An investigation into the impact of deprivation on demographic inequalities in adults

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Abstract

This research investigates the impact of deprivation on demographic inequalities in England and Wales among adults. Using demographic measures including the modal age at death, life expectancy, lifespan variation and mortality, it shows a negative correlation with deprivation as measured by the 2015 Index of Multiple Deprivation. Although it finds that life expectancy is increasing overall and the gap between men and women is lessening, improvements are slower paced in more deprived areas such that the gap between rich and poor is slowly worsening over time. Men are more adversely impacted by deprivation than women with the gap in period life expectancy at age 30 in 2015 between the top and bottom 1% of deprived neighbourhoods at 10.9 years for men and 8.4 years for women. Between 2001 and 2015 inequalities in male mortality rates at age 44 were 4.4 times greater in the most deprived 10% of neighbourhoods than those in the 10% least deprived, and were much higher than in intervening deciles. The worst deprivation is concentrated in specific areas. For example, in 22 out of 326 English districts 25% or more of neighbourhoods are in the most deprived 10% and in 5 districts it is 40% or above.

Keywords: Mortality inequalities, life-span variation, deprivation

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1. Introduction

For the last century, adult life expectancy in the UK has been growing apace although these improvements have not been equally shared between its citizens. These differences appear to be correlated with rich and poor areas, urban and rural districts, between genders and socio-economic groups. The research question is to investigate the extent of these inequalities and whether they are widening. A key finding is that the gap between areas is widening slowly and that it is strongly correlated with deprivation.

The better news is that, based on a range of indicators, most areas are improving but at very different speeds. In addition, there are differences between men and women, but male life expectancy is slowly catching up with females raising the possibility that they may converge after 2030. However, a key concern is that in the most deprived areas male mortality in middle age is over four times the mortality in the least deprived areas and higher than that of women in similar situations and this is dragging down national averages.

The link between life expectancy and socio-economic variables such as education, income, occupation or deprivation is well established in the literature with people in lower socio-economic groups typically having shorter life expectancy than those in higher socio-economic subgroups. Much of the research has concentrated on the variation of life expectancy and other health outcomes across deprivation subgroups defined using the Index of Multiple Deprivation which measures socio-economic circumstances at a small area level (Department for Communities and Local Govement, 2015).

For example, recent official statistics indicate that for the period between 2015 to 2017 the gap in period life expectancy at birth between the most deprived decile and least deprived decile of the English population sits at 9.3 years for males and 7.5 years for females (Public Health England, 2018). Furthermore, Bennett et al. (2015) and Villegas & Haberman (2014) have reported that the life expectancy gap has not only widened over the past two decades but is also forecasted to continue to widen in the next decades.

The differences in life expectancy across deprivation groups in England can be explained by significant differences in cause-specific mortality. Bennett et al. (2018) have found that in 2016 deaths rates at every age and from every disease are higher in the most deprived areas than in the least deprived ones, with differences in neonatal deaths along with inequalities from respiratory diseases, ischaemic heart disease, and lung and digestive cancers in working ages, and dementias in older ages being the main contributors to the life expectancy gap.

Along the same lines, Alai, Arnold (-Gaille), Bajekal, & Villegas (2018) argue that to reduce social inequalities in life expectancy it is key to target the mortality differential associated with circulatory, digestive, and respiratory diseases. Ultimately, mortality differentials can be traced back to differences in the incidence of risk factors. Adults in more deprived areas have a higher propensity to smoke, be overweight, and have a poor diet and lack of physical exercise (Scholes et al, 2012; Public Health England, 2017). Moreover, more deprived areas tend to have more binge drinking (Fone et al, 2013; Ng Fat et al, 2017), higher prevalence of diabetes and raised blood pressure (Scholes et al, 2012) than more affluent ones. If the country is to succeed going forward, then health inequalities will remain a strategic impediment to this.

As useful and as familiar as life expectancy is, it suffers from the problem that it only deals with average longevity potentially masking other important aspects of inequalities. To get a better picture of longevity differentials, van Raalte, Sasson, & Martikainen (2018) highlight the importance of supplementing average longevity metrics with a metric of life span variability that can capture the variation in ages at death. This is because less advantaged socio-economic groups not only have below average longevity, but also tend to experience a wider variability in their lifetimes.

For instance, for Scottish men, Seaman, Riffe, & Caswell (2019) have found that in 2011 the life expectancy at birth in the most deprived quintile was 9% lower than in the least deprived quintile, whereas the life span variability (measured using the standard deviation of the lifetime) in the most deprived quintile was 21% higher than in the least deprived quintile. Such variations are not only disturbing from a health perspective but have many implications not least in in terms of financial planning and pension systems (see e.g., van Raalte et al (2018) and the recent review of the UK state pension age by the Department for Work & Pensions (2017)).

Mayhew and Smith (2016, 2019) argued that unhealthy lifestyles are the main reason for variations in lifespan – causes being poor diet, lack of exercise, smoking and obesity. This is because major killers of the last century such as polluted water and air and slums are now largely in the past with one or two exceptions such as toxic vehicle emissions. More recent data also show that deaths from external causes such as drug misuse, self-harm and suicide have now replaced deaths involving motor vehicle incidents (ONS, 2017c). In this research we show that deprivation is often the common link, the areas being identifiable from the levels of mortality, unhealthy lifestyles and vice versa.

Our contribution to the literature on the relationship between mortality and deprivation in this paper is fourfold. First, we contrast how gender inequalities have evolved over time to provide a much more rounded as well as detailed picture of mortality rates and age of death. We use partial life expectancy to break down whole-life expectancy into small segments of the age range to look at inequalities within age brackets over time. We show that more men and women that would have expected to die in their 60s now live to their 70s and more in their 70s live to their 80s and so on with men gradually catching up on women within each 10-year age bracket.

The choice of start age from which to measure inequalities is important. We concentrate on adults age 30+ rather than from birth. Different results are obtained when comparing, for example, inequalities at birth with those at some other age due to variations in infant mortality, childhood mortality and so on. Given that our focus is on adult inequalities, we were keen to avoid the possible confounding effects of infant mortality, but also deaths in earlier adult age which tends to be higher for men than women (Kannisto, 2000; Mayhew and Smith, 2014).

Second, we present an up to date picture of the relationship between life expectancy and deprivation by using the Index of Multiple Deprivation 2015 as our marker of socio-economic circumstances. This contrasts with previous studies which categorised deprivation groups based on less up to date markers such as the 2011 Carstairs score (Bennett et al., 2015) and the 2007 Index of Multiple Deprivation (Villegas & Haberman, 2014). We also measure differences in mortality and lifespan between men and women who are exposed to different decile levels of deprivation. In contrast with previous studies, we also provide a more granular picture of inequalities by reporting inequalities at the percentile (centile) level and find, for example, that the mortality gradient accelerates within the most deprived deciles.

Third, we broaden the understanding of socio-economic inequalities in longevity in England by supplementing the standard life expectancy metric with a life span variability metric. To the best of our knowledge, we provide one of the first analyses of life span variation by deprivation decile and gender in England shedding light on this additional aspect of inequality. We undertake this analysis at both the decile and centile levels to ascertain greater detail. Fourth and finally, we supplement our mortality analysis with a discussion on the geographical distribution of deprivation in England.

The remainder of this paper is structured as follows. Section 2 provides a description of our methodology and a structural plan of the research. Section 3 provides an overview of trends in gender inequality based on descriptive measures such as mortality, modal age of death and partial life expectancy. Section 4 discusses inequalities due to deprivation, according to measures based on life expectancy and lifespan variability at the decile and centile levels. Section 5 analyses deprivation by English district and Section 6 discusses our conclusions.

2. Methodology

Our aim is to analyse the gender, socio-economic and geographical variation of three demographic measures - life expectancy, lifespan variation and mortality. To accomplish this goal our methodology encompasses three complementary strands of work: (i) gender differences in mortality and life expectancy, (ii) deprivation differences in mortality and (iii) the geographical impact of inequalities. These strands of work are summarised in Figure 1 based on a three- layered approach.

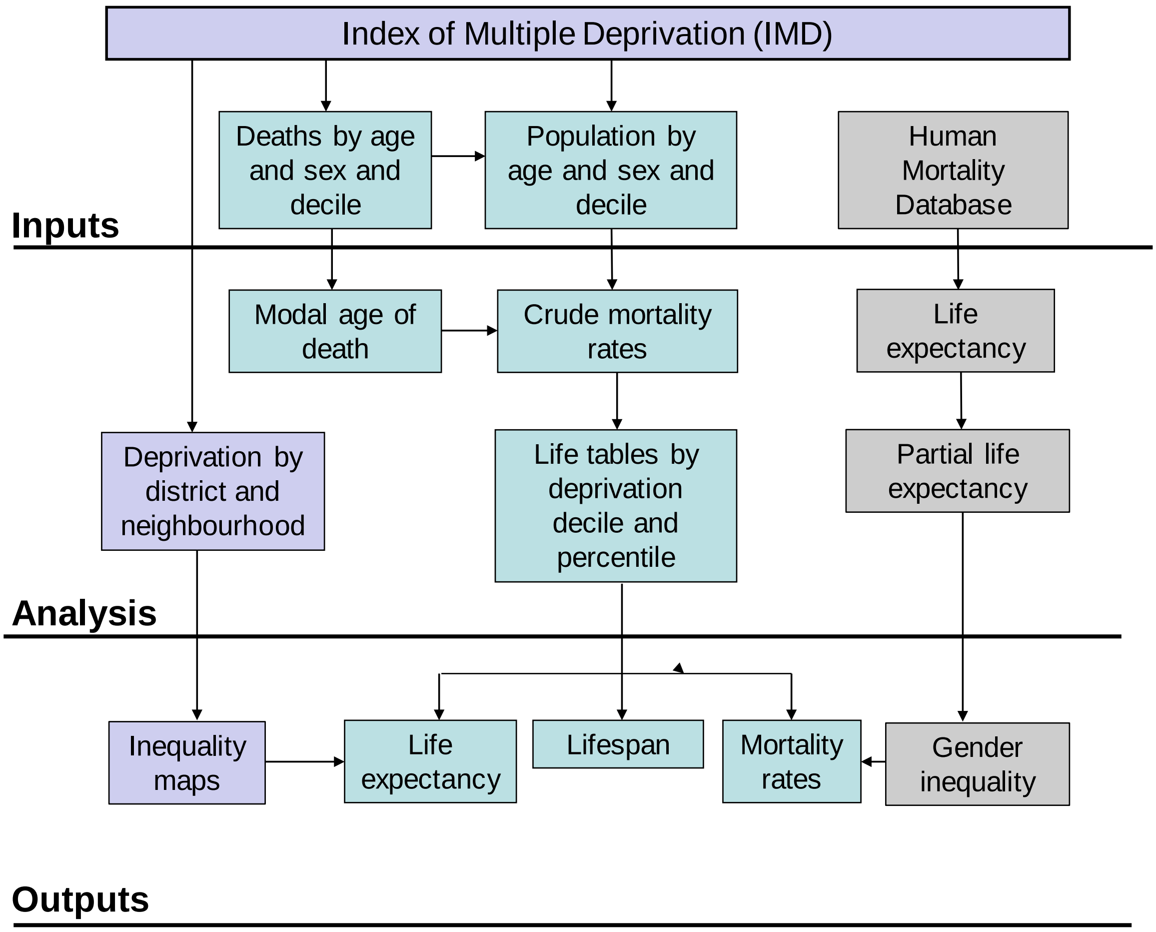


Figure 1: Method and approach. The elements are colour-coded to represent separate strands of work.

