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Stalling of mortality in the United Kingdom and Europe: an analytical review of the evidence

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Abstract

Improvement in UK mortality rates has declined substantially in this decade and the overall value is now close to zero, a finding which has become politically controversial. A similar but less severe change has been observed in some neighbouring European countries, and the US has exhibited a longer term deterioration in mortality improvement. We review the literature and associated commentary on this phenomenon. These UK trends are observed across sex and age groups, but appear to be more marked in more deprived areas. We assess the hypotheses that have been put forward to explain these trends within a framework that distinguishes between short-term fluctuations and longer-term underlying trends; in particular, the role of seasonal influenza, changes in cardio-vascular disease mortality, Government austerity measures and tempo effects. We conclude that that there is no clear evidence for any specific explanation or combination of causes and that additional studies, especially those including cross-national comparisons are needed.

Key words: Life expectancy; UK mortality trends; Europe mortality trends; Influenza; Austerity.

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Note

This Report contains material up to May 2019, when the project finished. In particular, the latest available official information on UK life expectancy at that time was for calendar year 2017, and the latest standardised death rate for England was for 2018. In the subsequent period, later data for quarterly standardised death rates for England up to mid-2019 have become available. These show that there have been substantial mortality improvements for the past 18 months or so, with each quarter in period July 2018 to June 2019 being the lowest recorded for that quarter (Q1 2019 equal lowest). This raises questions about the factors which may be responsible for recent trends and also how these trends may develop. For further details, see Mike Murphy, *The data behind mortality trends: explaining the recent improvement in mortality in England*, LSE Politicsandpolicy Blog, 16 October 2019 available at , https://blogs.lse.ac.uk/politicsandpolicy/explaining-the-recent-improvement-in-mortality-in-england/.

Summary

Long-term trends

There has been a remarkable reduction in the level of underlying mortality improvement in the United Kingdom (UK) in the current decade as compared with the early 2000s. Although still positive, current underlying levels of mortality improvements have been stalling in the UK since about 2011. This is of concern and is in contrast to what had been experienced in the early 2000s, when the UK exhibited the fastest-ever rates of improvement for the past 70 years.

Overall trends in UK mortality are primarily determined by those groups in which deaths are most common, i.e. people above about age 70. Trends in mortality for different age groups above age 40 are similar, although levels of improvement for older people (above age 85) are generally lower and, in some cases, death rates have been increasing. Some downturns in improvements have also been noted at young adult ages.

Trends for males and females are similar. Although male improvement levels remain higher as they have for many decades, differentials exhibit little if any change in recent decades, with changes in life expectancy for women tending towards zero in the most recent years.

There is evidence that the impact of these recent negative trends has been greater among more deprived groups.

There has also been a reduction in the level of underlying mortality improvement in recent years as compared with the early 2000s in many, but not all of the most industrialised European countries. This is particularly the case in the Netherlands, France and Germany, and to a lesser extent in some other neighbouring countries to the UK such as Belgium. Over this century, overall changes in mortality have been very similar in comparator Western Europe countries. However, annual improvements since 2010 have been greater than in the 1990s in some European countries in contrast to the UK.

Declines in mortality improvement from the very high levels of the early 2000s have been built into most forecasts, but the speed of decline has been unexpected.

The significance of recent results may be over-emphasised since they are often comparisons with unprecedented improvements since WWII in the early 2000s. Any explanation for the pattern since 2010 should include analysis of both earlier and later periods around that year – ideally fitting to one period and testing the model on out-of-sample data, although the small number of observations clearly limits options.

Short-term fluctuations

Overall levels of excess winter mortality in the UK show a long-term decline, with some levelling-off or minor increases in this decade. Trends have been largely monotonic apart from a period in early 2000s with slightly lower values. In particular, values in the period 2011-2016 have been very similar to those in earlier periods.

However, there are at least two high excess mortality winter years, 2015 and 2018, in this decade. This suggests that special attention may be required in future and that this decade may turn out to have higher values than at present although we note that values in the past 12 months are the lowest ever recorded. However, the particular case of the 2018 winter is not relevant to the period up to 2017 where most data are available and most analyses to date have been undertaken. Seasonal flu has little contribution to long-term trends since on average seasonal levels have remained largely constant over this century.

Short-term fluctuations in annual deaths, including the “spike” in winter 2014-15 that has attracted much discussion, have distinct determinants and consequences from the long-term underlying trends.

The widespread reductions in life expectancy at birth in 2015 were due to the combination of three factors.

1. Some reduction in the underlying rate of improvement.
2. Unprecedented below-average excess mortality in 2014.
3. Above-average excess mortality in 2015 (although lower than the highest values in the previous two decades in the UK).

Year-to-year variability in rates is substantially driven by years with below-average values as well as above-average ones. Although much has been made of 2018 Q1 death counts, 2018 experienced the second-lowest ever level of mortality in England and Wales, and mortality so far in 2019 remains particularly low.

Many of the studies on this topic have failed to make a clear distinction between short-term fluctuations and long-term trends.

Potential explanations

A number of possible explanations for these trends have been advanced, such as data artefacts, population ageing and international migration, but these cannot provide more than a small proportion of explanation for the observed patterns.

Some stalling of mortality improvement has been expected and built into the forecasts of international and national agencies, research institutes and private firms. The pace of deterioration in the UK has been unexpectedly fast. The magnitude of difference between UK values before and after around 2011, and the simultaneous difference with comparator countries differ substantially. Explanations should be able to explain not only UK trends, but also cross-national differentials.

Given the similarity between UK and comparator countries in overall country-level changes over the period 2006-16, but the divergent patterns within the time interval, these trends could arise in part from timing changes (i.e. tempo-effects) within the interval as well as factors that may have longer-term implications. Understanding the role of tempo-effects is important for assessing future trends and differentials in mortality.

Four potential explanations remain from those suggested so far: influenza, declining rates of cardiovascular disease (CVD) mortality improvement, austerity in the UK, and long-term cohort changes in risk profiles.

Influenza has a major contribution to year-to-year variability in mortality, but the impact of flu and other respiratory infections does not appear to be any greater than in earlier periods and estimates of long-term trends are in any case insensitive to fluctuations in deaths.

The decline of CVD rates has had a long-term influence on patterns across developed countries and this continues into the most recent period. The sharp reduction in improvement in CVD mortality in recent years, especially when compared with the early years of the 21st century has had a substantial effect on the slowdown in mortality improvement. The stalling of overall mortality improvement across many countries is substantially driven by CVD mortality trends. The question of how the determinants of CVD trends lead to an apparently sharp change in the underlying trend remains unanswered. The scope for further CVD improvement to influence overall mortality is becoming less since CVD deaths now form a smaller proportion of the total than hitherto, although there is still space for reducing the social gradient in CVD mortality.

Austerity is a strong candidate for a role in explaining the difference between countries, since the UK exhibited high levels of mortality improvement around 2006-2011 compared with European comparators when expenditure on health and local authority services was increasing rapidly, but particularly low rates in period 2011-16 when UK funding increases were relatively low. Thus, there is some evidence for austerity as a plausible major determinant of mortality trends in the UK since 2010 as these coincided with substantial cuts in a range of welfare, social care and health services. However, a similar explanation would not appear to hold for countries such as the Netherlands, France and Germany that have similar mortality trends, but less austerity. However, stalling is generally more pronounced in the UK than in a number of comparator countries and specific UK patterns, including the increase in mortality differentials between social groups observed since around 2011, need to be explained by UK-specific contextual factors. The explanations for mortality trends need to consider more than just the latter period.

There are problems of interpretation in cause of death statistics due to the increasing propensity to record Alzheimer's Disease/dementias as the underlying cause rather than CVD or other causes and, in addition, influenza deaths are under-recorded. The fact that many older people have a number of health problems and are substantial users of health and social care services, a range of factors such as multiple chronic conditions, infectious diseases and quantity and quality of care services need to be analysed, whereas individual deaths are allocated to a single underlying cause. There is some scope for further use of additional causes mentioned on death certificates.

Cohort factors such as the moving of the “golden cohort” across the Lexis surface, the classic demographic tool used to visualise events occurring to individuals of different cohorts, have some potential to explain part of observed trends. However, this will be challenging given the lack of suitable data to be able to explain relatively short-term period movements and of convincing explanations for much longer-term cohort effects. Nonetheless, some cohort-related factors, e.g. the long-term effects of smoking, might explain the lower reduction of improvements for women compared to men in recent decades.

Part of the changes for period life expectancy observed in the UK appear to be linked to underlying tempo-effects – which arise when substantial numbers of deaths are postponed as a result of changing mortality patterns.

Overall, the assumption that the main explanation for recent UK short-term and long-term patterns is monocausal – either influenza or austerity or CVD reduction – and that these are mutually exclusive is unhelpful and potentially misleading. It is likely that in addition to such hypothesised explanations, a number of other components are contributing, including positive or negative effects on different cohorts due to changes on a range of factors such as smoking, use of statins and obesity. In addition, the result of the simultaneous occurrence of reductions in quantity and possibly quality of services due to austerity, an influenza outbreak and low vaccine effectiveness will be potentially very different than if only one or two of these were to occur, i.e. there is an interaction between these variables. Last, but not least, tempo effects may add to a biased picture resulting from monocausal perspectives.

