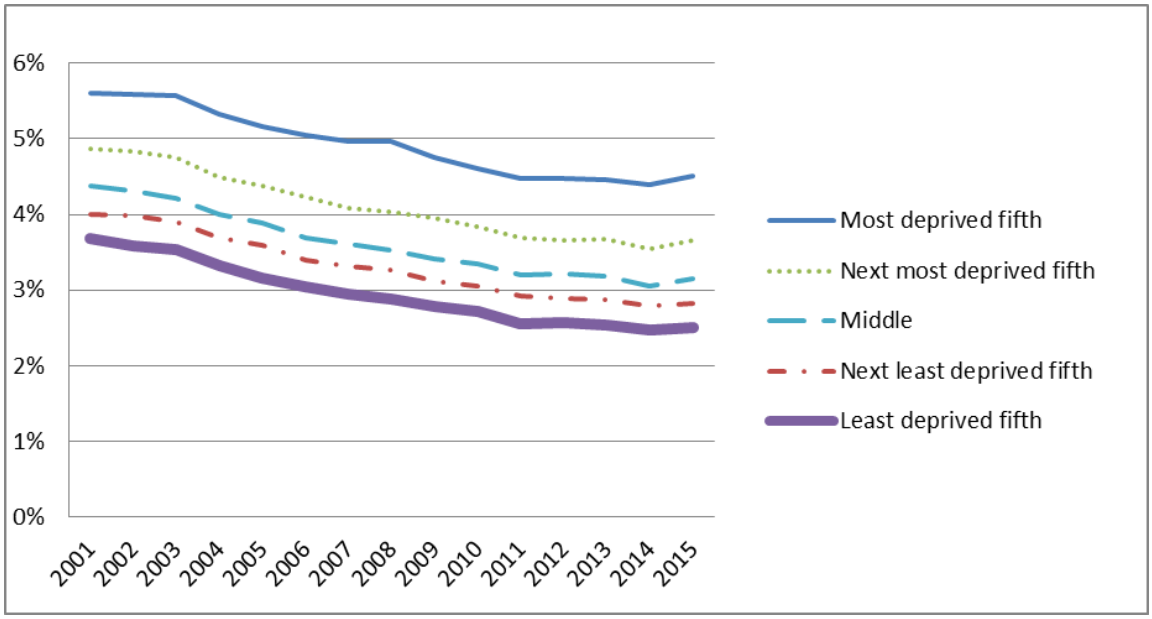

Figure 9 Mortality rates of males aged 60-89 in England, standardised to population distribution of European Standard Population 2013.

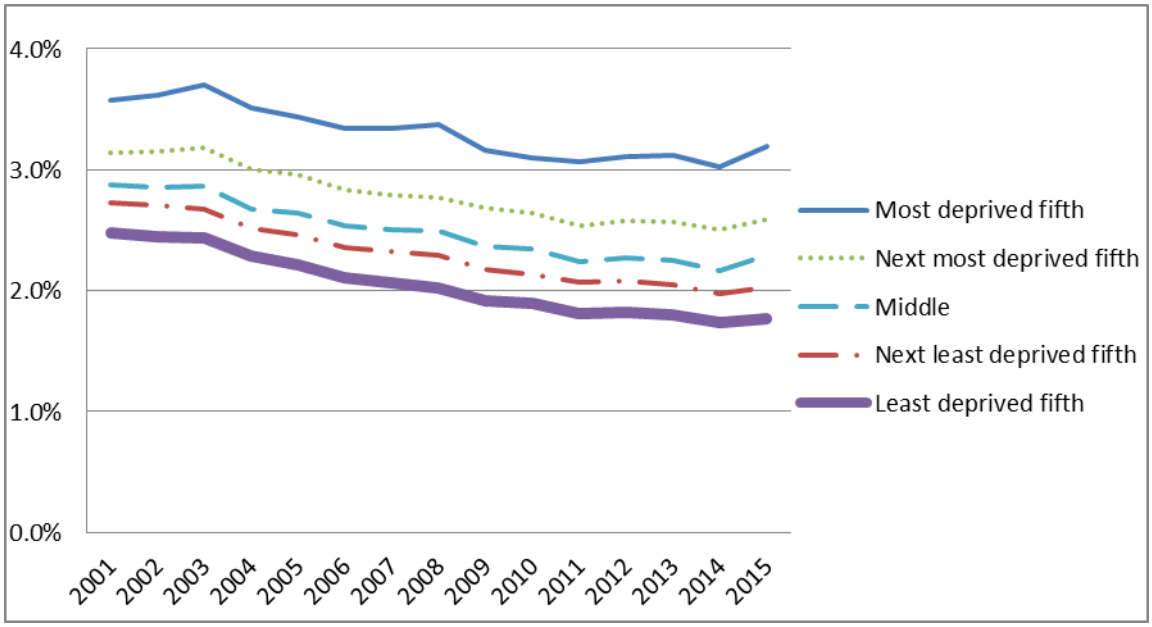

Figure 10 Mortality rates of females aged 60-89 in England, standardised to population distribution of European Standard Population 2013.

Table 2 Mortality rates of males aged 60-89 in England, standardised to population distribution of European Standard Population 2013.(1) (Figure 9)

	Most deprived fifth	Next most deprived fifth	Middle	Next least deprived fifth	Least deprived fifth
2001	0.0561	0.0487	0.0438	0.0400	0.0369
2002	0.0559	0.0484	0.0431	0.0398	0.0359
2003	0.0557	0.0476	0.0421	0.0391	0.0353
2004	0.0532	0.0449	0.0401	0.0369	0.0332
2005	0.0516	0.0437	0.0390	0.0359	0.0316
2006	0.0505	0.0423	0.0369	0.0340	0.0305
2007	0.0497	0.0408	0.0360	0.0332	0.0294
2008	0.0496	0.0403	0.0354	0.0327	0.0289
2009	0.0475	0.0395	0.0341	0.0312	0.0279
2010	0.0461	0.0384	0.0335	0.0305	0.0273
2011	0.0447	0.0370	0.0321	0.0292	0.0256
2012	0.0447	0.0367	0.0322	0.0289	0.0258
2013	0.0446	0.0368	0.0319	0.0288	0.0254
2014	0.0439	0.0354	0.0306	0.0279	0.0247
2015	0.0451	0.0366	0.0315	0.0282	0.0251

Table 3 Mortality rates of females aged 60-89 in England, standardised to population distribution of European Standard Population 2013.(1) (Figure 10)

	Most deprived fifth	Next most deprived fifth	Middle	Next least deprived fifth	Least deprived fifth
2001	0.0357	0.0314	0.0288	0.0272	0.0247
2002	0.0362	0.0315	0.0285	0.0270	0.0245
2003	0.0370	0.0318	0.0287	0.0268	0.0244
2004	0.0351	0.0300	0.0268	0.0251	0.0229
2005	0.0344	0.0296	0.0265	0.0246	0.0222
2006	0.0334	0.0283	0.0254	0.0235	0.0210
2007	0.0334	0.0279	0.0250	0.0232	0.0206
2008	0.0338	0.0277	0.0249	0.0230	0.0202
2009	0.0316	0.0269	0.0237	0.0218	0.0192
2010	0.0310	0.0264	0.0235	0.0214	0.0190
2011	0.0307	0.0254	0.0224	0.0207	0.0181
2012	0.0311	0.0258	0.0228	0.0208	0.0182
2013	0.0312	0.0256	0.0225	0.0205	0.0180
2014	0.0302	0.0250	0.0216	0.0197	0.0174
2015	0.0319	0.0259	0.0229	0.0203	0.0177

From Figure 11 it can be seen that at age 55 years, between 2001 and 2015, the difference between the top and bottom IMD quintiles is greater than the absolute mortality rate in the most advantaged group throughout. Figure 12 shows that the fall

in mortality over time has occurred in all deprivation quintiles, although men in the highest IMD quintile appear to have had the greatest fall in mortality between 2001 and 2012.