Our first strand shown to the right of Figure 1 relates to the analysis for gender inequalities and uses life tables available from the Human Mortality Database (HMD, 2017) for the period 1950 to 2013 based on England and Wales. Using these data, we apply the methods introduced in Mayhew and Smith (2015) to investigate gender differences in life expectancy and partial life expectancy at the national level. These measures are primarily descriptive but contain details of trends over time and the pace of any improvements.

Our second strand shown in the central part of Figure 1 is concerned with a demographic analysis of the trends in the differences in mortality rates, life expectancy and lifespan variation across deprivation deciles based on the Index of Multiple Deprivation 2015. We complement the analysis by deprivation decile with a more granular snapshot of life expectancy and life span inequalities at the percentile level. We explain the methodological details of these analyses in the next subsections.

Finally, in our third strand of work to the left of Figure 1, we identify the geographical impact of inequalities at district and neighbourhood level according to their level of deprivation. We are mainly interested in the concentration of deprivation in the most deprived neighbourhoods by district. Our primary measure is simply based on the percentage of neighbourhoods in each district that fall into the most deprived decile. In this way we are able to capture patterns that might otherwise be obscured by the sheer volume of neighbourhoods.

2.1 Measuring deprivation

We classify the English population into the socio-economic subgroups using the Index of Multiple Deprivation (IMD) 2015 which measures socio-economic circumstances for geographical areas in England only. Specifically, the geographical unit of analysis is based on Lower Super Output Areas (LSOAs) which we use as a proxy for a neighbourhood.[3] There are over 30,000 LSOAs in England containing about 1,500 people on average each of which is given a deprivation score and rank in the IMD methodology.

The IMD score of an LSOA is based on a total of 37 separate indicators including income but also many others and so it is very representative across a spectrum of influences. These indicators are grouped into seven domains, each of which reflects a different aspect of deprivation experienced by individuals living in an area – for example, education, health, and crime. Further details about the IMD and its composition can be sourced from the Department for Communities and Local Government (2015).

2.2 Modelling mortality by deprivation decile

The IMD measures relative and not absolute deprivation and so only allows consideration of changes in relative positioning. In our case we first adopt the standard convention of splitting LSOA's into deciles, with decile one ("D1") referring to the 10% most deprived areas and decile ten ("D10") the 10% least deprived areas. At the decile level we have obtained information on the population size, number of deaths for ages 25 to 89 and years 2001 to 2015 from the ONS (2017b).

In order to model and project mortality rates by deprivation decile we use the Three-Way Lee-Carter model introduced by Russolillo, Giordano, and Haberman (2011) and used in the context of modelling socio-economic mortality differentials by Villegas and Haberman (2014). The Three-Way Lee-Carter model extends the widely used model of Lee and Carter (1992) to capture the effect on mortality of a third variable beyond age and sex – in our case the effect of deprivation group.

[3] Lower Layer Super Output Areas are a geographic hierarchy designed to improve the reporting of small area statistics in England and Wales.

Let m_{xtg} denote the central death rate at age x in year t for deprivation decile g, $g = \{D1, D1, \ldots, D10\}$. Under the Three-Way Lee Carter model, we assume that this central death rate is given by

$$\log m_{xtg} \ = \alpha_x + \alpha_{xg} + \beta_x \lambda_g \kappa_t.$$

In this model α_x, β_x and κ_t capture the age and time evolution of mortality in England while α_{xg} and λ_g capture the difference in mortality and mortality evolution across deprivation deciles. We estimate the parameter of the model using a Poisson maximum log-likelihood approach (see Villegas and Haberman (2014) for further details).

As in the standard Lee-Carter model, mortality rate projections are obtained by treating parameters α_x, α_{xg}, β_x and λ_g as fixed and forecasting the time index κ_t using time series techniques. Specifically, we model κ_t using a Random Walk with drift:

$$\kappa_t = d + \kappa_{t-1} + \epsilon_t,$$

where d_t is a drift term and e_t is a white noise process.

2.3 Modelling mortality by deprivation percentile

In order to measure mortality at the percentile level we have obtained from ONS data on the number of deaths (ONS, 2016) and mid-year population estimates (ONS, 2018) by sex, age and Lower Super Output Area (LSOA) for year 2015. We have then aggregated these data to the IMD 2015 percentile (centile) level to obtain deaths and exposures[4] at age x and IMD percentile i, for $i = 1,2, \ldots, 100$, denoted D_{xi} and E_{xi}, respectively.

To construct sex-specific life tables by IMD percentile we use a generalised additive model linking log mortality rates to age and deprivation percentile. Specifically, we assume that $D_{xi} \sim \text{Poisson}(E_{xi} m_{xi})$ and that the central death rate at age x in percentile i, m_{xi}, is given by:

$$\log m_{xi} = a + s_b(i)(x - x^*) + s_c(i)(x - x^*)^2,$$

where a and x^* are parameters to be estimated and $s_b(i)$ and $s_c(i)$ are smooth functions of deprivation percentile. For this purpose, we assume that $s_b(i)$ and $s_b(i)$ are cubic regression splines. This model specification assumes that log mortality rates follow a quadratic form with the mortality rates at different income percentile converging at age x^*, i.e., $m_{x^*i} = m_{x^*j}$ for every two percentiles i and j. This assumption is consistent with the commonly observed decrease of mortality rate differential with rising age. We estimate the generalised additive models for men and women separately, using data for ages 30 to 89, noting that 89 is the oldest s age for which single year of age populations estimates are available from ONS.

[4] We take the exposures E_{xi} to be the mid-years population estimates for each percentile in 2015

2.4 Life tables, life expectancy and variation in lifespan by deprivation

As stated in the introduction, since our focus is on adult inequalities we concentrate on demographic quantities conditional to surviving to age 30. This is to avoid the possible confounding effects of infant mortality and of deaths in early adult age on our analysis. With the Three-Way Lee-Carter model and the generalised additive model described in the previous two sub sections we can derive deprivation specific central death rates for ages 30 to 89. However, to be able to compute period life expectancies and other life table related quantities, we require one-year probabilities of death beyond age 89 and up to age 110. Therefore, to extrapolate death probabilities beyond age 89 we use the quadratic differencing formula proposed in Haberman and Renshaw (2009).

Let m_x denote the central death rate at age x and let age q_x denote the one-year probability of dying for someone age x. For ages, 30 to 89 we set $q_x = 1 - e^{-m_x}$. For ages 90,91,..., 110, we follow Haberman and Renshaw (2009) and extrapolate one-year death probability along the x axis using the following formula:

$$\log q_{89+j} = a + bj + cj(j+1), \quad j = 1, \dots, 21,$$

with $a = \log q_{89}$, $b = \log q_{89} - \log q_{88}$, $c = (\log q_{110} - a - 21b)/(20 \times 21)$, and under the assumption that $q_{110} = 1 - e^{-0.7} = 0.50341$.

Given, the values of q_x, $x = 30, \dots, 110$ we compute period life expectancy at age 30 as

$$e_{30} = \sum_{k=1}^{110-30} l_{30+h} + 0.5,$$

where $l_{30} = 1$ and $l_{30+h} = \prod_{i=1}^{h}(1 - q_{30+i})$, $h = 1,2, \dots, 80$.

Finally, and similarly to Mayhew and Smith (2016,2019), we base our quantification of life span variation on the difference in years between the age to which 90% of the population survive and the age of the top 5% of survivors for people that have attained the age of 30. Formally, if x_l and x_u denote the ages that satisfy $l_{x_l} = 0.9$ and $l_{x_u} = 0.05$, then the life span variation would be given by $x_u - x_l$. We note that to compute x_l and x_u, we assume that l_x varies linearly between integer ages.

3. Trends in gender inequality

3.1 Mortality rates

Charts showing distribution or spread in age at death give a visual expression of inequalities in lifespan especially the differences between men and women. If everybody died at the same age there would be no inequality but this is plainly not the case. Deaths are classified by cause of death and whether they are unavoidable or avoidable but the point we wish to draw out in this section is how the pattern has changed over time and whether the gender gap is closing or widening.

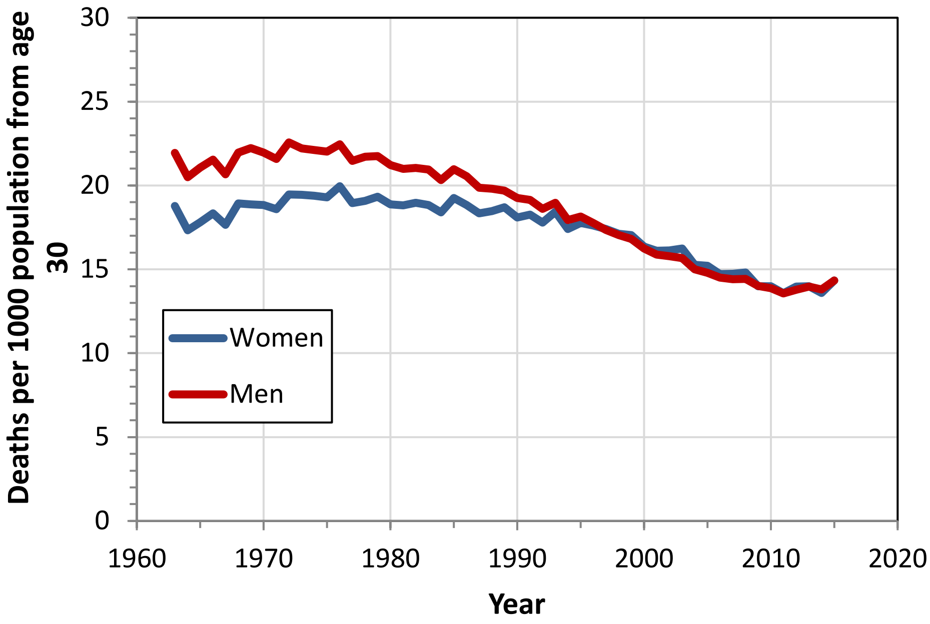
In a stable population with a constant number of births and deaths, a falling number of deaths usually signals an improvement in survivorship and an increase in life expectancy. An increase in the number of deaths signals the opposite and a levelling out in life expectancy. However, we do not live in a stable population and so reasons for changes in the number of deaths from year to year need to be treated circumspectly and mortality rates – deaths per thousand population is a better option for showing mortality trends.

Here, we consider both in general terms to be followed by more detailed analysis. However, a story that repeats itself is that men are catching up with women but also that the improvements are not spread evenly or at all ages. If we take England and Wales, the total annual number of deaths regardless of gender has fallen since 1976 from around 560,000 to 30,000 fewer in 2015. This may not sound like a big difference until it is pointed out that the population age 30+ increased from around 27m to 36m over the period.