It should be recognised that there is still substantial room for improving data availability, relevance and timeliness in all of these areas. However, developments should be informed by clear theoretical perspectives as well as data mining.

With the information available today, it is not possible to get a definitive analysis of causes. The lack of clear evidence for the drivers of recent trends implies no clear guidance on whether current trends reflect short-term adjustments and mortality rates will resume steady improvement (although probably not at the high rates of the early 2000s), or a secular long-term change. This report was finalised in May 2019 and therefore does not include later data. There are some encouraging signs of strong mortality improvement in England in the past 12 months or so, which will need to be closely monitored.

Introduction

The UK exhibited a stalling of long-term mortality decline in the current decade. This has led to calls for enquiries about these trends and possible factors underlying these findings. Before detailing the most salient aspects characterising these trends, the main question that has to be addressed concerns the importance of the phenomenon and whether it represents a "real" problem for population health in the UK. For example, a very recent editorial in British Medical Journal (BMJ) stated on the basis of analysis of data in the period 2014-16 by Ho and Hendi (2018):

> "Ho and colleagues report the significant decreases in life expectancy that occurred simultaneously in many high-income countries, usually in 2015. This *universal spike in mortality has often been attributed to the direct and indirect effects of severe flu epidemics*, particularly among older people. The fact that modern healthcare systems in the most advanced high-income countries were unable to cope with this unexpected challenge, resulting in the first reductions in longevity for decades, is *striking and might signal more profound problems*.
>
> Despite a strong recovery observed in many countries in 2016, it is too early to conclude that similar fluctuations or more long-lasting increases in mortality will not occur in the nearest future. Evidence suggests that discontinuities in secular trends can lead to prolonged health crises – *they are warning signs of fundamental and longstanding societal and health problems*." (Jasilionis, 2018; our emphasis in italics).

Such warnings based on widespread, if not universal, stalls in improvement and even a single unprecedented rise in mortality in recent decades need to be taken seriously and suggest that something peculiar is occurring. However, these signals coming early in the debate can push the discussion in the wrong direction and confuse the audience. For instance, in 2016 the BBC presented a News story titled "Over-65s in England 'living longer than ever before'"[1], but a year later the title was "Life expectancy rises 'grinding to halt' in England"[2]. It is thus important to place current events in a framework that considers at least three main aspects:

1. The increase in numbers of deaths since 2011 (primarily due to population ageing)
2. The evolution of *long-term* trends in mortality rates
3. The impact of *short-term* annual fluctuations especially in 2015 and 2018, linked to a substantial increase in deaths in the early weeks of these two years.

While these areas are not completely independent, they need to be distinguished as their magnitude, implications and underlying causes have sometimes been confused. For instance, the UK was one of the countries that experienced both an increase in mortality in 2015 and a reduction in the long-term rate of mortality improvement, but these one-off events occurred soon after a decade characterised by steady and impressive mortality improvements.

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[1] See: https://www.bbc.co.uk/news/health-35550407 12 February 2016
[2] See: https://www.bbc.co.uk/news/health-40608256 18 July 2017

This report thus focuses on unpacking discourses around these changes – detailing the influence of both *long-term* evolutions and *short-term* fluctuations on mortality in the UK – to systematically identify their magnitude and potential explanatory factors as far as possible with existing data. It is structured as follows: first, we start by reviewing what has been reported on this topic, in terms of description of the trends in long-term context, short-term annual events, and attempts to identify their causal variables. We further assess the literature comparing the UK experience with what has been written on similar European societies. Second, we highlight some of the key issues emerging from a diverse and sometimes contradictory literature and evidence base by providing analyses of existing data first to better elucidate long-term changes in mortality in the UK, including how common these trends are in the constituent UK countries, and by sex and age groups (Section II); We next compare the UK experience with that of similar European high-income societies (Section III). We then evaluate possible reasons for the observed patterns, with a particular emphasis on whether these trends arise from a particular set of circumstance around this time, or whether they represent a fundamental shift in mortality patterns (Section IV). In the next section, we explore a so-far neglected, but potentially important factor such as the influence of tempo-effects on current mortality changes in the UK (Section V). The last section summarises the findings and provide some conclusions, drawing on parallels in the attempts to identify the causes of the extreme increases in Russian mortality in the early 1990s (Section VI). The report also includes two appendices, one looking in detail at the evidence for a primary role of influenza on recent trends, and the second summarising the results of a survey of European statistical offices on their views about recent trends in mortality. These provide extra evidence linking long-term changes in mortality to short-term annual fluctuations, and report on what important information is perceived as needed from a policy perspective.

Section I – A review of the literature on recent stalls in mortality improvement in the UK

Introduction

Over the 20th century, overall mortality and life expectancy at birth have improved considerably on a global basis, a trend that has continued into the 21st century. In the first part of this century (2000-2010) women and men in the UK experienced average mortality improvements of about 2-3% per annum in age-standardised death rates (SDR)[3] and increases in life expectancy of about 1 year every 5 years and 1.5 years respectively (Office for National Statistics (ONS), 2018a). However, more recently these improvements have slowed down significantly in all the constituent parts of the UK, reaching levels close to zero (ONS, 2018a). The change since around 2011 has been sufficiently large to cause a reduction in life expectancy in 2015 as compared with 2014, most notably at some older ages. These changes in trends have understandably raised questions on the nature of the observed pattern, i.e. whether it is likely to be sustained or short-lived, as well as sparked a debate about the underlying causes of such apparent deterioration in mortality trends.

We reviewed the English language literature for academic studies, analytic reports, blogs and available peer-reviewed research that monitored mortality trends and patterns in the UK and in other high-income countries published between 2008 and May 2019 to first briefly report what has been written on mortality changes in terms of age, sex, levels of deprivation, causes of death and timing. Then, we synthetize the evidence and hypotheses on the determinants likely to have contributed to the observed pattern, including virologic, data- and policy-related factors, and less explored factors, such as cohort effects. Lastly, the literature review discusses the available body of research which compares changes in mortality in the UK to those occurring at the European and wider international level, including the U.S. This is necessary when gauging the plausibility of the explanations put forward in current UK research on the topic and what policy responses might be appropriate.

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[3] We use the term "mortality" to refer to the risk of death as measured by mortality rates by age, sex, socio-economic group etc. The two main indicators used are period standardised mortality rates (SDRs) and life expectancy at birth. Trends in SDRs adjust for age-structure differences, thereby allowing comparison across time and space and any identification of changes in underlying mortality rates. The direct method of standardisation, which is what this report is mainly concerned with, derives the age-standardised mortality rate which would have occurred if the observed age-specific mortality rates were applied to a given standard population. In this case, the standard population is the European Standard Population 2013. Another summary measure of mortality used throughout this report is life expectancy. Life expectancy is the average number of years that would be lived by children born in a given time period, if mortality rates at each age did not change over time. Equally, life expectancy at age 65 is the average number of remaining years of life that an individual aged 65 can expect to live, if mortality rates at each age over 65 remain constant. It is a "period" measure as it does not take into account future changes in mortality. Life expectancy is a summary measure of survival, but it is still widely used as a mortality indicator and it is thus discussed along with SDRs throughout this report as it also takes changes in population size and age structure. The two measures are interrelated so that when SDR declines, then life expectancy is likely to increase, and *vice versa*. The reciprocal of life expectancy at birth is the crude death rate in the life table population, i.e. the sum of deaths rates in the life table weighted by the life table population L_x values, making the link with SDRs clear. However, these weights are themselves a function of the mortality rates and therefore they vary from year to year and this should be borne in mind when interpreting values using different indices.

Is there a mortality problem in the UK?

The UK has experienced a long-term trend of mortality improvements and, consequent increases in life expectancy since the late 19th century. This has been observed for both sexes in all constituent countries until 2010-2011. Since then, however, trends have become more erratic and overall improvements have risen more slowly (Public Health England (PHE), 2018a) or flattened out (ONS, 2018a, 2019).

This change to the trends was not predicted by outside experts or the ONS and happened sooner and faster than it had been forecast. The deterioration in mortality improvements has been identified by several sources as primarily affecting the very elderly, notably women in deprived areas (PHE, 2018a; 2020 Delivery, 2017). The issue came to the forefront of public discourse, when the increase in deaths in England and Wales between 2014 and 2015 had been large enough to cause a fall in life expectancy at birth and at old ages (ONS, 2016a, 2018a, EuroMOMO, 2018). High numbers of deaths were also reported in the first months of 2018 (ONS, 2018b, 2018c).