Figure 12 shows the trend in smoothed central mortality for 85 year-old men and women. As with Figure 11, the fall in mortality over time is still obvious. However, in contrast to the data on 55-year-old adults, the gap between IMD quintiles in the very old has increased over time, especially in women.

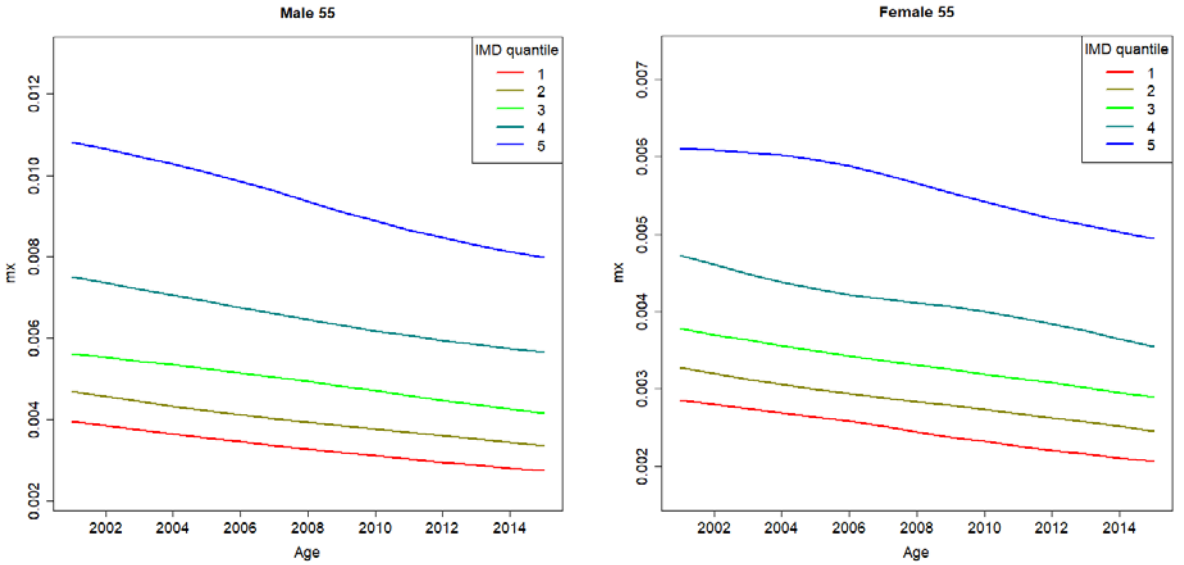

Figure 11 Trend in smoothed central mortality (mx) rates for 55-year-old males and females.

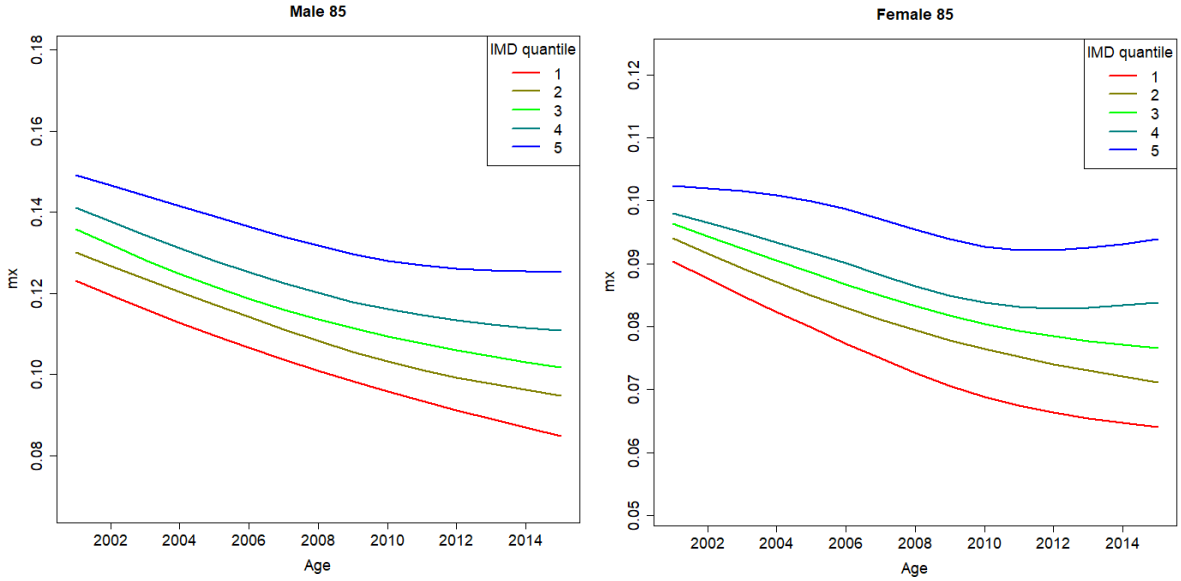

Figure 12 Trend in smoothed central mortality rates (mx) for 85-year-old males and females.

Next we can examine the change in mortality inequality relative to the most advantaged for the age group 60-89 years.