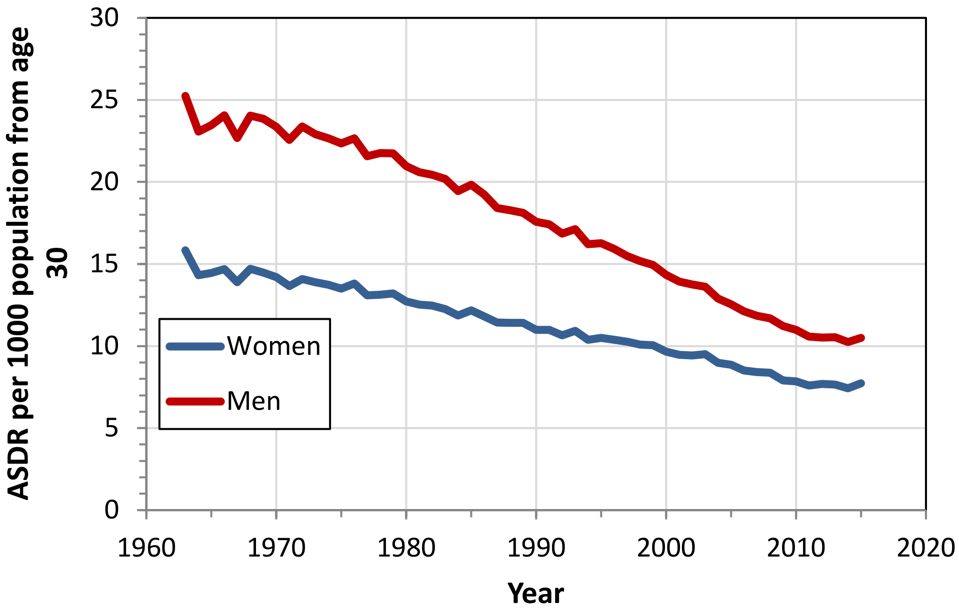
Figure 2 shows the trend in crude mortality rates and in age standardised mortality rates at age 30 by gender based on the observed population and number of deaths from 1963 to date. The crude mortality rates reported in Figure 2 are the simple ratio of deaths and population of people over age 30 while the age standardised mortality rates are a weighted average of age specific mortality rates with weights derived from the European Standard Population (Eurostat, 2013). [5]

As can be seen crude rates increased from 1963 and peaked in the mid-1970s before declining and flattening out after 2010. Male rates were consistently higher than female's before 1997 when they were equal for the first time, since when they have tracked each other closely. At their peak, crude male mortality rates were 56% higher than today and female rates 39% - indicating a huge decline. Similarly, age standardised death rates (ASDRs) – which account for the differences in structure of the male and female population – show a convergence between male and female mortality with the ASDR of men changing from being 59% higher than that of women in 1963 to being only 35% higher in 2015.

[5] The European Standard Population (ESP) is an artificial population structure that is used in the weighting of mortality or incidence data to produce age-standardised death rates (ASDRs).



(a)



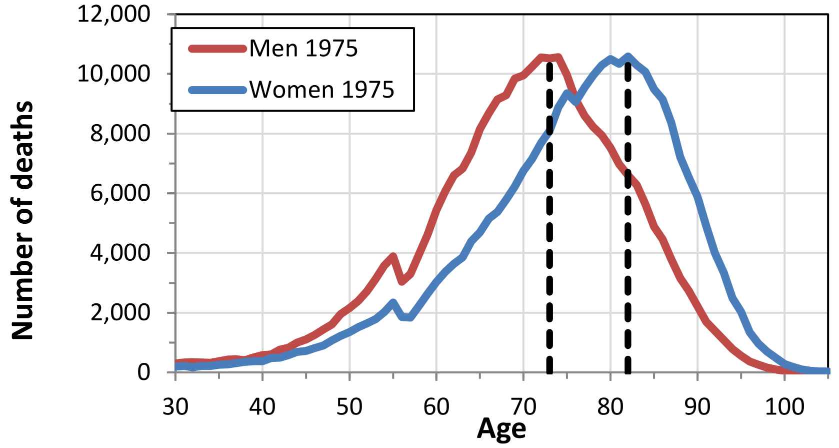
(b)

Figure 2: Crude mortality rates in the 30+ population (a) and Age Standardised Death Rates (ASDR) from age 30+ (b) in England and Wales from 1963 to 2015 for men and women. Age standardisation is performed using the 2013 European Standard Population

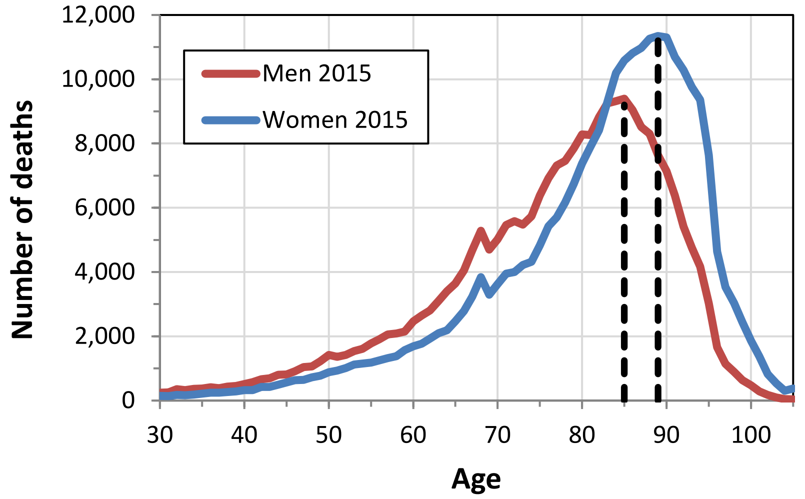
3.2 Distribution by age of death

Figure 3 shows the distribution in the observed number of deaths by age and gender at two snapshots in time 40 years apart – 1975 and 2015. It can be seen in Figure 3(a) that the total number of deaths represented by the areas under the curves was broadly similar in 1975 regardless of gender. The main difference was in the modal age at death which was 82 for women and 74 for men.[6]

Figure 3(b) shows the same distributions in 2015 in which the female modal age at death has increased by 7 years from 82 to 89 compared with 1975 and the male modal age at death by eleven years 74 to 85 and also fewer male deaths overall. This is clearly a significant improvement but an important question is whether age at death has become more or less compact, i.e. has the distribution narrowed or not?



(a)



(b)

Figure 3: Charts showing the number of observed deaths by age and sex for England and Wales in (a) 1975 and (b) 2015 (hatched lines show the modal age at death)

[6] The perturbation in both graphs between 50 and 60 in (a) 60 and 70 in (b) can be traced to a reduced number of births at the end of the first and second world wars.

Table 1 shows three measures of central tendency for each gender - the mode, average, and median - and two measures of variability - the standard deviation and inter-quartile range.[7] It shows an increase in all three measures and a widening in variability based on the inter-quartile range, which is 2.3 years greater for men and 0.1 years for women. The standard deviation also widens but the amount is 0.8 years for women and 1.8 years for men.

Men	Modal age	Average age	Standard deviation	Median age	IQR
1975	74	70.3	11.4	70.6	15.1
2015	85	76.5	13.2	78.6	17.4

(a)

Women	Modal age	Average age	Standard deviation	Median age	IQR
1975	82	75.6	11.9	77.0	15.5
2015	89	81.4	12.7	83.8	15.4

(b)

Table 1: Measures of central tendency in age at death for men and women in 1975 and 2015 based on observed deaths (Note: IQR = Inter Quartile Range)

In combination, the results indicate that there has been a significant postponement in the age at death over the period. This has benefited men more than women with whom they are catching up, although the variability in age at death remains higher for men than for women and so there is still some way to go before equality is achieved. Another notable point to make about these charts is that the number of deaths over 100 years of age has also increased, a point to which we return below.

3.3 Trends in adult life expectancy by gender

Historically speaking, as these results indicate, women live longer than men but the difference has varied considerably through the last 150 years and was actually narrowest in the early 20th century. The gap reached a peak in 1969 when women aged 30 had a life expectancy of 5.7 years longer than men but this has since fallen to 3.5 years (Mayhew and Smith, 2014).

Although demographers are in agreement that male and female life expectancy is converging, they disagree on the speed of convergence and also differ on the baseline. Although the ONS provides more recent data than the HMD, the HMD is available from 1950 to 2013 but is not broken down by deprivation decile. ONS data does this but is only available from 2001 to 2015 and at an England level.

We used HMD life table data to investigate gender differences in adult life expectancy from 1950 onwards which we then break down to investigate convergence within different age

[7] The gap in years between the age at death of the 25th and 75th percentiles of all deaths age 30+.

segments. Figure 4, based on HMD data, shows the trend in period life expectancy at age 30 from 1950 to 2015 for men and women. To all intents and purposes, the trend has been a fairly smooth upward progression (in earlier decades the progress was bumpier due to deaths from infectious disease or conflicts). The dotted extrapolation based on a quadratic trend using 1950 as a base shows how the trend might continue (See Mayhew and Smith (2014)).

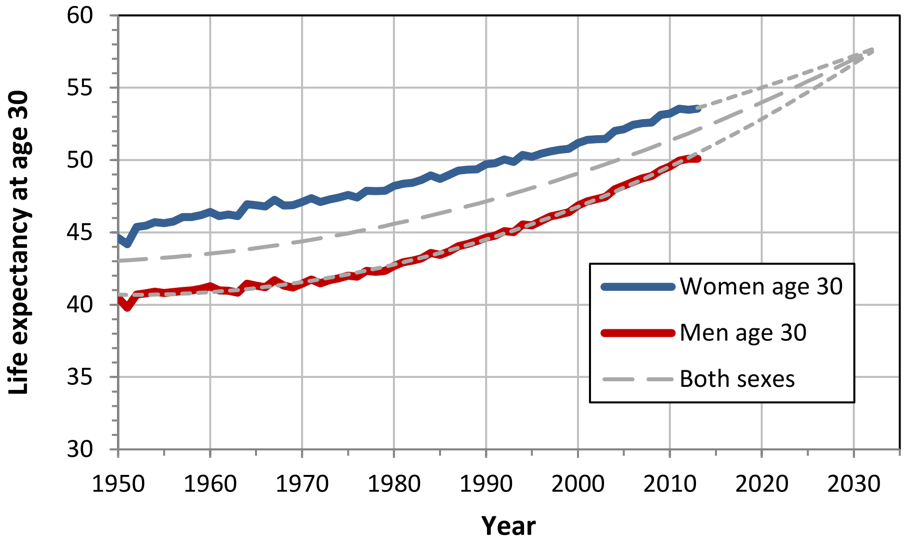


Figure 4: A comparison of adult life expectancy at age 30 1950 to 2013 with projections to 2032 (source: The Human Mortality Database)

In 1950 female life expectancy in 1950 at age 30 was 44.6 years, 4.1 years higher than for men. However, it was not until 1990 that men reached the level that women were at in 1950 when it was 44.6 years. The length of time it has taken illustrates how difficult it can be to close a gap once it has started. Since then improvements have continued and the gap has further narrowed confirming that gender equality is well underway.

If the trend continues the gap could disappear altogether after 2032 when life expectancy at 30 will be around 57.5 years for both genders. In international terms it is noteworthy that the current gap is already less than in comparable developed economies such as France, Japan, Italy and the US. If gender parity is achieved it would send the signal that there is no fundamental biological reason why men should not live as long as women.

However, it can be argued that more recent data are better representative of current trends and that the extrapolation is over-optimistic. If a shorter period from 2000 is used, we find that the trend is linear and the rate of convergence is slower, such that male life expectancy by 2030 would be only 55 years and the male female gap 2.3 years. Hence, whilst we observe a trend toward convergence the year of convergence itself is uncertain. Section 4 investigates the role played by deprivation in this regard.