Such unexpected fluctuations in mortality and in life expectancy sparked a debate in the media, among policy makers, third sector health organisations and actuarial analysts. For instance, following the experience of 2015, the Continuous Mortality Investigation (CMI), a private company owned by the UK's Institute and Faculty of Actuaries, recalibrated its Mortality Projections Model (CMI Working Paper 97, 2017). In the new model, SDRs in 2015 and 2016 were more than 10% higher than in the 2000-2011 trend for both sexes and life expectancies were revised downward, especially at older ages. Five-year average mortality improvements also were reported falling to the point that the 0.8% average improvement per year for the period 2011-2017 was the lowest calculated since the 1970s (CMI, 2019). Similarly, the observed trends and crucially the increase in mortality observed in 2015 led some academics to conclude that the longstanding downward trend in mortality of the last decades was reversing (Hiam et al., 2017a, 2017b; Green et al., 2017a).

At the same time, although not discounting the importance of the 2015 mortality "peak", several authors pointed out that up until 2017, this had been the only notable rise in SDRs in recent decades (Milne, 2017b; Newton et al., 2017, PHE, 2018a). ONS studies noted that the 2015 "spike" had been defined as the difference between values in 2014 and 2015, with 2014 having been a year characterised by exceptionally low mortality, especially in winter (ONS, 2015, 2016b, 2017a). Accordingly, some commentators suggested that the 2015 experience may not have been as exceptional as it might have appeared; rather, although it was the largest in the 2010 decade, there was evidence that it was less dramatic than those experienced in a number of years in the 1990s based on the Excess Winter Mortality Index (EWMI)[4] produced by ONS. The exceptional component seems to be the low excess mortality in 2014, the lowest ever recorded, certainly since 1950 (Baker et al., 2018). The difference between excess winter deaths in 2014 and 2015 was thus one reason for the decline in life expectancy; after allowing for changing excess winter deaths

[4] The ONS definition of excess winter deaths is the number of observed winter deaths minus the expected number of deaths. based on surrounding non-winter values. For a definition of EWMI and the associated Excess Winter Deaths (EWD) measure, see ONS (2018g).

(EWD), the other factor was the reduction in underlying rates of improvement in this decade (ONS, 2019).[5]

In 2017, SDRs decreased again by 0.4% and 0.2% for men and women respectively as compared to 2016. Although provisional figures for the first two quarters of 2018 (January to March and April to June) also showed an increase in SDRs compared to the prior year (yet not statistically significantly higher than the first quarter of 2015), the overall mortality rate for 2018 turned out to be the second-lowest since data became available from 2001, and this pattern has continued so far in 2019.

In summary, research showed that UK mortality patterns in the recent period have experienced some noticeable fluctuations. In 2015, the increase in deaths was substantial, but also came about after a year, 2014, characterised by exceptionally low mortality. More importantly though, the UK has been experiencing a slowdown of the long-term positive trend in the rate of mortality improvement and life expectancy as compared to the last years of the previous century and the first decade of the current one, when average annual improvements were particularly strong (ONS, 2017e, 2018b, 2019; PHE, 2018a). It is thus evident that important changes are taking place in the UK and that the historic trend of falling mortality lost pace.

Age-specific trends

As in other High-Income Countries (HICs), trends in mortality in the UK in the recent decades have been determined primarily by changing patterns among older age groups where most deaths now occur. Many sources have highlighted how the deterioration in mortality improvements detailed above appeared to be particularly marked among older people[6] (ONS, 2016a, 2018a, 2020 Delivery, 2017; PHE, 2018a; ONS, 2018e). For instance, while in the decade 2001-2011, individuals aged 60 and over experienced substantial reductions in mortality and thus made the largest positive contribution to changes in life expectancy increases, these improvements and therefore their contribution to life expectancy either stalled or diminished over time. This was particularly the case for older age groups (90+), whose death rates experienced virtually no improvement or even increased since about 2012 (PHE, 2018a).

While changes for older people have been the most prominent, some studies also reported stalling of mortality improvement (shortened to “mortality stalling” in many publications on this topic) at younger age groups, especially between ages 35 to 50 (PHE, 2018a; ONS, 2018e). In recent years, both men and women in England in these age groups have experienced lower mortality rate improvements than in the first decade of the century. Although this group makes only a limited contribution to overall trends, we note that it could become more significant in the future. These negative trends have been attributed to increases in external causes of death, including accidental

[5] The interpretation of 2015 data is discussed in more detail in Section 4 and in Appendix I.

[6] Since overall mortality is substantially determined by deaths in this group, absolute changes in the group will almost inevitably have a major contribution to overall changes, but the relative (i.e. proportionate) changes in rates of improvement may not necessarily be less than for other age groups.

poisoning arising from drug misuse, alcohol consumption, and suicide (ONS, 2018e).[7] This pattern appears to mirror that observed in the U.S., where deaths due to accidents, misuse of opioids and risky behaviours have led to an increase in mortality in these young adults (Ho, 2019; Ho and Hendi, 2018), while it is substantially different from much of mainland Europe, where mortality at young adult ages has continued to show improving trends.

Socio-economic status and deprivation

It is well-established that individuals' health outcomes are strongly influenced by the physical, social and economic conditions in which they are born, raised and live. It has also been shown that changes in the composition of the population by social status contribute significantly to changes in life expectancy and in mortality rates (Luy et al., 2019). In the UK, there are some, though not many, large individual-level databases[8] able to identify meaningful changes between various socio-economic groups in relatively short time frames such as those we are concerned with here. Nonetheless, a few publications have attempted to analyse the current trends in mortality and life expectancy in the UK through the lenses of socio-economic and community level factors.

For instance, research using CMI data[9] has shown the existence of a clear gradient in mortality improvements across different socio-economic categories in recent years. During the period 2011-2015, mortality improvements in the CMI's Self-Administered Pension Scheme (SAPS) database were larger than in the general population (CMI Working Paper 104, 2018). This is important because the SAPS population, which includes members of occupational, defined benefit pension schemes, tends to be more affluent than the general population of the UK and such findings could indicate a protective effect of socio-economic status against the flattening of mortality improvements. Unfortunately, the SAPS dataset also poses several difficulties, including the relatively small exposures to risk compared with the national population, the type of data collection and the relatively short length of the study, with only fourteen years of data in the sample for analysing trends present, which may preclude comparative analyses.

Research solely focusing on the general population of England and Wales also highlighted that mortality improvements differ substantially between socio-economic groups. Analysts at CMI first broke down the general population of England and Wales into four socio-economic categories depending on the wealth of the area in which individuals resided and then estimated mortality improvements for the periods 2001-2005, 2005-2010 and 2010-2015 for each group (Corquin, 2017). Mortality improvements were generally increasing and almost stable across socio-economic categories for men and for women between the first two periods. By contrast,

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[7] Changes in these causes of death over time are discussed in detail in Section 1.2.3.

[8] Note that the principal official Government statistical individual-level source of information on socio-economic differentials is the ONS 1% Longitudinal Study, that so-far included only a small fraction of the population and thus could not provide timely precise estimates of current trends. However, the next release which should be published later this year is likely to be large enough to compare information for the period 2012-16 to the trend over the previous 20 years. Alternative sources from CMI and Club Vita, however, show an emerging deterioration among more disadvantaged groups, who, as explained in above sections, have been doing better than average in earlier periods.

[9] Note that The CMI Model is calibrated to data for the general population of England and Wales, and widely used by UK pension schemes and insurance companies as a base for estimating future mortality developments.

improvements in the last period decreased in all socio-economic categories, and especially so in the lower socio-economic groups. The most affluent individuals retained higher improvements than other categories, both for men and for women. This led the researchers to conclude that a widening of the gap between the most and the least affluent was taking place and was pronounced enough to make mortality rates of poor women actually increase (ONS, 2018j).

Other longevity data analytics companies have carried out similar research. For instance, according to data compiled by Club Vita (2017), which advises pension schemes and insurance companies, "Comfortable" men (defined as individuals with defined benefit pension in excess of £7,500 per annum) experienced constant mortality improvements of about 2% per year from 2005 to 2010 and from 2010 to 2015. In contrast, improvements for the two lower socio-economic categories (i.e. pensioners with modest to low levels of retirement income and living in areas of average to low levels of deprivation) dropped from 3% to 1% between the two periods. For women, although improvements fell for both more and less affluent, the drop was more pronounced in the latter group. When compared to the general population of England and Wales, trends appear similar with high socio-economic groups having the largest improvements between 2010 and 2015. However, the stable improvements observed for men in the Club Vita dataset were not present in the general population, where instead these dropped from around 3% per year between 2005 and 2010 to around 1.8% during 2010-2015 (Corquin, 2017). For women in the general population, annualised improvements fell in all categories in the period 2010-2015 as compared to 2005-2010 and, strikingly, a negative rate of improvement of -0.1% (C.I. ± 0.6%) was calculated for the period 2010-2015 for women in the lowest wealth category.