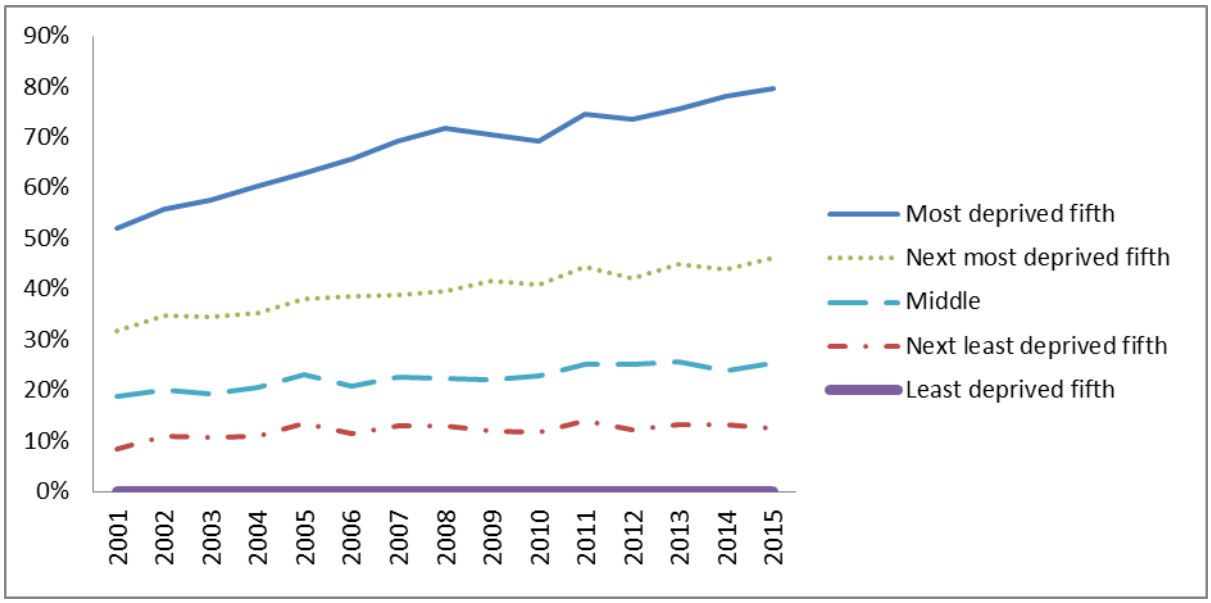

Figure 13 Percentage difference in death rates relative to the most advantaged fifth males aged 60-89 in England.

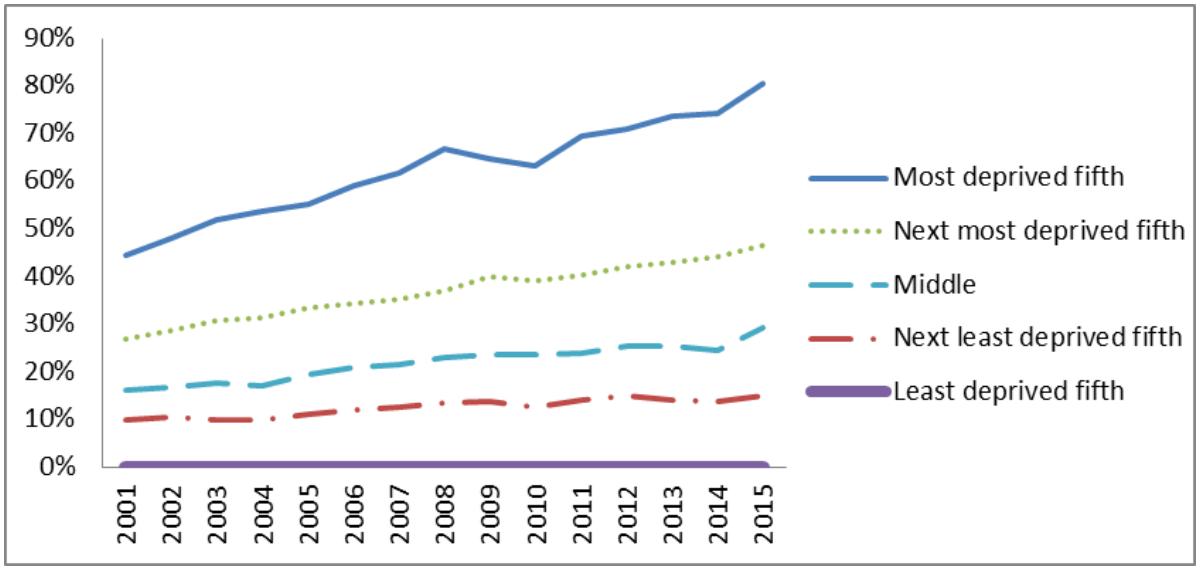

Figure 14 Percentage difference in death rates relative to the most advantaged fifth females age 60-89 in England.

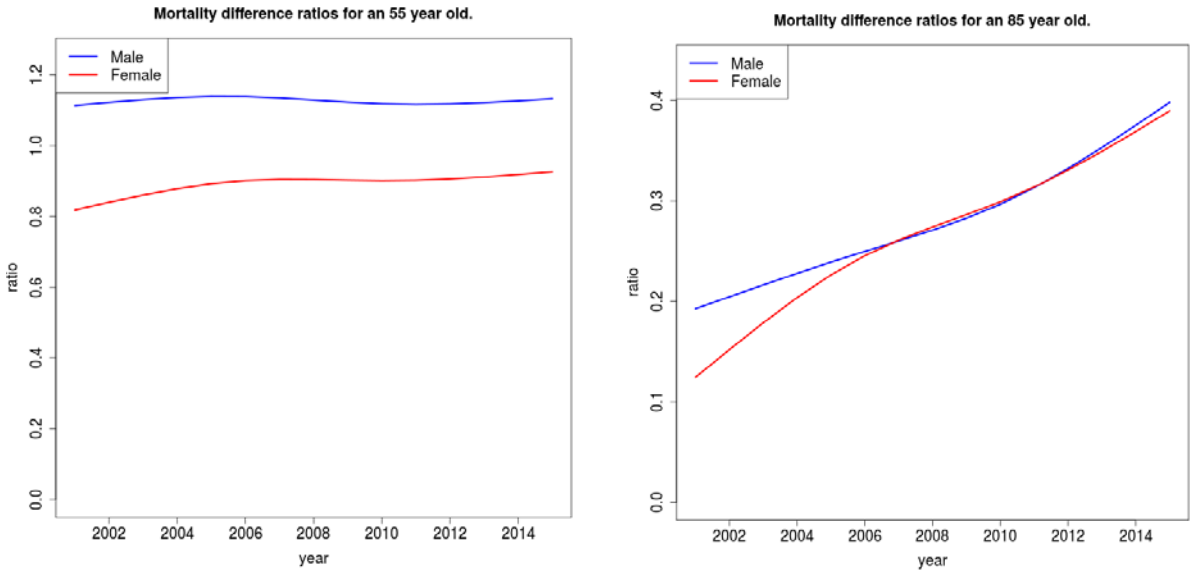

Figure 15 The difference ratios for 55- and 85-year-old males and females, and the trend in the difference in mortality between the most advantaged and disadvantaged as a proportion of the average mortality at that age.

Figure 15 shows the difference ratio for 55- and 85-year-old adults. The difference ratio is the central mortality rates in the 5th quintile minus that of the 1st quintile, divided by the overall average rate for that age and gender. This gives a measure of the scale of the difference, or inequality, in mortality as a percentage of all mortality.

We can see that, in 55-year-olds, inequality in mortality was greater in men than in women, but, while it increased slightly over time in women, it has fallen in more recent years in men. In contrast, inequality in 85-year-olds has increased over time in both genders.

In younger ages, and age 55 is shown here, the proportional difference is relatively large, but there is no clear trend over time. At older ages, and age 85 is shown here, the difference is smaller, but with a steep increase over this period of time. This reflects the smaller proportional inequality in the elderly and the sharp fall in mortality over that time in this age group.

Using the ESP standardised mortality rate for ages 60-89 years, we can observe the trend in mortality rate relative to 2001. The reduction in mortality has been greater in males than females. The difference in mortality rates between the most advantaged and most disadvantaged quintiles has increased for both males and females, but is

more marked in females. The slow down in improvement in mortality can be observed from around 2011, and is more marked in the more disadvantaged quintiles, particularly in women.