3.4 Trends in partial life expectancy

Although trends in life expectancy demonstrate gender convergence in life expectancy from 1970, this effect could be caused by different rates of progress among men and women at different ages. For example, aggregate improvements could be the result of far more women living to beyond 100 and fewer men than women dying in their 60s, resulting in the same life expectancy but diametrically opposed ageing patterns.

We use the concept of partial life expectancy to analyse the age groups that are advancing most quickly in terms of life expectancy (Mayhew and Smith, 2015). This is simpler than it sounds and works as follows. Suppose a person has reached a certain age, 30 say. Partial life expectancy measures how many of the next ten years a person will live on average. Since this cannot exceed ten years this is the absolute maximum achievable (see Mayhew and Smith (2015)).

We extend this idea to each decade of life. For example, we know that a typical thirty-year old can be fairly certain of reaching age 40 and so already has a partial life expectancy close to the maximum. However, a woman turning age 70 in say 2016 can expect to live only 8.3 years of the next ten, and if she reaches 80 only another 5.7 years. For a man it is 7.6 years and 4.7 years. The concept holds for other ages as well.

Because the trends are very regular it is easy to quantify which age groups have peaked and those where there is potential for improvement. The improvement ceiling of ten years means that it is also technically easier to produce forecasts. As partial life expectancies can be calculated separately for both men and women we can measure how much progress is being made both by gender and age group as well as the speed of progress.

The only exception is those aged 100 years for which forecasting partial life expectancy, in this case up to 110, is much more difficult. This is because life table data are less reliable for this age group since so few attain this age and because statistically the rates of improvement are still extremely small and hence harder to project for more than a year or two ahead. For these reasons this age group is excluded from the tables and charts that follow.

Tables 2(a) and (b) show partial life expectancy results for men and women at three points in time: 2001, 2016 and 2031 at ages 30, 40….90. They show that it has increased at every age between 2001 and 2016 and is predicted to increase further still to 2031. They confirm for example that men and women reaching age 30 can already expect to reach age 40 with relative certainty because they have partial life expectances of 10 years to one decimal place.

Men	30	40	50	60	70	80	90
2000	9.9	9.8	9.4	8.5	6.2	2.9	0.5
2016	10.0	10.0	9.5	9.0	7.6	4.7	1.1
2031	10.0	10.0	9.7	9.4	8.8	7.1	3.1

(a)

Women	30	40	50	60	70	80	90
2001	10.0	9.9	9.6	9.0	7.5	4.4	1.0
2016	10.0	9.9	9.7	9.3	8.3	5.7	1.8
2031	10.0	9.9	9.8	9.5	9.0	7.4	3.5

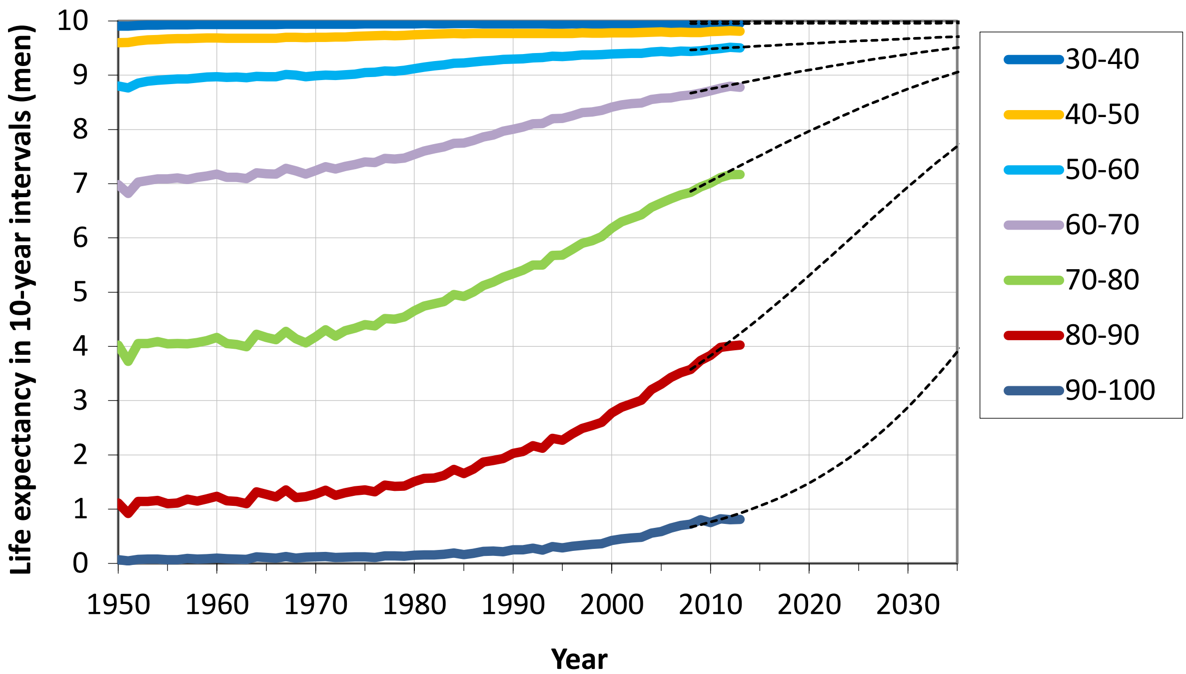
(b)

Tables 2(a) and (b): Partial life expectancy at ten year intervals for men (a) and women (b) in 2000, 2016 and 2031

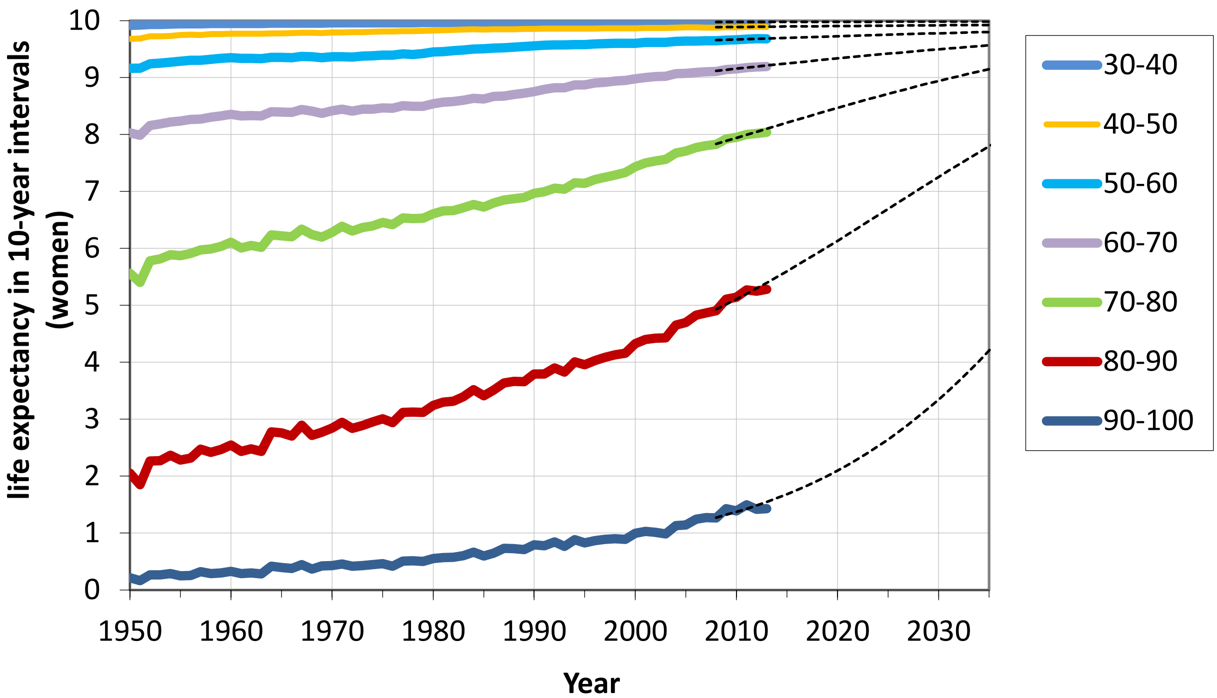
With partial life expectancies of just less than 10 years, reaching age 50 or 60 is slightly less certain than reaching age 40 but is still more certain for women than for men. From age 60 through to age 90 the prospects of surviving the next ten years fall much more quickly, so that a man attaining aged 90 in 2016 can only expect to live just 1.1 years and a women 1.8 years.

Because the trends are asymptotic i.e. no curve cannot exceed ten of the next ten years, this makes them relatively easy to project forward, so that the overall effect appears as a series of waves. This may be seen in Figures 5 (a) and (b) which show how partial life expectancy has evolved between 1950 and 2010, in which it is seen to be increasing fastest at older ages and slowest where the asymptote is closest to ten years. Particularly noteworthy are the improvements seen by men since 1950 at ages 60, 70, 80 and 90.

The tables show that by 2031 men achieve more or less parity with women by age 60 and so are improving at a faster rate, although this is not the case at age 70 when women are slightly in front. At age 80 men and women can expect to live another 7.1 and 7.4 years respectively which compares with only 2.9 years and 4.4 years in 2001. Overall it means that gender convergence is occurring such that both men and women who would have died in their 60s are living to their 70s, more in their 70s living to the 80s and so on.



(a)



(b)

Figure 5(a) and (b): Trends in partial life expectancy at ages 20, 30……90 for men and women from 1950 to 2013 with projections to 2040 (source: Human Mortality Database)

As far as we can tell the gains that have occurred will continue although the usual warnings apply as with all forecasts. Although women will still live for longer, at least for now, the male rate of improvement has been faster notwithstanding the most recent period. For example, the charts also show a slight slowdown after 2010 which may or may not be a blip. What happens from 100 is still uncertain for the reasons given but if the rate of change is slower than it was in the 80s and 90s overall life expectancy overall could start to level out, although this might take decades more.

4. Demographic inequalities due to deprivation

4.1 Integrating deprivation

That life expectancy and lifespan are adversely affected by deprivation has been studied for well over a century (Charlton and Murphy, 1997). The mechanisms by which this occur are based on a complex mix of factors such as low educational attainment, hazardous working environments, a lack of social mobility, adverse life styles including the self-inflicted health dangers of poor diet, smoking habits, drug abuse etc. which largely reflect individual behaviours, but also by ambient exposure to the physically harmful effects of crime, air pollution and accidents (Mayhew and Smith, 2019).

In this section, we focus on the analysis of the impact of deprivation on life expectancy, lifespan variation and mortality building on the approach of Villegas and Haberman (2014) and of Russolillo et al. (2011). As discussed in Section 2, we use ONS demographic data split into IMD deprivation deciles which we then convert into life tables. We compare results at three snapshots in time 15 years apart: 2001, 2016 and 2031 and present charts showing the long term trends over the period.

4.2 Male adult life expectancy by deprivation decile

We begin with life expectancy after which we turn our consideration to changes in lifespan variation and mortality. Overall the results reveal that whilst life expectancy continues to increase in each decile the gap between the longest and shortest lived is widening rather than narrowing. Secondly, for both genders, there is an increasing gradient from the most to the least deprived decile but that the largest inter-decile difference is between the two most deprived deciles, D1 and D2.

Starting with men, Table 3 shows that male period life expectancy at age 30 has improved over the period from 2001 to 2016 with the England average increasing by 3.1 years from 47.4 to 50.5 years. However, the gap between D1 and D10 increased from 8 years in 2001 to 8.6 years in 2016 and is expected to increase further to 8.8 years in 2031. It also shows that D1 to D5 have lower life expectancies than the England average as shown in the bottom row of the table and that D6 to D10 have higher life expectancies than the average.