When discussing socio-economic differences, we must also be wary of the fact that national mortality and life expectancy figures may hide more complexity at lower geographical and distributional levels of analysis. The 2017 Marmot Indicators (Institute of Health Equity, 2017), which measure inequalities in health and life expectancy in every local authority in England, showed a persistent gradient in life expectancy between and within local authorities. For instance, a 9-year gap in male life expectancy was observed between Blackpool and Kensington and Chelsea in London, and a 7-year gap for females between Manchester and Kensington and Chelsea. Compared with prior releases of the Marmot Indicators for 2010-2013, the lowest male life expectancy was persistently recorded in Blackpool (an 8.2-year average gap with Kensington and Chelsea). Similarly, female life expectancy was lowest in Manchester (a 7.0-year average gap with Kensington and Chelsea). This suggests little, if any improvement, in closing the gap between the most and least deprived areas of England (ONS, 2018j).

Other studies have analysed the effect of socio-economic factors on mortality improvements, particularly among older people, based on ecological data using area-level disadvantage. Green et al. (2017a) matched the 2015 Local Authority summary statistics of the English Indices of Multiple Deprivation[10] (IMD) with SDRs by sex at the local authority level to explore how changes in

[10] The IMD is a composite measure of deprivation estimated at small geographical areas, known as Lower Super Output Area, which includes the following domains: income, employment, education, health, crime, barriers to housing and services, and living environment. There are 32.844 LSOAs in England, each with an approximate average population size of 1.500.

mortality between 2014 and 2015 differed geographically and by level of deprivation in England. This study found that almost all local authorities experienced increasing mortality rates, but there was only a weak positive correlation between area deprivation level and the relative 2014-2015 change in mortality for people aged 85 and over. Jones (2017) showed that deprivation explained only 1.2% of the 2015 increase in mortality relative to 2014 in English local authorities.

Focusing on a longer temporal period, PHE Health Profile for England 2018 (2018b) recently highlighted slowdowns in mortality improvement in all deprivation decile areas based on IMD scores at Lower Super Output Area (LSOA) and across most local authorities since about 2010-2011. These were sometimes accompanied by a decline in life expectancy in the most deprived areas. When comparing the least and the most deprived areas in England, life expectancy was observed to grow more slowly in the latter between 2011-2016. Latest data further show a significant a widening of the level of inequality in life expectancy at birth as measured by the slope index of inequality (SII[11]) (PHE, 2018b).

Similar general findings were reported for Scotland (Fenton et al., 2019). While mortality declined substantially for both sexes between 2006-2011, since 2012 improvements were largely reduced in all deprivation quintiles as defined by the Scottish Index of Multiple Deprivation. However, in the pre-2012, but more evidently so in the post-2012 period, it was the most deprived who experienced the smallest mortality improvements, suggesting again widening inequalities. In short, although all groups seemed to have been affected by the slowdown to some extent both in England and Wales, and in Scotland, the effects appear to be worse among the least well-off.

Other recent studies used the IMD as a composite measure of deprivation and linked it to measures of health outcomes and to life expectancy. Steel et al. (2018) calculated correlations between IMD scores and the number of years of life lost[12] (YLL) for the constituent parts of the UK and for 150 English upper-tier local authorities. The authors found that the association between IMD score and YLL shifted over time in England: up until 1999, more affluent authorities had an advantage in YLL annual improvements, while from 2010 onwards, more deprived local authorities have done relatively better (Steel et al., 2018, p. 1658). Reasons for this change in trend in YLL improvement across socio-economic areas remain unclear. Further, this finding based on ecological analysis is in contrast with some of the above studies, which showed more marked declines in life expectancy among the most deprived socio-economic groups and its potential explanations do not fit well with data on suicide rates, which raised notably in areas experiencing the highest increases in unemployment (Barr et al., 2012).

The PHE (2018a) Report emphasized the decline in life expectancy for females in the most deprived decile areas since about 2010-12. Bennett et al. (2018) found large differences in life expectancy at birth according to where individuals reside (or, more exactly, die) over the period

[11] SII is a summary measure which captures the variation in life expectancy with deprivation deciles calculated using IMD data. Positive values indicate increasing mortality with increasing deprivation.

[12] YLL is a measure of premature mortality which indicates the average years a person would have lived if s/he had not died prematurely. It is calculated by multiplying the number of expected deaths by the standard life expectancy at age of death.

2001-2016. Although life expectancy increased in every deprivation decile in these 15 years, more affluent ones gained about 3-4 years (females) as compared to 1.6 years for the least well-off. This resulted in a widening in the life expectancy gap between the most and least deprived over time. Since 2011 females in the most deprived areas seemed to fare particularly worse than other groups. The authors identify a number of IMD-related factors which could explain this widening inequality, including lower accessibility to public health initiatives for more deprived segments of the population compared with those able to pay for care, as well as factors more linked to the funding squeeze for health services such as cuts to smoking cessation services over the past eight years. These latest official data at early 2019 include 3-year averages only up to 2014-16, so cover only about half of the period of mortality improvement stalling between 2011 and 2019; it is likely that these negative patterns will have continued to the present, so it may be that we will find out that we have already experienced additional divergences when data for the second half of this decade become available.

Chan et al. (2019) investigated the link between deprivation and life expectancy at older ages since 2001 in the framework of comorbidities. Using an open cohort design and assigning individuals to IMD deprivation quintiles according to place of residence, the authors showed that the life expectancy advantage for the more affluent was the result of later onset of multimorbidity, particularly for women, and of a subsequent longer survival as compared to the least well-off. These differences, they further highlight, could only in part be explained by differences in smoking prevalence between groups. Such analyses highlight the importance of comorbidities in the well-established gradient in mortality that exists between poorer and richer areas in the UK.

As remarked above, although the geographical patterning consistent with deprivation levels may suggest that something broader could be occurring at the population level, most of the findings of the abovementioned studies are subject to some limitations. The reviewed studies use fine geographies, including IMD scores at LSOA. Nonetheless, any deprivation measure that is assigned to a group of individuals (in most cases here a LSOA) is an aggregate measure of the experience of that group and does not say anything about individuals' experience of deprivation within that particular group. The ecological nature of these studies, thus, (i) may hide important differences at the individual level or smaller geographical level than local authorities (including the well-established fact that most poor people do not necessarily live in poor areas) and may understate the extent of differences between social groups, and (ii) area-level data cannot prove individual-level causal relationships, although they provide strong evidence that these are likely to be found. Second and importantly, some of these analyses are based only on mortality changes occurring in a short time frame or even a single year, 2014-2015. As noted above, 2014 was a peculiar year with exceptionally low mortality, while 2015 was characterised by the opposite trend of unusually high mortality. This may explain why the authors such as Green et al. (2017a) and Jones (2017) found only small or no effect of deprivation on mortality in the short time period analysed. Therefore, considering that mortality rates tend to be presented as three- or five-year averages, the modest findings may possibly be the result of a one-off event. More research is thus required on the association between deprivation/socio-economic status and mortality trends since 2010, and its various contributing elements before conclusions can be drawn, but these findings are consistent with earlier studies showing a tendency for differentials to reduce in good times and to increase in bad ones (ONS, 2015b).

While acknowledging that the UK lacks the detailed comprehensive micro-data on life-course socio-economic influences on mortality compared to countries with high-quality register data, and also that some of the reviewed analyses are based on averaged temporal data, nevertheless studies generally point in the same direction – that socio-economic differences in mortality have increased since about 2010, following a period when they had been decreasing. This gap increases as lower social groups lag more and more behind and they are much more likely to experience absolute reductions in life expectancy. Failure of these groups to match the improvements of the more advantaged is likely to also contribute to the general slowdown of life expectancy improvements.

Changes in causes of death

The next informative question addressed in the literature is whether the observed mortality patterns have been accompanied by substantial changes in the leading causes of death and, thus, if any of these have been identified as "responsible" for the observed increases in mortality.

Since the early 2000s, mortality improvements in the UK constituent countries occurred in almost all leading causes of death (Bhatnagar et al., 2016; Mayor, 2016), but those in circulatory diseases were particularly important. This was mainly due to improvements in heart surgery, to wider use of medicines to lower blood pressure and cholesterol and to lower rates of smoking. In the last few years, however, improvements in mortality from CVDs have slowed down, particularly in the period 2011-2016 (PHE, 2018a), with the prevalence of stroke and coronary heart disease in particular remaining constant over time at around 3% in England and 4% in the other UK countries (Bhatnagar et al., 2016). This phenomenon has also been noted elsewhere outside the UK (SwissRe, 2018; Raleigh, 2019) and has been attributed to the falling away of the effects of long-term drivers, like the impact of smoking cessation, and/or the lack of introduction of effective new drug treatments for, for instance, heart failure, and possibly to more selected populations at risk. A study of deaths due to heart diseases in England and Wales further highlighted that these stalls in improvements had started to become visible for people aged 45-54 by 2002 (O'Flaherty et al., 2008). The emergence of population-level risks such as poor diet and lack of exercise that have led to rising levels of overweight and obesity and increases in prevalence of type-2 diabetes are also likely to have curbed the decline in CVD mortality (Purcell, 2013). Reductions in the pace of improvement of the other main set of causes of death, cancer, also occurred, but at a much lower rate (Palin, 2017). Changes in these slower-operating factors are likely to be contributing to slowing down of improvements in mortality. Nonetheless, apart from PHE (2018a) CVD does not appear to have received much attention in the UK as a possible key factor behind the changing patterns of mortality observed in the past years (Raleigh, 2019) although it has in the sparser international literature on mortality improvement stalling (SwissRe, 2018).