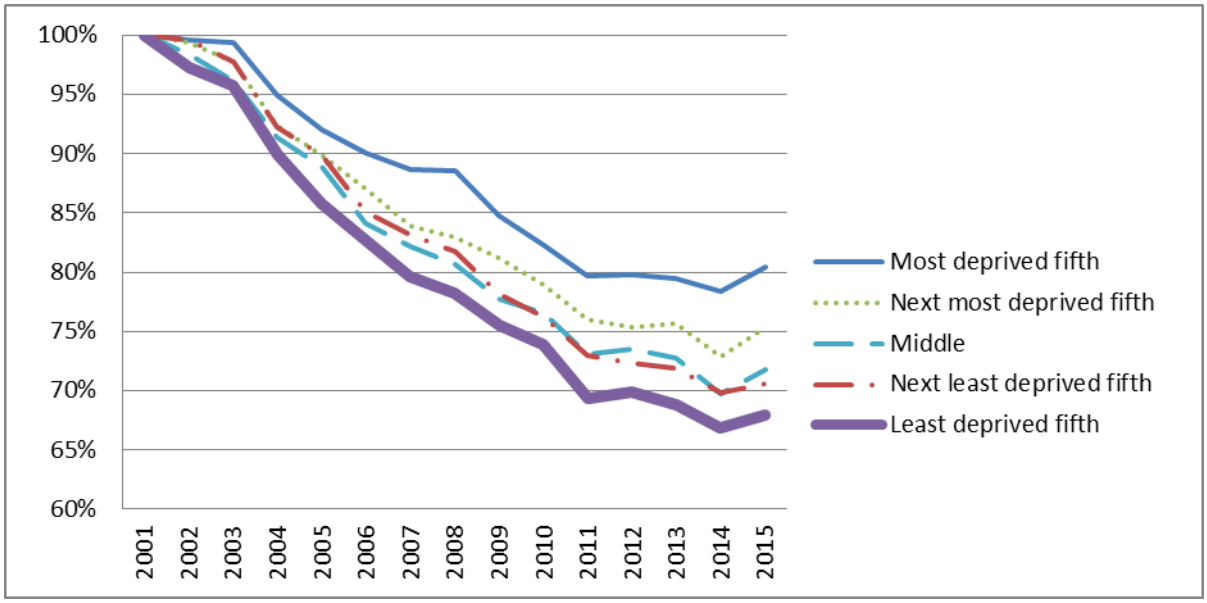

Figure 16 Progression of male death rates, aged 60-89 of each socio-economic circumstances quintile in England, relative to their levels in 2001. For each quintile, the value of mortality is given as a percentage of the mortality rate in 2001.

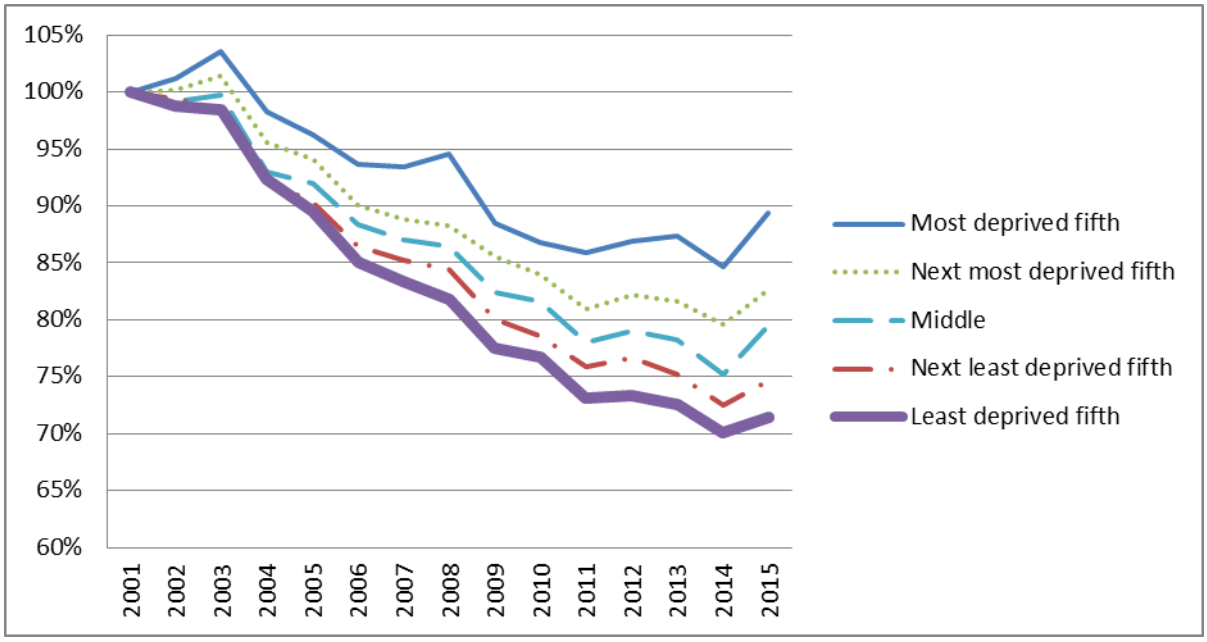

Figure 17 Progression of female death rates, aged 60-89 of each socio-economic circumstances quintile in England, relative to their levels in 2001. For each quintile, the value of mortality is given as a percentage of the mortality rate in 2001.

Life expectancy

The focus of interest of this paper is the inequality in life expectancy driven by deprivation. There is a direct relationship with mortality, but with an accumulation over a lifetime. It is a more useful metric in many ways, both for individuals from their own perspective, and for society. The costs of pensions or the premature loss of life are more clearly related to length of survival than risk of death at any given point in time. Figure 18 shows the remaining life expectancy by age and IMD quintile in 2001 (left) and 2015 (right) for males.

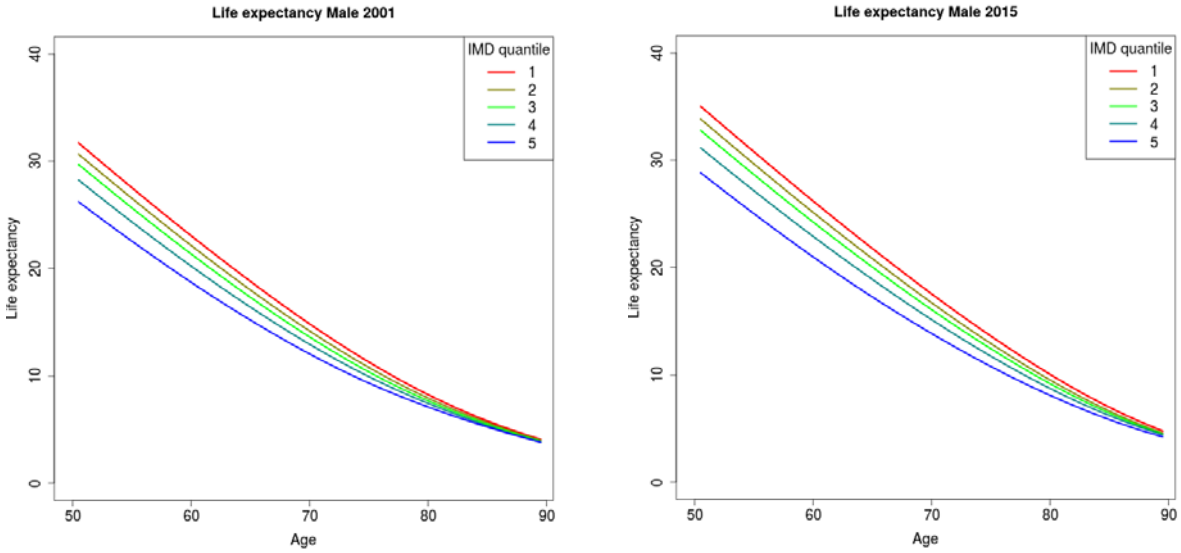

Figure 18 Change in the remaining life expectancy by age in 2001 and 2015 for males.