Male life expectancy at age 30 by deprivation decile	2001	2016	2031	Forecast gain(+)/loss(-) 2016 to 2031
D1	42.5	45.2	47.9	2.7
D2	44.3	47.1	49.9	2.7
D3	45.4	48.5	51.3	2.9
D4	46.6	49.7	52.6	2.9
D5	47.4	50.6	53.5	2.9
D6	48.1	51.3	54.2	3.0
D7	48.6	51.8	54.7	2.9
D8	49.1	52.3	55.3	2.9
D9	49.5	52.9	55.8	2.9
D10	50.5	53.8	56.7	2.9
Gap High –Low	8.0	8.6	8.8	0.3
England average	47.4	50.5	53.5	2.9

Key: All figures in years; D1 = most deprived; D10 = least deprived

Table3: Trend in male adult life expectancy in years by deprivation decile

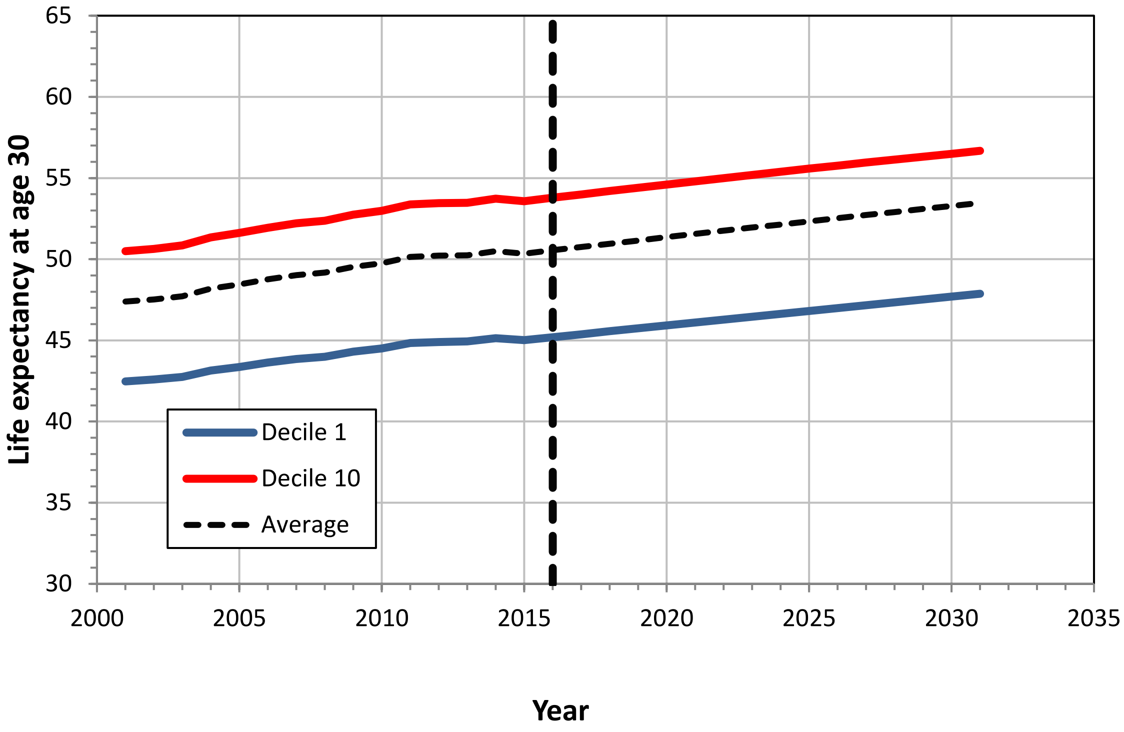


Figure 6: Trend in male life expectancy in England: Most and least deprived deciles centred on 2016

Figure 6 shows the long term trend in life expectancy for the top and bottom deciles and the England average for men in chart form. It shows that the trend is upward but the gap is widening slightly over time. It is seen that the rate of increase slowed slightly between 2010 and 2015 due to a slow down in the rate of increase in life expectancy after 2010 but is projected to continue its upward trajectory thereafter, albeit is a slightly slower rate than between 2001 and 2010.

4.3 Female adult life expectancy by deprivation decile

A similar picture applies to women except that the level of inequality is less but in other respects the same pattern recurs. Table 4 shows that period life expectancy at age 30 increased by 3.2 years between 2001 and 2016 from 51.6 to 55.8 years. In the same period, the gap in life expectancy between D1 and D10 increased from 5.5 years in 2001 to 6.6 years in 2016 and is expected to increase further to 7.3 years in 2031. As might be expected, D1 to D5 have lower life expectancies than the England average and that D6 to D10 have higher life expectancies. However, disparities are highest between deciles one and two.

Figure 7 shows the long term trend in life expectancy for the top and bottom deciles and the England average for women in chart form. It is seen that the trend is also upward with the gap also widening slightly over time. As for men, the rate of increase slowed slightly between 2010 and 2015 due to a slow down in the rate of increase in life expectancy after 2010 but, as for men, is projected to continue its upward trajectory thereafter.

Female life expectancy at age 30 by deprivation decile	2001	2016	2031	Forecast gain(+)/loss(-) 2016 to 2031
D1	48.2	49.8	51.3	1.5
D2	49.4	51.2	52.9	1.7
D3	50.3	52.3	54.2	1.9
D4	51.1	53.1	55.1	1.9
D5	51.7	53.7	55.7	1.9
D6	52.0	54.2	56.3	2.1
D7	52.4	54.7	56.9	2.1
D8	52.6	55.0	57.2	2.2
D9	53.0	55.5	57.8	2.3
D10	53.8	56.4	58.7	2.3
Gap High -Low	5.5	6.6	7.3	0.8
England average	51.6	53.8	55.8	2.0

Key: All figures in years; D1 = most deprived; D10=least deprived

Table 4: Trends in female adult life expectancy in years by deprivation decile

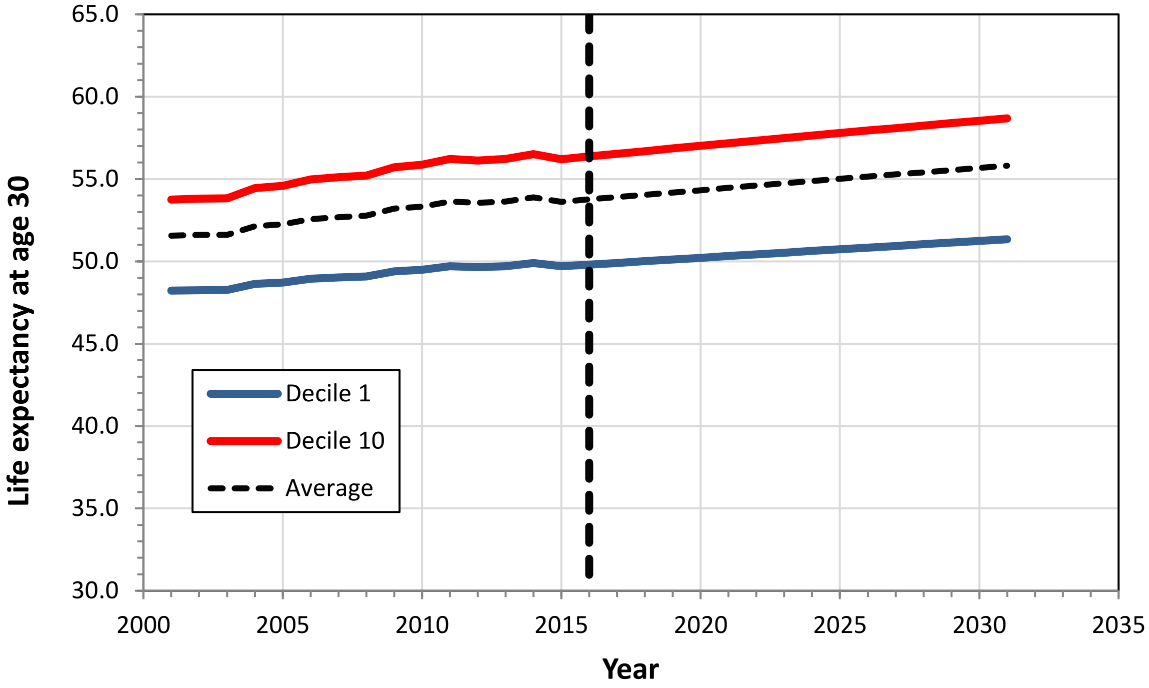


Figure 7: Trend in female life expectancy at age 30 in England: Most and least deprived deciles centred on 2016

4.4 Inequalities in lifespan by deprivation decile

As useful and as familiar as life expectancy is, it suffers from the problem that it only deals with average longevity. This is because it conceals variations around the average that may be suppressing important information about other measures of inequality such as lifespan variability (e.g. within a country or region with extremes of rich and poor).

We performed the same analysis for lifespan variation as for life expectancy based on the definition set out in Section 2.4. We base our quantification of life span variation on the difference in years between the age to which 90% of the population survive and the age of the top 5% of survivors for people that have attained the age of 30. The higher the value the greater the disparity there is in lifespan with zero indicating perfect equality.

We choose this measure of lifespan variation over rival measures (e.g., the standard deviation of the age at death or the Gini Index) for its simplicity and ease of calculation.[8] Note however that the use of the 90% and 5% cut offs are arbitrary and derived from the value of l_x based on the corresponding percentiles for any given life table. Our experience is that this definition is good at picking up outliers in distributions and is therefore more sensitive to variations in deprivation than alternatives such as the inter-quartile range (Mayhew and Smith, 2016 and 2019).

[8] See Mayhew and Smith (2016) for a discussion on alternative measures of life span inequality.

Table 5 (a) and (b) shows the decile variation in lifespan for men and women based on this approach. They show that, similar to life expectancy, there are significant differences in lifespan variation between men and women at either end of the deprivation spectrum. However, it can be noted that the trend going forward to 2031 is for a reduction rather than an increase in variation as the final columns indicate, which means a narrowing in within decile inequality.

In 2016, for example, the variation in male lifespan in 2016 was 32.2 years in 2016. This ranged from 38.4 years in D1 to 28.1 years in D10, a difference of 10.3 years. Although differences in lifespan variation within deciles are seen to be getting smaller over time, we find that differences between deciles are getting wider. For example, in D10 the gap is reduced by 2.2 years between 2000 and 2031 for men but in D1 it is reduced by only 0.2 years. The net reduction for the whole country is 1.4 years.

A similar pattern applies in the case of women. The range in their case is from 35.6 years in D1 to 26.5 years in D10 in 2016, so the inequality gap between top and bottom deciles is smaller than men's. Their net reduction for the whole country is 1.2 years. Overall we can therefore conclude that the reduction in inequalities applies to all levels of deprivation, but is proceeding at the fastest rate in the least deprived deciles and at the slowest rate in the most deprived.

This subtle difference probably accounts for the perception that inequalities are getting worse relatively speaking although in absolute terms they are improving, albeit at a slower pace in the poorest areas. Nevertheless, the slow rate of improvement in lifespan variation in the more deprived areas shows that inequalities are more entrenched than in the less deprived areas which itself is a cause for concern especially in D1. For poorer deciles, it is also noteworthy that it is the 90^{th} percentile which is not improving fast enough as opposed to the top 5% which is similar among all deciles. This suggests that the divergence in lifespan variation between the most deprived and least deprived deciles is driven mainly by the difference in the pace of mortality decline at young and middle ages.