Deaths attributed to age-related degenerative mental conditions, such as dementia, have been increasing sharply over the first years of the century, to the point that they are now the most common reported cause of death among older people. It is undisputed that this increase is in part due to the ageing of the British population and to improved medical treatment for other conditions. However, a large part of the increase is likely to be due to changes in discovery, definitions and coding practices, making these diseases more likely to be classified as primary causes of death as well as to the 2013-2014 introduction of financial incentives for GPs for early dementia diagnosis (Institute of Health Equity, 2017). This in turn complicates the temporal interpretation of the contribution not only of age-related degenerative diseases to changing mortality trends, but also by affecting the interpretation of trends in other causes including CVDs where transfer of deaths to another cause will result in an apparently higher rate of improvement than would be observed with more consistent coding. This issue is also discussed in more detail in Section 4.1.3.

Bearing these points in mind, ONS data adjusted only for coding changes show that in 2015 mortality from dementia including Alzheimer's was well-above average values, and SDRs for deaths with an underlying cause of Alzheimer's disease and other dementias continued to increase significantly in both 2016 and 2017 for women and men, particularly in winter (ONS, 2018f, 2018k). Among other reasons, this is possibly due to the heightened vulnerability of people with such conditions to respiratory diseases, which are the leading cause of excess winter deaths (ONS, 2016a). However, it should be noted that there is evidence that the age-specific prevalence of dementias is declining in the UK. For instance, the Medical Research Council Cognitive Function and Ageing Study (CFAS) showed a decline in dementia prevalence among residents of Cambridgeshire, Newcastle, and Nottingham over the past 20 years (Matthews at al., 2013). However, even forecasts of future trends in dementia including Alzheimer's disease that assume that the prevalence of dementia will continue to decline suggest that the absolute number of those affected by 2040 will increase by 57% in England and Wales due to population ageing (Ahmadi-Abhari, 2017), so the importance of such conditions for the overall mortality trends of the British population should not be discounted, even if their contribution to mortality improvement stalling is over-stated. Moreover, if CVD and respiratory deaths are now being coded as dementia and Alzheimer's disease deaths, then the decline in such diseases has been also over-stated and needs to be considered when analysing stalling mortality improvements.

The UK has also performed poorly when it comes to respiratory conditions, as compared to other Western countries (Salciccioli et al., 2018; De Carlo and Chung, 2018). In the post-2010 period, besides increasing mortality due to Alzheimer's and other types of dementia, mortality from respiratory diseases has also increased (ONS, 2015a). In 2015 outbreaks of respiratory conditions in care homes, especially in January, i.e. in conjunction with the mortality peak, were reported by ONS and PHE. According to Hiam et al. (2017a) increasing deaths from pneumonia contributed to the excess mortality of 2015, particularly for women. In the same article, though the authors calculate that pneumonia was responsible for as little as 0.01 years (about three days) loss in life expectancy that year. Respiratory diseases were the also the predominant cause of excess winter deaths, particularly among the very old, in 2016 and in 2017 (ONS, 2017a, 2017e). ONS reported that in period 2016 to 2017 there were around 62% more deaths due to respiratory conditions in winter months than in non-winter months, and that this accounted for 12.500 excess winter deaths. Among these, pneumonia caused the largest number of excess deaths, probably as a result of a range of bacterial and viral respiratory pathogens including influenza. It is well-recognised that influenza is rarely recorded on death certificates, especially as the underlying cause of death and therefore death certification is a poor basis for assessing the role of influenza on overall mortality (Raleigh, 2017, 2019; ONS, 2018e, PHE, 2018a).

Lastly, it is relevant to note that other important changes in causes of death are taking place in the UK, notably at young ages. For instance, between 1993 and 2016, ONS (2017f) figures showed that drug-related deaths increased by 78% with a peak in 2016 in England and Wales. The highest rate of deaths attributable to drugs was among adults aged 40-49. Further, PHE (2018a) reported that heroin-related deaths doubled between 2011-2016 and mortality from accidental poisoning (mostly for other drugs) at ages below 50 also increased, with negative impacts on life expectancy at birth. Comparative research showed that these trends and age profiles in mortality from drug overdose, although to a lower extent, resemble those observed in the past in the U.S. (Ho, 2019).

After years of substantial decline in rates of suicide, an increase was observed in 2015, especially in Northern Ireland, and in ages 20-34 (ONS, 2016c). Past research had shown that in Northern Ireland, suicide was more strongly associated with individual-level characteristics than with area-level factors, and more likely to occur among middle-aged men (O'Reilly et al., 2008). However, such increase seems only temporary and the lowest ever number of deaths due to suicide was recorded in 2017, although there are issues with coding of suicide, particularly with treatment of some drug-related deaths versus suicide (ONS, 2018h). While numbers of deaths at younger ages are small and therefore have relatively little influence on indicators of overall mortality, the decline in improvement has also been observed in these age categories. This highlights the importance of looking at the whole age-group spectrum and beyond overall trends.

Burden of disease

Changes in leading causes of deaths have been accompanied by changes in the burden of disease. The UK analysis of the Global Burden of Disease (GBD) Study 2016 by Steel et al. (2018) provides insights into the patterns of disease burden across the constituent nations of the UK, English local authorities, and over time from 1990 to 2016, see Section 1.2.2.

Some findings, such as higher premature mortality in Scotland and twice as high levels in more deprived local authorities are consistent with other studies. However, the study found that the number of years lived with disability[13] (YLD) now exceeds YLLs across the UK. The scarcity of data at the local level reduced the precision of estimates of disability, but at the country level, as expected, women were found to spend more years with disability for all the ten leading conditions as compared to their male counterparts and YLDs spent with mental health conditions were particularly high in Northern Ireland.

As for the more data-robust YLLs, Steel et al. (2018) also show slow-downs in improvements since 2010 as compared to the prior decade and even increases in YLL rates in 9 out of the 150 analysed English upper-tier local authorities. Such flattening or worsening in the rate of improvement for

[13] YLD is a measure of the burden of disease and is typically computed by calculated by multiplying the prevalence of a disorder by a disability weight (i.e. the short- or long-term loss of health associated with that disability).

YLLs is attributable in particular to reductions in improvements from CVDs, especially for the oldest age groups, and from cancer. Although varying in size across UK nations, behavioural factors, often by-products of psychosocial factors, e.g. tobacco, poor nutrition, alcohol and drug use, and low physical activity, were identified as the principal risk elements contributing to YLLs.

Explanatory factors behind stalling improvements

The stall in mortality improvements surprised many commentators and inevitably sparked speculation and debates over the potential reasons influencing recent trends. It has been argued that the phenomenon might be driven by medium to long-term factors (Hiam et al, 2017a, 2017b), including austerity measures and cohort-effects. Other researchers indicated the presence of more virulent strains of influenza as a substantial cause of more recent mortality patterns. In general, a number of individual causal factors have been investigated in the literature. Although the causes of recent mortality and life expectancy trends are likely to be multifactorial and interconnected, and somehow linked to events occurring in the first decade of the century, we discuss each of them separately, as they appeared in the extant literature, in the following sections.

Impact of population ageing

The first factor considered in the literature is the changing demographic profile of the UK population. In the context of an ageing population, the increase in deaths observed in recent years could just reflect the fact that there are now more old people in the UK than in previous years and death rates are higher at older ages, so deaths would increase even if age-specific mortality rates remained constant (or even if they continued improving in some cases). Overall mortality is always going to be primarily determined by the level of mortality experienced by those age groups in which most deaths occur.

To measure the impact of ageing, researchers at PHE applied the 2010-2014 death rates to the 2015 population and argued that two-thirds of the excess deaths in women in 2015 as compared with 2010-14, and all the excess deaths in men were explained by changes in population size and age structure over the preceding 5 years (Newton et al., 2017), leaving only 5,000 more female deaths than expected of the original 30,000 additional deaths between 2014 and 2015 to be explained by other factors. However, this conclusion was based on comparison of observed values with those expected if there had been no improvement in mortality since 2010-14, whereas mortality had been improving, so continuation of this trend would have led to a lower number of deaths than observed. Other analyses (Hiam et al., 2017a; Loopstra et al., 2016) have also argued that population ageing is a slow-acting process, unlikely to cause the sudden rises in mortality observed in recent years.

Of course, death counts are a poor indicator for mortality risk compared with alternative indicators such as life expectancy and standardised death rates that control explicitly for population size and structure, but population ageing could have indirect effects as discussed later.