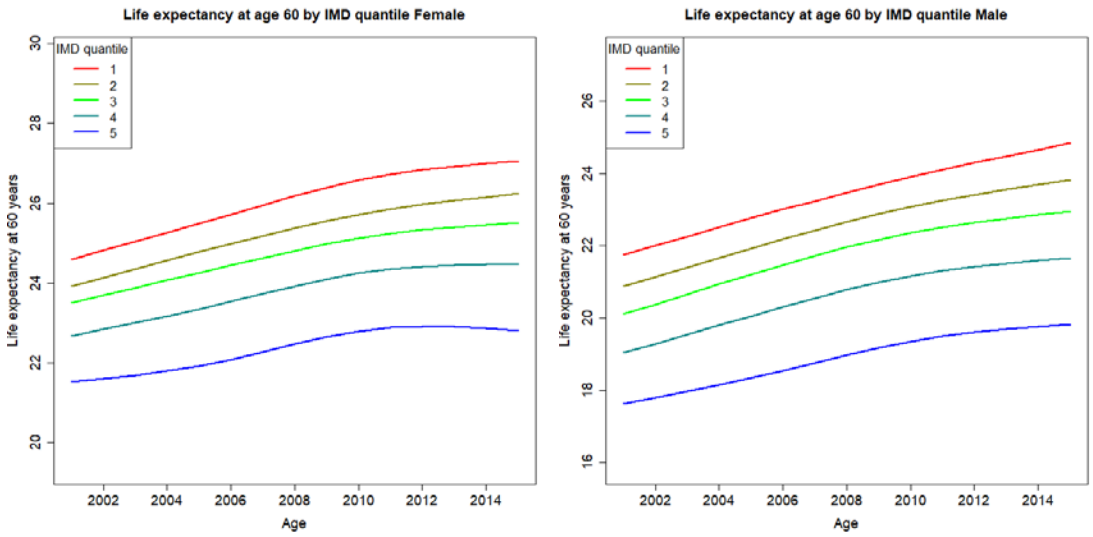

Figure 19 The change in life expectancy at age 60 by IMD quintile between 2001 and 2015 for females (left) and males (right).

It can be seen from Figure 19 that the life expectancy is higher in females, but that the rate of increase in life expectancy in males has been greater over that period of time. The plateau in life expectancy is more obvious in women from about 2011, particularly in the 5th quintile for deprivation.

The difference in life expectancy at the age of 60 for males in families living in the most and most disadvantaged fifth neighbourhood has increased from 4.1 years in 2001 to 5.0 years in 2015. Similarly, for sixty-year-old women, it has risen from 3.1 years in 2001 to 4.2 in 2015.

In 2001, men aged 60 to 89 from the most disadvantaged fifth of the country were 52% more likely to die in a year than the most advantaged fifth. This figure has climbed to 80% in 2015. The equivalent figures for women are 44% in 2001 and 81% in 2015.

Figure 20 shows how the improvement in life expectancy at age 60 declined after 2007 in both men and women. The rate of improvement in life-expectancy more or less halved in that time. Examining how the improvement in life expectancy at age 60 breaks down across IMD quintiles (Figure 21), it appears that between 2007 and 2011, the gap narrowed markedly, largely accounted for by an increase in improvement rates in the most disadvantaged quintiles, but since 2011 there has

been a marked increase in the gap between quintiles, and a fall in improvement across all quintiles.

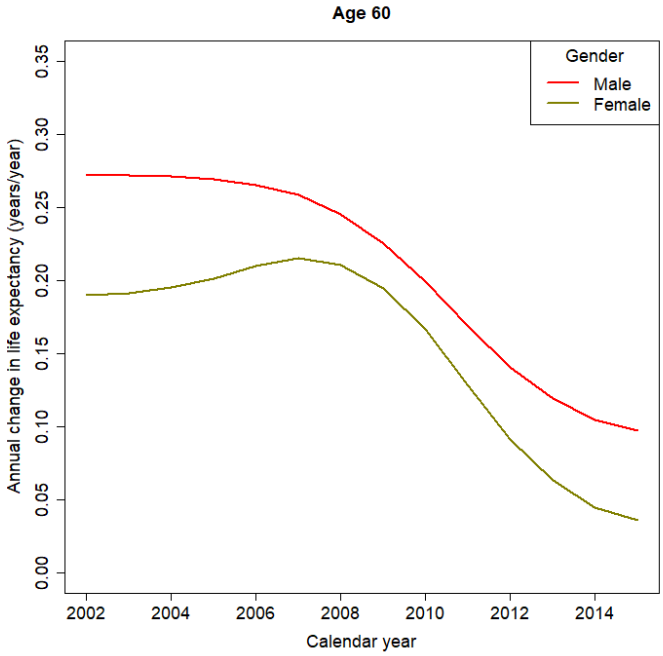

Figure 20 The rate of change of life expectancy (years per year), at age 60, between 2002 and 2015, and for males and females.

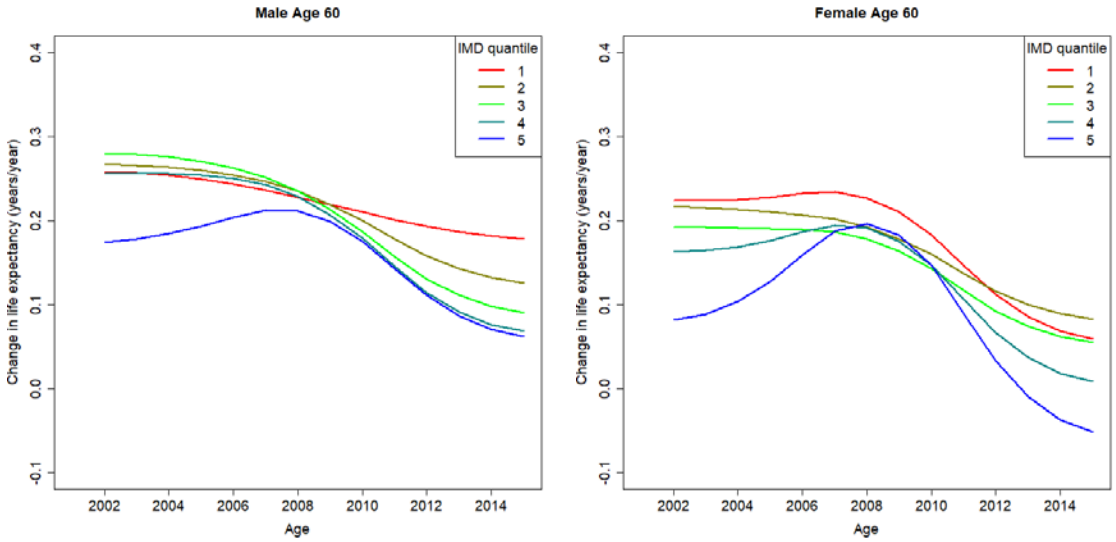

Figure 21 The rate of change of life expectancy at age 60 between 2002 and 2015 for males and females by IMD quintile.