(a) Men

Variation in male lifespan at age 30 by deprivation decile	2001	2016	2031	Forecast gain(+)/loss(-) 2016 to 2031
D1	38.1	38.4	38.2	-0.2
D2	35.8	35.9	35.4	-0.5
D3	34.7	34.6	33.8	-0.8
D4	33.8	33.4	32.3	-1.1
D5	32.6	32.0	30.7	-1.4
D6	31.8	31.1	29.5	-1.6
D7	31.0	30.2	28.5	-1.7
D8	30.5	29.6	27.8	-1.8
D9	29.9	28.8	26.8	-2.0
D10	29.4	28.1	25.9	-2.2
Gap High -Low	8.7	10.3	12.3	2.0
England average	32.7	32.2	30.8	-1.4

(a) Women

Variation in female lifespan at age 30 by deprivation decile	2001	2016	2031	Forecast gain(+)/loss(-) 2016 to 2031
D1	35.8	35.6	35.2	-0.4
D2	33.9	33.5	33.0	-0.6
D3	33.1	32.6	31.8	-0.8
D4	32.1	31.4	30.4	-1.0
D5	31.0	30.2	29.0	-1.1
D6	30.3	29.3	27.9	-1.4
D7	29.7	28.7	27.1	-1.6
D8	29.2	28.1	26.4	-1.7
D9	28.8	27.4	25.6	-1.9
D10	28.1	26.5	24.4	-2.1
Gap High -Low	7.7	9.1	10.9	1.8
England average	31.2	30.4	29.1	-1.2

Key: All figures in years; D1 = most deprived; D10=least deprived

Table 5 (a) and (b): Tables showing variations in lifespan by deprivation decile (units years)

4.5 Extremities in life expectancy and inequalities in lifespan

Previous sections identified striking differences in life expectancy and lifespan variation by deprivation decile. However, deciles are large groupings, each decile comprising 10% of all

LSOAs ranked by level of deprivation. Within each decile it means that the demographic experiences of the populations in some 3,200 LSOAs or neighbourhoods are being averaged, so concealing the extremities in the top and bottom 1% of deprived neighbourhoods.

(a) Life expectancy by deprivation percentile

To identify these extremities, we derive the same measures at a percentile level – in other words we create groupings of LSOAs comprising 1% intervals instead of 10% and then repeat the analysis. Figure 8 charts the change in period life expectancy at age 30 in 2015 by deprivation percentile for men, women and both genders combined resulting from this analysis.

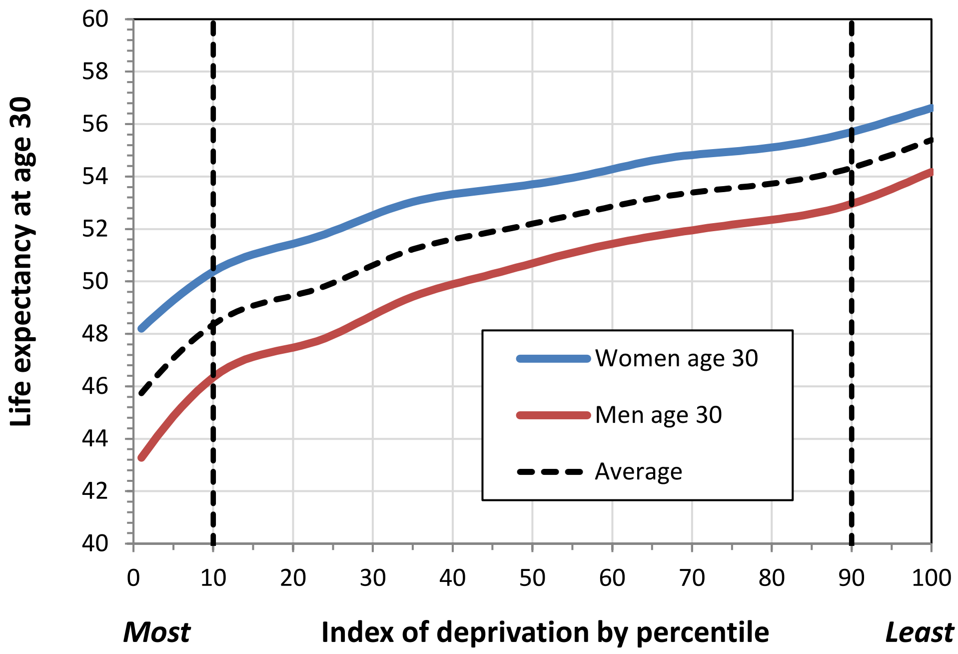


Figure 8 Male and female period life expectancy at age 30 in 2015 in England by deprivation percentile

The percentiles now range from the 1st percentile (most deprived) to 100th percentile (least deprived). For men, life expectancy now ranges from 43.3 years to 54.2 years, a gap of 10.9 years; for women, it ranges from 48.2 years to 56.6 years, a gap of 8.4 years. It is particularly noticeable that men appear to be affected much more by extreme deprivation than women. Not only do women have a higher life expectancy than men but the range of difference between the most and least deprived percentiles is less by a couple of years.

The other striking point to make is the difference in mortality at the extremes causing the poorest of the poor to have much lower life expectancy. For example, the decrease in life expectancy between the 1st and 10th percentiles is somewhat higher than the average decrease between adjacent deciles. By contrast life expectancy is boosted between the 90th to 100th percentiles i.e. in the richest areas of the country but not as much as the boost between the 1st and 10th percentiles.

(b) Lifespan variation by deprivation percentile

We conducted the same analysis at percentile level this time based on lifespan variation. These results are shown in Figure 9. To recap, lifespan variation is based on the difference in years between the age to which 90% of the population survive and the age of the top 5% of survivors for people that have attained the age of 30. The results again show that the variation in range of lifespan is always higher for men than for women.

For either gender it is highest in the 1st percentile and lowest in the 100th deprivation percentile. For men the range is from 26.5 years to 39.7 years, a difference of 13.2 years and for women from 24.7 years to 36.3 years, a difference of 11.6 years. As with life expectancy the gender gap in lifespan variation is a minimum in the 100th percentile and a maximum in the 1st, indicating that the difference in gender impact of deprivation on lifespan variation is inversely correlated with socio-economic conditions. Furthermore, these results show that the most deprived parts of England not only experience shorter life expectancy than the least deprived parts, but also experience higher variability in their timing of death.

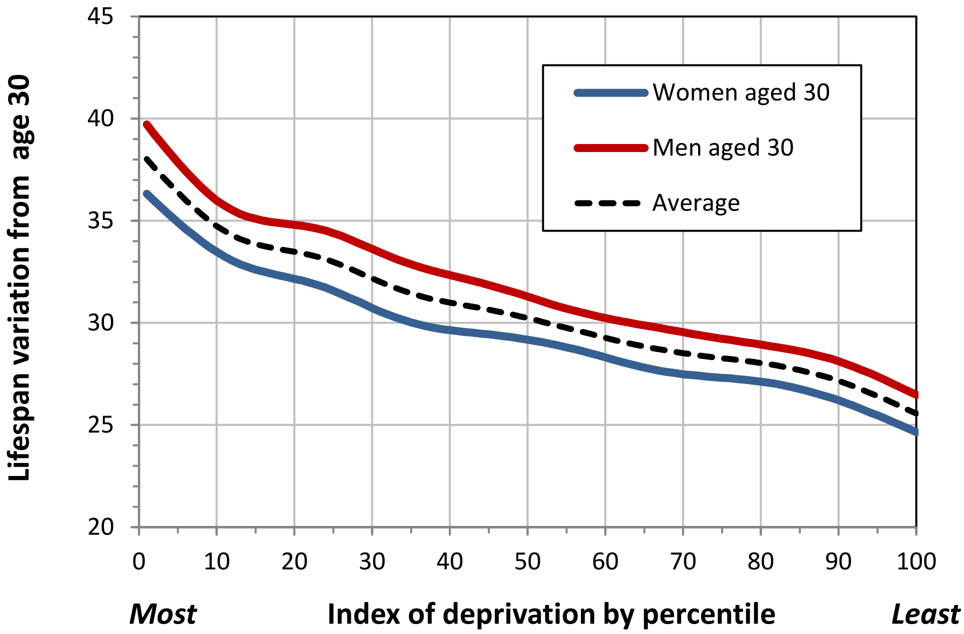


Figure 9: Variation in lifespan by deprivation percentile

4.6 Relative mortality by deprivation decile

The results from the preceding sections indicate that deprivation affects both life expectancy and the lifespan variations of both genders but men appear to be more disadvantaged than women. None of our measures of inequality so far has been concerned directly with differences in mortality rates between deprivation deciles.

Although adult life expectancy is increasing over the long term and therefore causing mortality risk to reduce, we have shown in previous sections that some ‘stickiness’ remains in terms of improvements in the poorest deciles which is causing them to fall behind relative to other deciles.

The ‘stickiness’ referred to is the result of higher mortality rates and hence number of deaths in early adult and middle-age especially among men but also women. This may be seen in Figure 10 (a) which shows the relative mortality rate among men from 2001 to 2015 by age and deprivation decile from ages 25 to 89.[9]

In this chart, the England average is represented by the hatched line so that any decile above this line has a higher mortality rate and any below a lower rate. As can be seen the difference that stands out most is in D1 for which the mortality rate at age 44 is about 2.3 times the England average and 4.4 times that of D10.

From age 44 onward, relative mortality shrinks and starts to converge so that by the time men reach age 80 the mortality rate in D1 is only around 1.7 times the rate in D10. Figure 10 (b) shows the comparable pattern for women. Here, the differences are less pronounced with relative mortality at age 40 in D1 being only 1.9 times the England average and 3 times the rate seen in D10.

Both charts confirm the previous findings that men in general are more susceptible to the adverse effects of deprivation than women. Of particular interest is the fact the difference in the rate between D1 and D2 is consistently higher than the difference between any other pair of deciles. In other words, the more extreme the deprivation is, the bigger the mortality impact.