The case for data and statistical artefacts

A second factor which has been discussed in the literature is the possibility that data issues and statistical artefacts are driving the trends (ONS, 2016d, Raleigh, 2017). For instance, Milne (2017b) has shown that trends may look different according to the length of the time series examined or the segment of the overall mortality curve which is considered in the analyses. The calculation of mortality rates is affected by the way in which changes in population structure and size are adjusted for and by the type of denominator used (Newton et al., 2017). ONS and PHE continue to monitor the possibility of data artefacts to ensure that the analytical methods used in the analyses are suitable and consistent. These include the effects of revision of population estimates following the 2011 census; age groups used for standardisation (especially at older ages); the population used for standardisation (specifically whether the 2013 European Standard Population reflects the current UK population structure); and issues of the accuracy of data in times of rapid mass migration which, if not recorded properly, may affect mortality estimates. These issues are also relevant to life expectancy estimates, where, in addition, different agencies (ONS, Eurostat, IHME and Human Mortality Database (HMD)) use different methods of calculation. Nonetheless, given the similarity of trends in countries with different systems and non-official data bases such as those of pension providers, there is no evidence suggesting that the observed trends are the by-product of problems with data collection and analysis.

A neglected element of artefacts – not directly linked to the construction of data itself, but emerging from such data – is the effect of so-called tempo effects (TE)[14]. TE were identified only recently as potential distorters of period life expectancy (Bongaarts and Feeney, 2002).[15] TE are an inherent element of period life expectancy and one of the main biases of its typical interpretation as reflection of current mortality conditions (Guillot, 2011). In brief, TE emerge in death rates whenever mortality is changing during the observation period, and their impact varies with the extent of the changes in mortality. Death rates are calculated by dividing the number of deaths which occurred during a particular year (and in a particular age) by the average number of people alive in the same period (and age). When improvements in health and living conditions lead to a reduction in mortality, a certain number of deaths – which would have occurred under unchanged mortality conditions – are postponed to a later period. Such a postponement consequentially deflates the enumerator of death rates by the number of avoided deaths, while the denominator is inflated by the same number of saved lives. Albeit these numbers are identical in absolute terms, they differ notably in relative terms. The number of deaths decreases by a much larger proportion than the increasing number of the population at risk in the denominator. In this way, TE magnify the effect of the shifted number of deaths in the death rate. The larger the changes in mortality, the larger the magnification effect.

This magnification effect can lead to paradoxical situations in which the conventional

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[14] The description of TE is taken from taken from Luy, et al. (2019): "Life expectancy—frequently used, but hardly understood" (2019) in *Gerontology*. detailed illustration of the general "tempo approach" can be found in Luy (2010).

[15] We refer to the impact of TE on life expectancy. Note, however, that the same impacts and biases emerge in all other period mortality indicators that sum up age-specific death rates, such as the SDRs which was used in some of the previous sections.

demographic indicators, such as life expectancy, provide a misleading picture of actual mortality trends (Bongaarts and Feeney, 2010; Luy, 2010). For instance, it is possible that period death rates increase despite all cohorts living in this period are experiencing only decreasing or stagnating mortality (Bongaarts and Feeney, 2002; Feeney, 2010; Horiuchi, 2005; Luy, 2008). Luy and Wegner (2009) showed that, ultimately, even total life expectancy can be distorted by TE when a sufficient number of age-specific death rates – the central basis of the life expectancy indicator – are affected by TE. In fact, TE can be a highly relevant factor for explaining trends and differentials in period LE in situations of marked changes in mortality dynamics. It has been shown, for instance, that TE caused by the sudden decrease of mortality in eastern Germany after unification are likely to be a significant contributor to the unexpectedly rapid convergence of eastern Germany's LE to the level of western Germany (Luy, 2006; Peters et al., 2014). In this context, it would be important to assess whether TE factors could be, at least in part, responsible for the trends we observe today in the UK. Given that to date this potential explanation has not been investigated in the literature dedicated to the UK, we explore it in more detail in Section V of this report.

The case for flu

One of the few largely uncontested elements of the mortality increases of recent years is that large peaks in death rates in the UK, but also in other European countries (Vestergaard et al., 2016; Mølbek, et al., 2015; Raleigh, 2019**)** coincided largely with winters dominated by the A(H3N2) flu virus, the influenza strain most frequently associated with mortality among older people[16] (ECDC, 2017; Flu News Europe, 2017)**.** Several sources noted that increasing mortality coincided with medium or high influenza activity, suggesting a link between flu outbreaks and rapid increases in mortality (PHE, 2018a; PHE, 2018d: Vestergaard et al., 2016). Moreover, the associations with other data series on, for example, GP consultations and hospital admissions with confirmed links to influenza could suggest that it made a substantial contribution to spikes in winter mortality. However, it is worth noting that there have still been considerable numbers of excess winter deaths (EWD) in years with very low levels of influenza, such as winter of 2013-14, and there are other respiratory diseases and different types and strains of influenza as well as a range of other causes of death that are exacerbated by cold weather, and alternative estimates of the qualitative impact of influenza exist.[17]

The links between the circulating flu and fluctuations in the number of deaths have been made particularly for the year 2015 (Mølbak et al., 2015; Pebody et al., 2018). PHE suggested a relationship between the 2015 spike of deaths and the A(H3N2) virus, particularly as a result of influenza outbreaks in nursing homes (PHE, 2015a, 2015b). Moreover, PHE (2018a) showed that in 2015 flu, pneumonia and other respiratory diseases constituted a sizeable proportion of hospital admissions for people who died from most causes of death that year. Consistent with PHE reports

[16] Since becoming prominent in 2009, influenza strain A(H1N1) has been a prevailing virus type, and this type is known to have less impact on older people. Conversely, in 2015 and 2017, the main circulating strain, A(H3N2), is known to have a particular effect on older age groups.
[17] Note that the PHE report *Surveillance of influenza and other respiratory viruses in the UK: Winter 2017 to 2018* (2018) shows that the number of flu deaths in those aged 65 and above was 400 in 2013-2014; 27,000 in 2014-2015 and 15,000 in 2017-2018. However, the robustness of these estimates remains unclear.

for the UK, ONS noted a number of influenza outbreaks in care homes and a larger number than expected of patients' admissions to hospital and intensive care for flu-related symptoms.

A "remarkably similar" pattern was identified in the 2016-17 winter also in the UK and across European countries by Vestergaard et al. (2017), who. also studied influenza-attributable mortality using data from the European Monitoring of Excess Mortality for Public Health Action (EuroMOMO) programme adjusted for extreme temperatures and contended that throughout Europe excess mortality in that winter could be mainly explained by the peak, which occurred earlier than in 2015, and by widespread circulation of influenza virus A(H3N2). They suggest that this outbreak may have put a strain on health facilities around the continent, although their estimates of all-cause and influenza-attributable mortality at week 8/2017 were slightly lower those for the 2014-15 season. Similar impacts of the A(H3N2) virus were observed for the winter 2017-18[18] (EuroMOMO, 2018; PHE, 2018a). Adlhoch et al. (2018) report that in the winter 2017-18, the peak period of influenza activity across the European countries, including the UK, was unusually protracted (positivity of tested sentinels for over 12 weeks as compared to prior years, when positivity ranged between 0 and 8 weeks), although the causes of such increased influenza activity is not fully understood.

It has been suggested that the effect of influenza on mortality in these years could have been due to lower than usual vaccination effectiveness. Reduced effectiveness of the A(H3N2) component of the flu vaccine was reported not just in the UK (Pebody et al., 2015; Vestergaard et al., 2017), but in several countries (Skowrosnki et al., 2015; Flannery et al., 2015). In this context, it is important to note that in 2018 a new flu vaccine was made available in the UK which, according to PHE (2018c), could potentially avert around 700 hospital deaths from flu in England – although this is a relatively small number in relation to the estimates of many thousands of additional deaths associated with seasonal influenza. The number of excess deaths in early 2019 appears to be relatively small but more detailed data are not yet available.

Monthly analysis of UK figures indicates that in some years, notably 2015 and 2017, mortality increased throughout the year, not just in the winter season. This led some commentators to argue that the protracted flu epidemic had long-lasting debilitating effects on the elderly (Jones, 2017, Hiam et al., 2017a) in particular in 2015; although flu might not be the whole answer or may be just partially contributing to the abnormal rates of that year. While cold snaps probably had an impact in some European countries (Mølbek, et al., 2015), peaks of winter deaths in the UK have also occurred in months when temperatures were typically above average (ONS, 2015a). While in the past, there had been particular emphasis on cold weather as a factor for higher winter mortality, often associated with poor housing and heating, and fuel poverty, this area has recently attracted little attention as a factor relevant to stalling of mortality improvement. Furthermore, since overall deaths were generally increasing as compared to the previous year, even without structural changes, monthly deaths across 2015 would be expected to be larger than the corresponding month in 2014.
The pattern of EWD in winter 2017-18 attracted considerable attention. The final figure reported in November 2018 of 50,100 deaths in England and Wales was the highest recorded since winter

[18] No annual report or detailed analysis for winter 2017-18 has so far been published by EuroMOMO.