Figure 22 shows the gap in life expectancy at age 60 for men and women between 2001 and 2015. The difference in inequality between men and women has fallen slowly from 1.06 years in 2001 to 0.78 years in 2015.

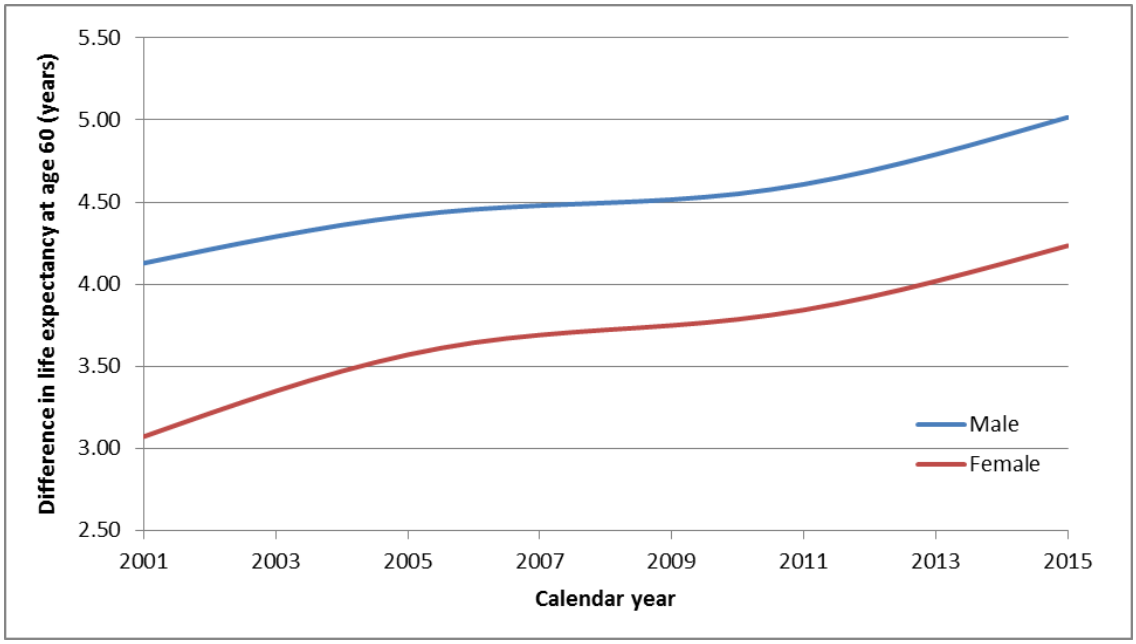

Figure 22 Difference in life expectancy at age 60 years between the most and least deprived quintiles for IMD 2015 for males and females in England from 2001 to 2015.

Regression analysis

The results of the regression analysis are shown in the following tables and graphs.

Table 4 shows the results of the univariate analysis of the deprivation domains of the IMD 2015 and the average age in the LSOA. Based on the coefficient of determination Health, Income, and Employment predict the greatest variation in the ln(SMR), and Housing and Environment predict little to none of the variation.

Figure 23 is based on the results of the multivariate analysis shown in Table 5, and shows Income to be a substantial factor as it has the highest partial coefficient of determination. Income is also highly correlated with Employment as found in Table 6. Figure 24 gives a visual representation of these results, with scatter plots of life expectancy from age 60 against ranks of each of the deprivation dimensions.

Table 4 Results of the univariable analysis of all the domains of the IMD 2015 and the average age in the LSOA including the metrics for income, employment, education, health, crime, housing and environment deprivation for each LSOA, the average age in each LSOA and with the ln(SMR) for the LSOA as the dependent variable. The results include the coefficients, the standard error, the t-statistic and the p-value and the coefficient of determination (R^2).

Deprivation domain	coefficient	t-statistic	p*	R^2
Income	1.9766	140.2	<0.0001	44%
Employment	2.6397	139.0	<0.0001	44%
Education	0.0095	112.8	<0.0001	33%
Health	0.2397	196.4	<0.0001	54%
Crime	0.1816	85.3	<0.0001	22%
Housing	0.001	5.8	<0.0001	0.0%
Environment	0.0043	38.3	<0.0001	5%
Average age	-0.1813	-65.56	<0.0001	12%

*p < 0.05 conventionally regarded as being statistically significant.

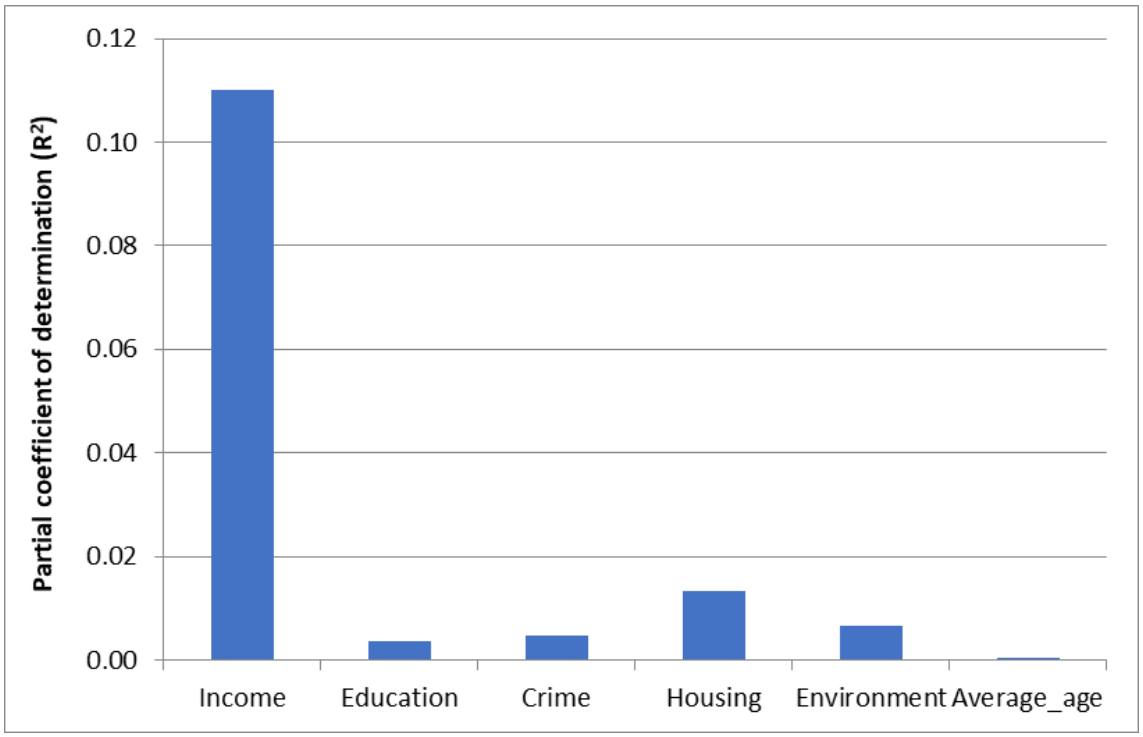

Figure 23. Bar chart of the partial coefficients of determination for each of the independent variables in the multiple regression analysis. R^2 indicates the proportion of the variation in the dependent variable (ln(SMR)) that is explained by the independent variable over and above the variation explained by all the indepenent variables collectively.