5 Deprivation by English districts

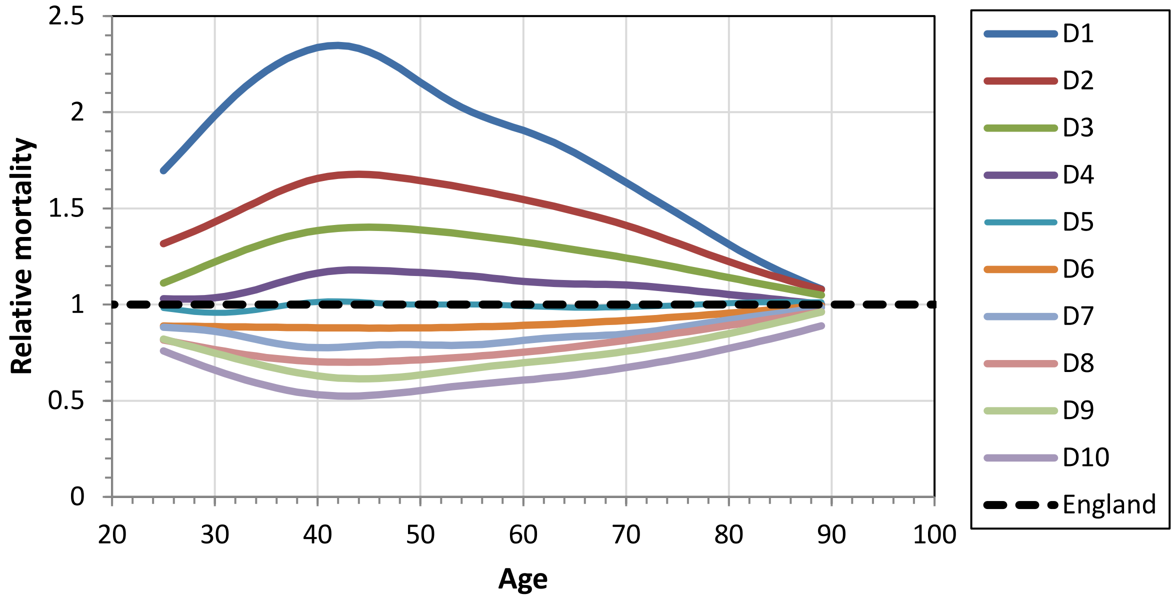
5.1 Geographical considerations

The Index of Multiple Deprivation (IMD) which is used to breakdown mortality, lifespan and life expectancy is known for every local area of England. Although comparable analyses are possible for constituent countries of the UK, it is not possible to join them in a single table due to differences in how the index is calculated in each.

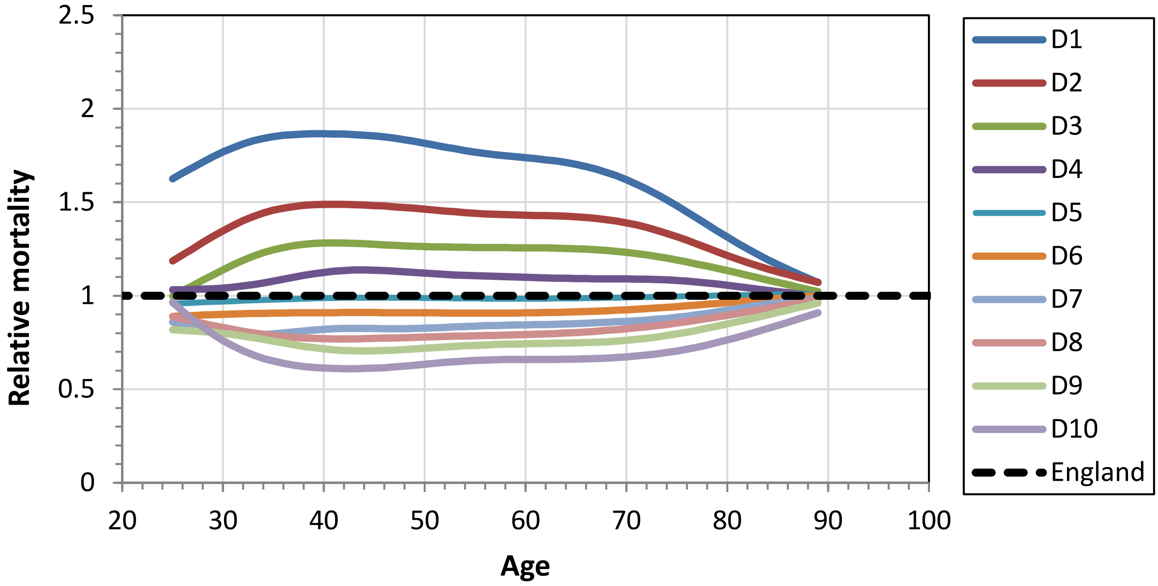
For this reason, we are only able to report on England here. As noted in Section 2.1, the English Indices of Deprivation 2015 are based on 37 separate indicators, organised across seven distinct domains of deprivation in 34,000 neighbourhoods each with an average of

[9] The plotted values correspond to the exponential of parameter α_{xg} in the Three-way Lee-Carter model introduced in Section 2.2.

1,500 people. These are then combined, using appropriate weights, to calculate the IMD for each. With an average of 100 LSOAs per council district the granularity with which it is possible to identify pockets of deprivation is very high.



(a)



(b)

Figure 10 (a) and (b): Relative mortality of men (a) and women (b) in England between 2001 and 2015 by single year of age and deprivation decile as compared with the England average (see dotted line)

Neighbourhoods can be aggregated into higher level geographies as required making it possible to identify whether deprivation in each decile is localised or more common over wider areas. Here we link LSOAs in decile one to the district councils in which they sit for ease of identification in terms of the scale of the problems they face.

For the most part council districts are sub-divisions of counties or metropolitan areas, although some counties known as unitary councils are too small to combine all the functions of both and so are not sub-divided. We are particularly interested in which districts are most affected by deprivation and there are a number of ways to represent this in a map or table.

We choose to base our definition on the percentage of LSOAs in each district that fall into D1, the highest level of deprivation because, as was seen, they have the highest adult mortality levels and shortest lives. Our analysis shows that 200 of the 326 district analysed have at least one single LSOA in the top decile suggesting that deprivation is fairly widespread.

However, further analysis indicates a more unequal picture with deprivation heavily skewed with urban areas in the forefront. We find that among the 22 most deprived districts 25% or more LSOAs fall into D1 and of these the top five districts have 40% or more of their LSOAs. These districts are Middlesbrough, Knowsley on Merseyside, Kingston-upon-Hull, Liverpool and Manchester all in the north of England.

In London by contrast, only Tower Hamlets, Haringey and Hackney fall into the top 50 by rank out of 33 London districts in total, although there are also localised pockets of deprivation even among the richest London boroughs. In the bottom 50% of least deprived districts, the percentage with LSOAs in decile one is only 2.5% or less.

The concentration of inequality in England is captured graphically in Figure 11. This shows the percentage of LSOAs in decile one versus the percentage of all districts. If the most deprived neighbourhoods were spread evenly throughout the country, each district would have an even share and the result would be a line at 45 degrees to the origin.

As is seen, the actual picture is very different and much more unequal with 10% of all districts accounting for 50% of all LSOAs in D1 (A) and just 25% for 80% of all LSOAs (B). Although at least one deprived neighbourhood in D1 is found in two thirds of all districts, the vast majority are concentrated in a relative small number of mainly urban areas. Even in Kensington and Chelsea, one of the richest districts in the country but also the location of the Grenfell Tower fire (Wikipedia, 2019), 11 out of 103 LSOAs are in D1.

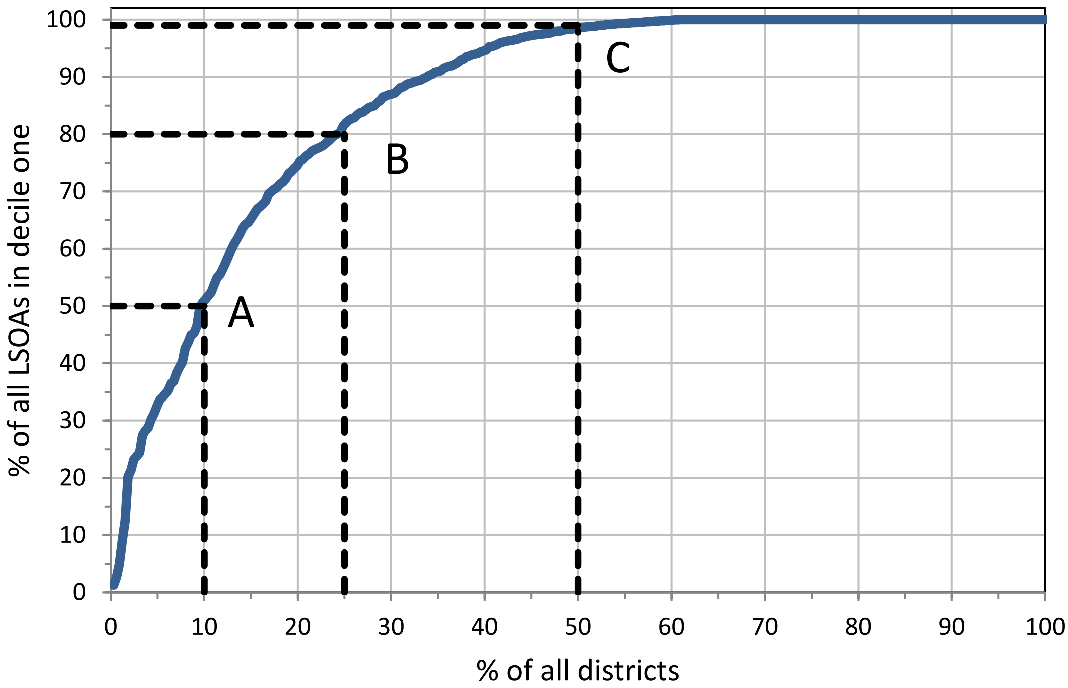


Figure 11: Chart showing the degree of concentration of deprived neighbourhoods in English districts (Key: A 10% of all districts; B=25% of all districts, C=50% of all districts)

5.2 Tabulating and mapping deprivation

Annex A provides a summary table showing the top 80 most deprived districts in England based on this measure. This information is also represented in the map shown in Figure 12 which is a district map of England that has been colour coded according to the percentage of LSOAs in D1.

Overlaid is a 50 km grid to enable the easy identification of specific areas. It shows that deprivation is least in districts surrounding London. For example it shows that the popularly termed north-south divide starts at around row eight moving northward. The hardest hit districts are in the northwest and lie inside rows five and six. These correspond to parts of Liverpool, Manchester and neighbouring northern districts like Blackpool and Burnley in which well over 20% of communities fall into D1.

However, as deprivation levels tend to increase in all directions from London, a more accurate description might be the southeast-rest-of-country divide. Cities such as Birmingham (cell G8) and Stoke (cell G7) and also districts in coastal or estuarine locations such as Middlesbrough (cell H3) and Hull (cell J7) also standout as being among the most deprived districts in England.