1975-76 (ONS, 2019). It was discussed in two BMJ editorials (Hiam and Dorling, 2018; Raleigh, 2018), although there were differing suggestions on the reason for this particularly large value, with Hiam and Dorling rejecting influenza (and cold weather) as causes and Raleigh arguing for the importance of influenza (a conclusion that ONS (2019) was to agree with A(H3N2) circulating and a low vaccine effectiveness especially among older people).

Fluctuations in winter death numbers have been associated with the prevalence of influenza. However, evaluating the effect of influenza is not easy, as flu is rarely recorded as underlying cause of death (Pebody, 2018; Raleigh, 2019). Currently available estimates of “flu-related” deaths are based on temporal correlations between time series data from surveillance systems and mortality rates or death counts. Although the importance of such estimates is not to be discounted, macro-level temporal correlations cannot prove causation, a general issue covered in the final section. Influenza as an overarching cause has also been contested as a long-term effect as varying predominant strains of influenza are likely to only explain short-term fluctuations in mortality rates, not longer-term changes in trends (Hiam and Dorling, 2018). Furthermore, there is the possibility that this temporal relationship between life expectancy and the flu may be actually influenced and biased by the presence of TE. Last, but importantly, in the U.S. at least, some have argued that its importance may have been overstated as a cause of premature deaths that had remained otherwise unexplained (Doshi, 2013). This clearly limits our understanding of the causal link between flu outbreaks and recent mortality trends. These issues are considered in more detail in Section 4.1.1 and Appendix I.

The case for austerity

The factors mentioned above seem to provide minimal or inconclusive explanations for the excess deaths that occurred in recent years in the UK, apart from influenza that provides a partial explanation for the fluctuations observed. However, influenza does not appear to have any major contribution to the explanation of longer-term underlying trends unless annual fluctuations can be shown to be explicitly linked to long-term trends.[19]

Mortality improvement stalling occurred not only in conjunction with fatal influenza seasons, but also in the context of a large-scale radical change to public policy – the newly imposed austerity policies implemented as a response to the 2008 financial crisis and economic recession.[20] A number of studies have explored this link and cited cuts on health and public spending in the UK as potential contributors, if not causes, of deteriorating mortality trends. Before detailing the existing available evidence on this particular relationship, it is important to note that most of the research into recession and health is limited to population averages and does not test relationships at the individual level (Steventon, 2017; Milne, 2017a). Further, it typically evaluates routine fluctuations in

[19] This and related mechanisms are considered in more detail in Appendix I.

[20] Here used to indicate large-scale cuts to the spending of many departments, notably social services, welfare and education. As for health services, most of the slowdown in growth of NHS funding impacted adult healthcare services. Austerity further meant higher NHS funding constraints and apparently reduced performance as measured by waiting times, delayed discharges. However, NHS budgets and state pensions were substantially protected as compared with social security for younger age groups, and, in particular, for social care. The definition and implications of the various dimensions of austerity are considered by Stuckler et al. (2017).

the economy rather than 'austerity measures', which are themselves conceptualised differently in the literature, or 'recession' *per se* (Suhrcke and Stuckler, 2012). Care is thus needed when interpreting and drawing conclusions from such studies.

While there had been a number of blogs and comments about the stalling of mortality improvement in relation to austerity, the first publications investigating the link between austerity measures and mortality outcomes in British elderly population was by Loopstra et al. (2016). Examining the impact of cuts to income support and pension credit on mortality patterns of people aged 85 and over across 261 local authority areas (excluding the City of London), the authors found that between 2007 and 2013, a 1% decline per beneficiary in pension credit expenditure was associated with an increase of 0.68% in old age mortality. In addition, a 1% decline in social care spending was found to be associated with an increase of 0.08% in mortality. The suggested mechanisms for increases in mortality included stress and anxiety due to lower disposable income, poorer nutrition, as well as poor home heating[21]. Such findings ostensibly highlighted the particular strain imposed on the health of the frailest, i.e. older pensioners, by cuts to spending on income support and social care.

In two more recent and widely debated studies, Hiam et al. analysed the sources of the 2015 rise in mortality (2017a) and posit links between rising mortality and austerity (2017b). In the first article, the authors analyse the contributors to changing mortality in the UK and make the strong claim that the long-term declining pattern had reversed as a result of overall 30,000 excess deaths in 2015 as compared to 2014, particularly concentrated among those aged 85 and over. In the second article, Hiam et al. (2018b) analysed the 2014-2015 mortality peak and, although acknowledging the contribution of influenza and low vaccine effectiveness, they highlight that all markers of NHS performance (other than cancer care) in 2015 had worsened markedly. For instance, they show that call-out times of ambulances fell below target, waiting times for emergency care and diagnostic tests increased, and calls to the NHS telephone number 111 increased substantially. They concluded that since the implementation of austerity measures, the NHS has been unable to keep up with increasing demand due in part to the ageing of the British population and rising levels of chronic conditions (Kingston et al, 2018), thereby being at least partially responsible for the observed mortality spike. Hiam et al.'s studies draw attention to the fact that the disease environment, with the widespread re-emergence of the A(H3N2) influenza virus strain, and the ability of those potentially at risk to cope with the threat, which is related to the resources available to them, are both important. A debate structured around one single explanatory factor, for instance, focused only on whether either the changing disease environment or austerity was responsible for recent patterns would be short-sighted and fail to acknowledge the inevitable interactions between factors, and the clustering of risk factors for mortality.

Watkins et al. (2017) also made a link between expenditure cuts in the NHS and recent mortality increases in the UK. Using time trend analyses comparing the observed mortality rates between 2011 and 2014 with the counterfactual rates expected based on trends which would have occurred

[21] There are some apparently perverse results that show that poorer economic conditions can have beneficial short-term impacts on health by, for example, reducing work-related factors and consumption of alcohol (Ruhm and Black, 2002; Bor et al., 2013) and tobacco (Ásgeirsdóttir et al., 2013), but these are more than offset by long-term negative effects.

without austerity measures, the authors argue that spending cuts were associated with approximately 45,000 more deaths than expected in the counterfactual model. Moreover, they reported that a £10 per capita decline in real public expenditure on social care was associated with an increase of 5.1 care home deaths per 100,000 people, although the relationship was mediated by the number of available nurses. No relationship was found though for deaths occurring in hospitals. Hence, overall, the main conclusion of the study was that older people, particularly those in care homes, were the hardest hit by the implementation of cuts to, for instance, the number of nurses. Watkins et al.'s methodological approach and interpretation of the results have been questioned. Milne (2017b), for instance, revised the calculations made by Watkins et al. and suggested the possibility that some findings were driven by the use of an out-of-date standard population (while use of different standards will affect the levels, we would be surprised if it made substantive differences to the estimate of trends, which was the main focus of this paper). Fordham (2017) offered alternative explanations, including the possibility of cohort effects affecting the trends, a topic discussed in more detail in later sections. A greater burden of multiple morbidities as compared to prior cohorts, the emergence of new conditions and changes in the profile (e.g. affected by more end-stage conditions) of current patient cohorts could contribute to rising mortality rates.

Another study pointing at the relationship between increased mortality and austerity compared monthly data of death counts from the ONS with delay in discharges from the NHS and showed a positive association between overall mortality and delayed discharge of acute patients (Green et al., 2017b) between 2010 and 2016. While the same association was not reported in cases of non-acute delayed charges, they estimated that in 2015 the increased proportion of patients with acute conditions being delayed in discharge accounted for up to a fifth of the observed mortality increase. Specifically, they found that each additional day that an acute admission was late being discharged was associated with an increase in 0.39 deaths and that each additional delayed discharge was associated with seven extra deaths. From this, the authors concluded that the relationship may be driven by the stretching of NHS funding and worsened quality of adult care during times of austerity. These conclusions have been challenged on the ground that the population-level responses were implausible in that a single delayed discharge would result in seven deaths in the wider population (Steventon, 2017; Milne, 2017a). These are valid criticisms and especially in a politically and policy-sensitive area such as this, published work is likely to attract more scrutiny than would often be the case simply because it's more important. However, if discharge is a valid indicator of more generalised strain in the health and social care systems, the correlation with mortality would indicate that there is an *a priori* case for a causal relationship and suggest that further work is needed to identify and measure the pathway from austerity to excess mortality.