Table 5. Results of the multiple linear regression with the income, education, crime, housing and environment domains of the IMD 2015, average age in the LSOA and with ln(SMR) as the dependent variable. The results include the coefficients, the standard error, the t-statistic and the p-value and the partial coefficient of determination (R^2).

	coefficient	Standard Error	t-Value	p-value	Partial R^2
(Intercept)	-0.234	0.012	-19.120	<0.0%	46% (all)
Income	1.530	0.024	63.712	<0.0%	11%
Education	0.001	0.000	11.016	<0.0%	0.37%
Crime	0.027	0.002	12.544	<0.0%	0.48%
Housing	-0.003	0.000	-21.110	<0.0%	1.33%
Environment	0.001	0.000	14.879	<0.0%	0.67%
Average age	0.000	0.000	-1.798	7%	0.01%

Table 6. Pearson partial correlation coefficients between the ln(SMR), the seven domains of the IMD2015 and the average age in the LSOA.

	Income	Employment	Education	Health	Crime	Housing	Environment	Average age	Ln(SMR)
Income	1.00	0.81	0.20	-0.06	0.14	0.28	0.03	-0.41	0.09
Employment	0.81	1.00	0.18	0.38	0.00	-0.14	-0.06	0.40	-0.06
Education	0.20	0.18	1.00	0.01	-0.05	-0.06	-0.16	-0.12	0.03
Health	-0.06	0.38	0.01	1.00	0.04	-0.18	0.16	-0.03	0.42
Crime	0.14	0.00	-0.05	0.04	1.00	-0.10	0.28	-0.25	0.04
Housing	0.28	-0.14	-0.06	-0.18	-0.10	1.00	0.23	-0.04	0.00
Environment	0.03	-0.06	-0.16	0.16	0.28	0.23	1.00	-0.09	0.00
Average age	-0.41	0.40	-0.12	-0.03	-0.25	-0.04	-0.09	1.00	-0.04
Ln(SMR)	0.09	-0.06	0.03	0.42	0.04	0.00	0.00	-0.04	1.00

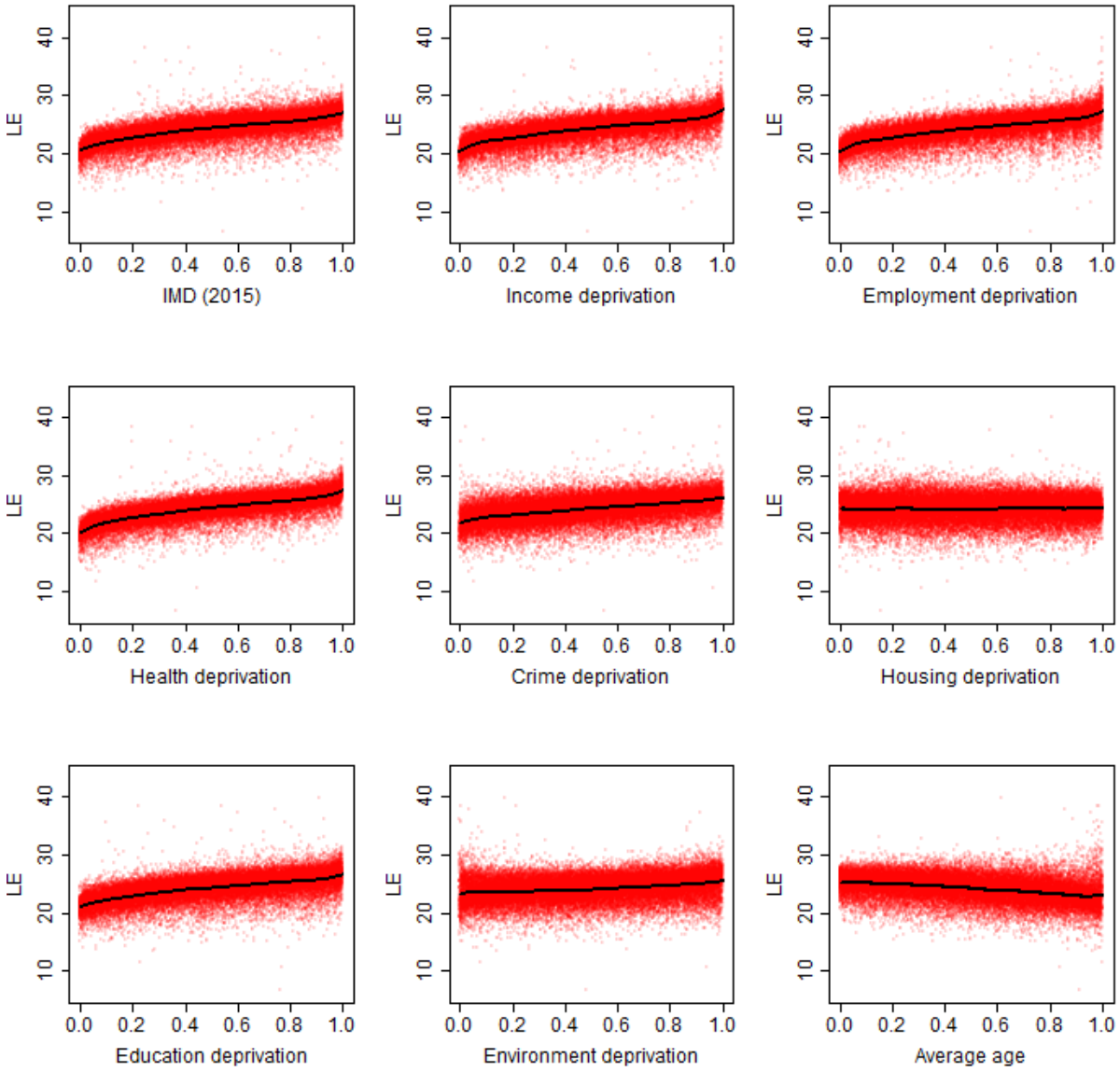

Figure 24. Scatter plots of the life expectancy aged 60 years in an LSOA neighbourhood against the ranking by one of the seven IMD dimension metrics in turn and the average age in each LSOA. The black line is a spline fit of a curve to the life-expectancy values.

Discussion

This analysis supports the findings of the King's Fund report, which found a decrease in the difference in life expectancy associated with IMD inequalities between 1999-2003 and 2006-2010. However, our analysis has found that inequalities in life expectancy at age sixty by deprivation quintile increased between 2001 and 2015 in older people.

Figure 25 compares the life expectancy at birth by IMD rank between the Marmot report (1999-2003), the King's Fund analysis and the Longevity Science Panel analysis for 2011 to 2015.