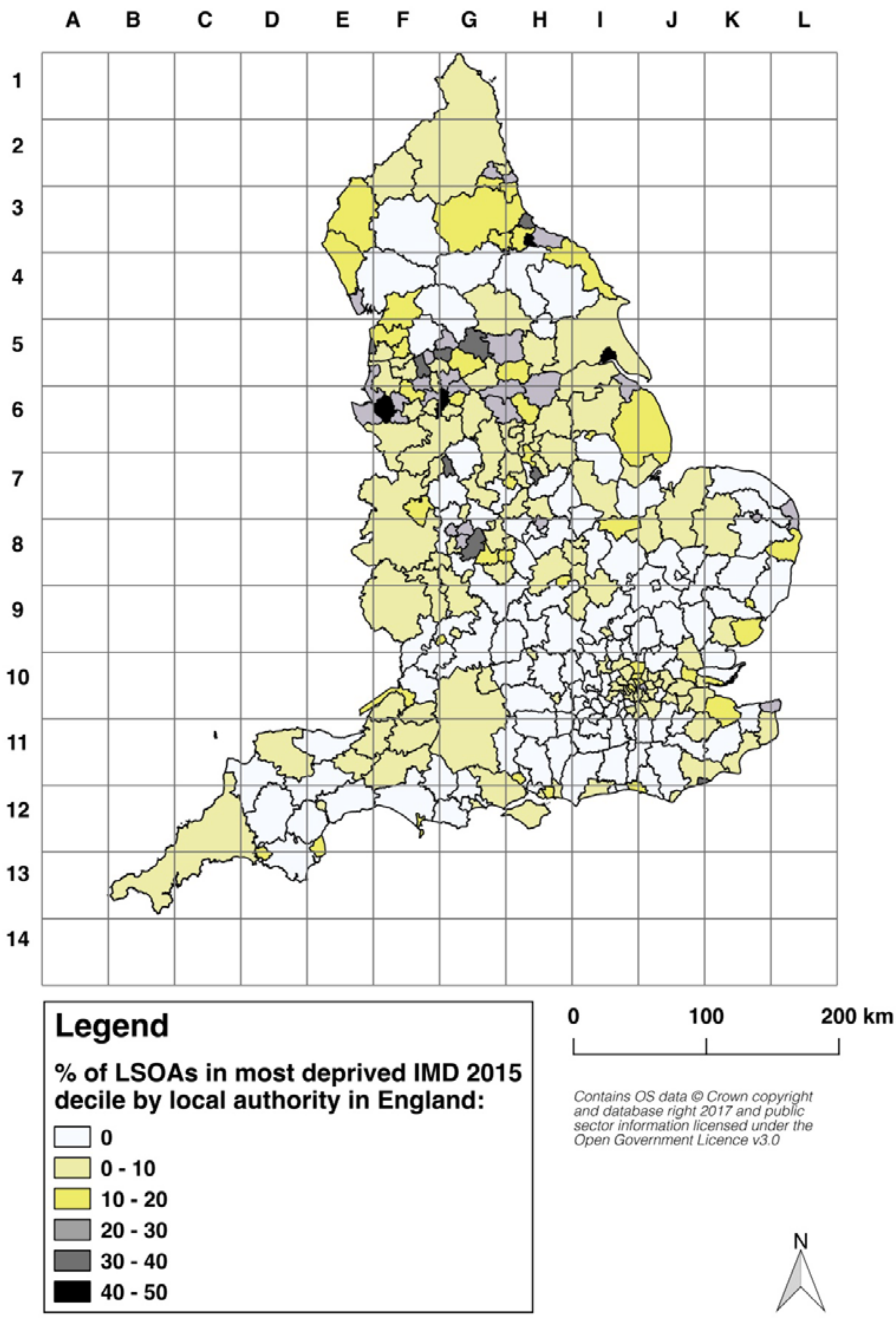


Figure 12: Map showing the percentage of LSOAs falling into decile one (most deprived) in English districts

Additionally, some rural areas are unable to escape deprivation such as Cornwall in cells B12 to C13, but it is also noteworthy that northern rural areas, principally in rows three and four, buck the north-south division. Other areas affected by deprivation are in coastal districts including parts of the south and southwest. In Hastings, for example (located on the southeast corner of cell J11) over 30% of LSOA are in decile one.

6 Discussion

In previous research, we analysed inequalities in lifespan from the 1870s to the present (Mayhew and Smith, 2019).[10] We found that these were inversely correlated with life expectancy so that as life expectancy improved the gap in lifespan narrowed. This was the pattern to 1950, but from then until 1990 the gap in lifespan has been largely unchanged, despite further increases in life expectancy. Indeed, after 1990, we found signs of re-widening, worryingly suggesting that inequalities were growing again.

In this paper, which is concerned with the impact of deprivation on demographic inequality in adults, we found a mixed picture. A positive finding was reducing inequalities between men and women, which is a continuation of a pattern starting in the 1970s. Much of the gain in male life expectancy is attributable to male smoking reduction (Doll et al, 2004; Preston and Wang 2006; Pampel 2006; Murphy and Di Cesare 2012; Mayhew and Smith 2014; Peters et al 2016) and to changes in male employment patterns away from heavier industry.

This is clearly a welcome trend and will lead, among other things, to fewer years of female isolation in later life and longer working lives. However, a second key finding is that these improvements are not being equally shared across society or in all areas, echoing the findings of some others (e.g. Raleigh and Kiri, 1997; Villegas and Haberman, 2014; Bennet et al., 2015). In particular, we find an increasing mortality gradient, and a widening gap in life expectancy and lifespan variation, between the poorest and richest areas of England. We found that the severest problems occurred in the lowest deprivation centiles and were geographically localised.

Although life expectancy is improving generally, we found that the inter-decile gap between the richest and poorest areas was getting wider over time albeit at a slow pace. The adverse effects of deprivation were more noticeable in terms of lifespan variation and were particularly noticeable among men. For example, the lifespan gap among males in the poorest decile D1 is projected to reduce by only 0.2 years from 38.4 years to 38.2 years between now and 2031. In the least deprived decile, D10, it will reduce by 2.2 years from 28.1 years to 25.9 years, so a far greater margin of improvement.

This suggests that the poorest parts of England are experiencing a double burden of inequality, having not only shorter life expectancies than their richer counterparts but also facing higher uncertainty in the timing of death. Inequalities on this scale are a much debated area of health and social policy but to understand whether they can be closed or not it is necessary to step back in time. Prior to 1950, people died in large numbers from

[10] See also: 'An investigation into inequalities in adult lifespan'. ILC-UK, London. http://www.ilcuk.org.uk/index.php/publications/publication_details/an_investigation_into_inequalities_in_adult_lifespan

infections or accidents, but by 2015 the most common causes of death were from cancer, heart conditions or external causes. One exception is death from drug overdoses or self-harm which have increased and appear to have filled the space once dominated by car accidents and which are more prevalent in deprived areas.

What is driving these patterns and are they set to continue and in addition, if they are set to continue, is it possible to influence them in some way? In addressing this issue, it is important to separate gains in life expectancy after 1950. Pre-1940 improvements derived from societal changes from which everybody benefited but in different measure i.e. the poorest in society closed the gap on the richest which benefited less from their introduction. Examples included clean drinking water, improved sanitation, health and safety legislation, cleaner air, and affordable housing (Mayhew and Smith, 2019; Charlton and Murphy, 1997)

The health benefits that are the result pre-dated the big advances in health care with the exception of mass vaccination against infectious diseases. Despite huge progress since, future advances in health care cannot be relied upon to produce similar reductions in inequalities, the implication being that the very big gains achieved are now in the past. As ever there will be exceptions, one example being excess mortality from vehicle emissions and another is the damage to health caused by shortages of affordable good standard housing.

A key point is that, today, the causes of ill health are increasingly life-style related and rooted in the cultures of different socio-economic groups – these include smoking, excessive drinking, drug abuse, mental illness and obesity (Marmot, 2010). For example, recent US research (Islami et al, 2017) found that 47.9% of deaths from cancer were attributable to avoidable risk factors including cigarettes (33.1%), excess body weight (5.7%) alcohol (4.3%) and other factors such as low physical exercise, diet etc (4.8%) (Islami et al, 2017).

This is not to deny huge improvements in healthy living which are occurring, related for example to diet, physical exercise and smoking cessation. The problem is that uptake is very uneven. Districts with low life expectancy also have a lower healthy life expectancy such that a greater proportion of years are spent in ill health (ONS, 2017a). Sasson (2016), for example, argues that wealthier segments of society are better educated on average and so are more likely to adopt healthy behaviours, giving smoking cessation as an example.

In line with this argument, Case and Deaton (2015) have reported a recent significant increase in mortality from drug and alcohol poisonings, suicide, and chronic liver diseases and cirrhosis among less educated non-Hispanic Americans. The link to UK experience is telling because the US does not have a health care system that is free at the point of use and yet inequalities are widening in both countries. However, it is not within the scope of this research to compare causes and ages of death although this would be an obvious area for further research.

It is the case that people from deprived backgrounds are also less likely to make social progress (Social Mobility Commission, 2017). University educated brighter children from poorer backgrounds prefer to seek careers elsewhere rather than returning to their communities, thereby perversely perpetuating the cycle. Stayers are less educated and more likely to be stuck in their ways thus making it even harder to effect change. Creating attractive job opportunities for the young and better-educated in order to retain talent is one way to address this.

The evidence presented here includes the finding that among the 22 most deprived districts in England (6.7% of the total), 25% or more neighbourhoods fall into decile one (D1) and of these the top five districts have 40% or more. The geographical pattern is well established and the reputation of these districts as 'undesirable places to live' tends to go before them also making many of them unattractive as places to invest in. However, glibly labelling it 'a north-south divide' is unhelpful and that a more accurate definition would be 'southeast-rest-of-England divide' with local extremes.

If the poorest in society could be made healthier through greater redistribution of available heath care resources, the negative health and higher rates of mortality which we observe would not exist today but this is plainly not the case (House of Commons, 2009). This suggests that skewing resources towards prevention is a better way forward, otherwise inequalities will worsen as this research identifies. Clearly, other policy tools aimed at changing behaviour using monetary incentives including taxes are needed to steer people towards healthy lifestyles, because if they benefit all of society benefits.

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Annex A: Top 80 ranked English districts according to concentration of deprivation based on 2015 IMD

Deprivation rank	Local Authority District	% of LSOAs in most deprived decile	Deprivation rank	Local Authority District	% of LSOAs in most deprived decile
1	Middlesbrough	48.8	41	Sefton	20.1
2	Knowsley	45.9	42	Sunderland	19.5
3	Kingston upon Hull	45.2	43	Rotherham	19.2
4	Liverpool	45.0	44	Haringey	18.6
5	Manchester	40.8	45	Derby	18.5
6	Birmingham	39.6	46	Coventry	18.5
7	Blackpool	38.3	47	Stockton-on-Tees	18.3
8	Nottingham	33.5	48	Lincoln	17.5
9	Burnley	33.3	49	Hackney	17.4
10	Hartlepool	32.8	50	Tameside	17.0
11	Bradford	32.6	51	Plymouth	16.8
12	Blackburn with Darwen	30.8	52	Swale	16.5
13	Hastings	30.2	53	Preston	16.3
14	Stoke-on-Trent	30.2	54	Peterborough	16.1
15	North East Lincolnshire	29.2	55	Bristol, City of	16.0
16	Salford	28.7	56	Tendring	15.7
17	Rochdale	28.4	57	Torbay	15.7
18	Pendle	28.1	58	Darlington	15.4
19	Halton	26.6	59	Calderdale	14.8
20	Great Yarmouth	26.2	60	East Lindsey	14.8
21	Wolverhampton	25.9	61	Islington	14.6
22	Hyndburn	25.0	62	Wakefield	14.4
23	Leicester	24.0	63	Ipswich	14.1
24	Tower Hamlets	23.6	64	Westminster	14.1
25	St. Helens	23.5	65	Telford and Wrekin	13.9
26	Sheffield	23.5	66	Wigan	13.5
27	Oldham	22.7	67	Wyre	13.0
28	Sandwell	22.6	68	Southampton	12.8
29	Barrow-in-Furness	22.4	69	Gloucester	12.8
30	Newcastle upon Tyne	22.3	70	Portsmouth	12.8
31	Leeds	21.8	71	Scarborough	12.7
32	Barnsley	21.8	72	Waveney	12.3
33	Redcar and Cleveland	21.6	73	Copeland	12.2
34	South Tyneside	21.6	74	Ashfield	12.2
35	Thanet	21.4	75	Southend-on-Sea	12.1
36	Wirral	21.4	76	Northampton	12.0
37	Doncaster	20.6	77	Solihull	11.9
38	Norwich	20.5	78	Gateshead	11.9
39	Walsall	20.4	79	Allerdale	11.7
40	Bolton	20.3	80	Lancaster	11.2