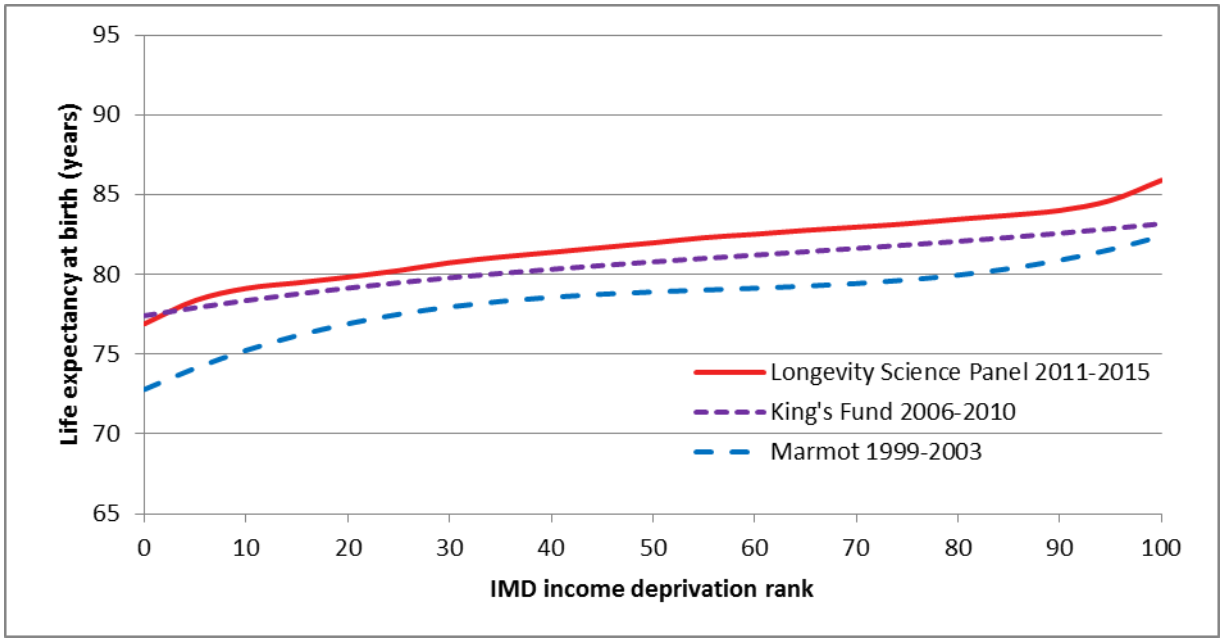

Figure 25. Marmot curves comparing the original analysis in the 2010 Marmot Review the King's Fund update and the Longevity Science Panel analysis 2011-2015.

The first observation is that there is a clear trend in increasing life expectancy at birth across the three time categories. The curve for the King's Fund analysis is rather flatter than the LSP and Marmot curves, and this may reflect that the King's Fund analysis was conducted at the MSOA level rather than the LSOA level. The greater heterogeneity in an analysis at the MSOA level would be expected to reduce observed differences by IMD quintile when compared to an LSOA analysis.

All three analyses used the income deprivation metric from the Index of Multiple deprivation. Life expectancy at birth is used in the LSP analysis as this was the outcome metric in the previous reports. Elsewhere, life expectancy at age 60 has been preferred.

To begin to explain the changes, we need to see what the trends have been for the major risk factors for inequality in life expectancy. Our previous reports discussed some of the possible explanations for the difference in life expectancy across socio-economic groups. These include inequalities in income, smoking, obesity and alcohol consumption across socio-economic groups, as well as different rates of uptake of preventive health services and treatment rates for diseases.

What the change in life expectancy means in terms of mortality improvement rates over this period, and how it projects forwards, is subject to continuing analysis.

Trends in income inequality

Income inequality in England remains high, but has decreased slightly in recent years. The ONS report *The effects of taxes and benefits on income inequality: 1977 to financial year ending 2015* found that there has been a slight decrease in income inequality since 2007/08, although the absolute level of inequality between the highest and lowest paid remained higher than in the 1980s.(10) The updated report for 2016 (*Household disposable income and inequality in the UK: financial year ending 2016*) found that the Gini coefficient, a measure of inequality, had continued to fall between 2011/12 and 2015/16 in the UK, and was then back to the level last seen in 1985-86.(11)

Trends in smoking

Smoking is a potent driver of mortality, so it is important to consider if differential trends in smoking rates within deprivation quintiles might account for changes in mortality inequalities.

Smoking rates in England continue to fall. The ONS report *Adult smoking habits in the UK: 2015* showed that smoking rates fell by 3% between 2010 and 2015 in men and women across the UK.(12) A regional difference in smoking prevalence persists, with particularly high prevalence of 25.3% in Blackpool in 2015, one of the most disadvantaged areas of England, compared with 8.8% of adults in Chiltern and 9% in South Staffordshire. Similarly, although smoking prevalence has fallen in both

employed and unemployed adults since 1990, smoking rates remain higher in the unemployed than employed adults, although again, the gap has narrowed. Similarly, the *Integrated Household Survey (Experimental Statistics): January to December 2014* found that 28.2% of adults in routine and manual occupations were smokers, compared with 12.1% of adults in managerial and professional occupations.(13)

It would appear that whilst higher smoking prevalence persists in more disadvantaged districts, this gap is narrowing and would not account for increases in mortality inequality over this period.

Deprivation regression analysis

About 46% of the variation in mortality across LSOAs is explained by the IMD 2015 domains which are derived independently of each other or of the mortality rate. This includes income, education, crime, housing and environmental deprivation along with the average age in each LSOA. Income deprivation alone explains about 11% of the variation in mortality rates between LSOAs which is greater than the predictive power of all the variables combined.

The income deprivation index is partly derived from rates of Job-seeker's Allowance which is also included in the derivation of the unemployment deprivation index. The correlation between income deprivation and employment deprivation is very high at 80% suggesting unemployment plays a significant role in income deprivation in a neighbourhood.

Conclusions

There are three key messages from this analysis.

- Differences in life-expectancy between the rich and poor in England have widened between 2001 and 2015.
- Death rates have fallen faster for those more advantaged between 2001 and 2015.
- Income deprivation is the strongest independent predictor of mortality rates in a neighbourhood.

Our analysis shows that, despite life expectancy having increased in all ages and IMD quintiles, inequalities in life expectancy linked to social deprivation have increased since 2001, especially in the elderly, and are greatest in working age adults. Whilst mortality rates have fallen in all deprivation groups, the rate of fall has been greater in the more advantaged groups.

Income deprivation has the greatest explanatory power with respect to variation in mortality rates, with education, crime, housing and the environmental deprivation having a smaller impact.

It is difficult to know how far the differences in our results and those from the earlier King's Fund report are due to the impact of a further three years of austerity imposing restrictions on health, social care and public health spending and benefit caps. Our analysis shows that the increase in life expectancy in recent years is no cause for complacency. As our population ages, inequalities are likely to increase further.

Against this background, it will be even more important to think about how government, society and the private sector can help address these inequalities. For working age adults, where the mortality gap is widest, the decline in public health spending of recent years is a particular cause for concern, as this may be contributing to widening gaps in lifestyle risk factors, in particular smoking rates.

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