There are other findings that have little detectable effects on overall mortality levels, but may be indicative of an environment where austerity was leading to more general pressures. It has been argued that austerity policies in the UK have had a negative effect on homelessness and mental health in the UK (Fransham and Dorling, 2018; Green et al., 2017a), and since 2010 there is evidence that self-reported health has been declining and at a faster rate in recent years (Dorling, 2016). In a study matching ONS data on daily number of suicides for England and Wales with an index capturing the daily level of economic uncertainty in the UK for the 2001-2015 period, Vandoros et al. (2018) showed that economic uncertainty had an effect on the number of suicides, although the increase was found to be only immediate and short-lived to the same or next day of the economic shock. More generally, although deaths from suicide increased in 2015, more recent data suggest that such increase was only temporary (ONS, 2018h). Similarly, the estimated total number of homeless deaths has increased by 24% between 2013 and 2017 (ONS, 2018i), although it is difficult to determine whether this was due to an increase in the number of homeless or to other factors. The British Medical Association (BMA, 2016) and the Royal College of Physicians (RCP, 2016) have both highlighted the serious public health consequences of austerity and the underfunding of the NHS.

The hypothesis that cuts to the NHS may have affected overall quality of care and consequently translated into higher mortality is plausible, but identifying the specific role of cuts to, for example, NHS rather than to cuts in other sectors occurring at the same time is clearly difficult (although analyses using more disaggregated data might provide more insight). The PHE report (2018a) concluded that recent mortality trends have to be evaluated in the context of changing government expenditure on social care and public health services. However, the report also acknowledges limited evidence on potential causal mechanisms. Most analyses ascribing the stalling of mortality improvements to “austerity” measures, as noted earlier, mainly focus on population averages and temporal associations, thereby being unable to refute the possibility of ecological fallacy. Linked to this, studies looking at the relationship between local authority deprivation and mortality in 2015 found no association (Jones, 2017; Green et al., 2017a).

There is also no agreement about whether general economic conditions (although different groups have been affected differently, with older people being better-protected than younger ones), welfare changes e.g. pension credit, which was used by only a fraction of the older population, cuts to social care or to the health system could have been the most important potential drivers and, in any case, it appears infeasible to disentangle the specific effect of each component. Furthermore, as temporal associations do not prove causation, it is impossible to rule out reverse causality, i.e. the sudden increase in poor health and ensuing greater need for care triggered a decline in NHS and social care performance, e.g. in delayed discharges, and a reduction in the rate of mortality improvement and not the other way around. Second, and as for the case of ageing, presumably austerity measures would manifest their potential negative effects gradually; however, mortality trends across and within years have been more volatile than in the immediately preceding period and followed an “on/off switching” path since 2011 (Jones, 2017). Third and more important, the rise in deaths occurred across a number of European countries as well as all constituent parts of the UK, not just in England. Given that similar trends have been observed in Scotland, Wales and also in Northern Ireland, where (i) austerity has been on several measures less severe and (ii) health and social care are integrated, the austerity explanation has been challenged (e.g. Jones, 2017). The same argument is even stronger for some neighbouring European countries which have experienced similar slowdowns in mortality improvements, but which suffer more moderate austerity measures than those imposed on social care in England. Ireland which had much more severe austerity after 2008 than the UK, improved life expectancy substantially more than the UK – and Northern Ireland – in the following period. Some European countries have experienced different timing patterns or have seen little change in life expectancy, despite the introduction of severe austerity measures such as in Spain. On the other hand, Germany that was much less affected (Pearce, 2013) had particularly poor mortality trends. If it is accepted that there are wider factors than changes in austerity involved in recent trends, then they should be included in analyses since results from models that exclude important variables are biased and potentially misleading. If such wider factors are not included, then it would be appropriate to use local variables to explain the difference between the UK and other countries.

The golden cohort

The recent debate sparked in the media about changes in life expectancy in the UK has been underpinned by the fact that the 2016 ONS projections of life expectancy (ONS, 2017g) were lower than those published in 2014 (ONS, 2015c) This change was essentially due to the fact that the 2016 revision modified the assumed mortality rate improvements for one particular group – the so-called

"golden cohort"[22], i.e. the generation born in the decade centred around 1930 (those born between 1925 and 1934). Compared to prior and later generations, this generation has been characterised by particularly high levels of health and mortality improvement over time (Murphy, 2009) which were assumed to continue into the future in recent ONS projections. Members of this group were in their 80s in this decade, the age group that has most impact on overall mortality measures. Some argue that part of the factors responsible for the slowdown in life expectancy of recent years has to be traced back to the fact that the golden cohorts are now in their 80s and 90s and hence make less of a contribution to overall death rates (Wilson and Coghlan, 2018). In recent years, however, the positive health experience of this cohort seems to have reduced substantially, if not disappeared entirely, possibly due to increasing prevalence of co-morbidity, and its mortality improvements appear now closer and closer to other population subgroups.

Some hypotheses have been advanced to explain why the golden cohort mortality improvements have slowed down in recent years (Goldring et al., 2011; Shindler, 2018; Wilson and Coghlan, 2018; Ortiz-Ospina and Ritchie, 2018), but little, if any evidence exists supporting one or the other. Ortiz-Ospina and Ritchie (2018) note that the relative advantage of this group was likely to end at some point, especially if the predominant driver of the cohort's better health outcomes was a dramatic reduction in smoking. Although we note that there still is a social gradient in smoking patterns, the authors show that gains from reduced smoking have been almost fully realised, leading to stalls in improvements in lung cancer mortality, although smoking also makes a major contribution to CVD and respiratory mortality. It is thus reasonable to expect that this effect would eventually fade

[22] It is not precisely known why individuals belonging to the generation born around the period between the late 1920s and mid-1930s have enjoyed exceptional and higher mortality improvements throughout most of their life span as compared to prior and post generations. Hypotheses include the fact that this generation benefited from a number of health improvements, including better sanitation, improved nutrition, preventative and treatment measures for infectious diseases affecting young and middle-aged adults, and, in later middle-age, improvements in the treatment of circulatory diseases. This so-called 'golden cohort' was also exposed to rationing in their adolescent and early adult years (between 1940 and 1954) which might have bettered general health during childhood and later. Further, increasing smoking behaviour may also partially explain why the generations born later have had lower improvements. For a full account see Murphy (2009) and O'Connell and Dunstan (2009).

away. At the same time, they also consider that changes in health outputs, including flu, the possibility that older patients may be facing more complex and multiple morbidities and lifestyle changes might have decelerated the mortality improvements of the golden cohort. For instance, if flu is the key trigger for the observed increase in mortality and, as it is known, mortality rates for specific influenza strains are particularly high for the elderly, it might be that this generation now in its 80s and 90s has been particularly affected by the recent fatal influenza seasons.[23]

Migration

The relationship between immigration and health is complex and multifaceted. The 'healthy migrant' effect, i.e. that migrants tend to show better health outcomes than the sending, but also than the host population, is well-established. This migrant health advantage is also known to erode over time with the length of stay in the host country (Benfante, 1992; Zeeb et al., 2002; Minas, 1996). At the same time, research has shown that migrants who experience poor health during their time abroad are more likely to return to the origin country than immigrants in better health condition, the so-called "salmon bias" effect (Giner-Monfort et al., 2016).

On the one hand, in recent years the UK has experienced an important influx of migrants from Central and Eastern Europe. PHE (2018a) showed that, for instance, mortality of migrants from Poland was higher than the average for England in 2011 to 2013, possibly reflecting pre-existing differences in mortality between origin and destination. Yet, it is also reported that in the same period mortality of other non-European migrants, such as Bangladeshi or Pakistani, was lower than the English average. These contrasting observations highlight the difficulty in assessing the effect of in-migration on mortality trends. However, whichever it might be, it is likely that it would be quite modest as recent migrants tend to be of young ages and account for a relatively small proportion of the whole UK population and, more importantly, of deaths.

On the other hand, recent research has highlighted increasing return of British emigrants, and especially of older retirees from countries with warmer climate as a result of declining health conditions, the salmon bias effect (Hall and Hardill, 2016; Age Concern, 2007). However, data on retirement migration is notably hard to capture given the fluidity and flexibility of such migration patterns. This makes it difficult to assess whether the timing and size of this return migration flow coincided or somehow influenced recent changes in mortality. Further studies in this direction, for now exploiting already existing migration data with assumptions about migrants' health characteristics, would thus be important, especially in light of the potential changing position of the UK within the European Union and its implications on health and social care systems.

The broader question of the <u>total</u> contribution of migrants to UK mortality trends would need in-depth investigation to establish, for example, the role of overseas workers in maintaining the health care system and, in particular, the social care system.

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[23] There have been arguments that cohorts had differential protection depending on their earlier exposure to influenza. However, as in the case of other potential explanations it is hard to determine why the risk profile of the older population should have changed in such a relatively short period of time. For instance, changes in the proportions of smoking, hypertensive and increasingly obesity do not move quickly enough to support this claim.

European and international comparison

Understanding of what is happening in the UK cannot be separated from the experience and developments of other countries in Europe and around the world. Although annual improvements in life expectancy since 2011 in the UK had been particularly low (second only to the U.S. among major rich countries), the slowdown and associated declines in life expectancy at birth has been observed among other high-income countries (Ortiz-Ospina and Ritchie, 2018; ONS, 2018d; PHE, 2018a, 2018b, 2018c; Raleigh, 2019; Cardona and Bishai, 2008; Ho and Hendi, 2018; Fenton et al., 2019). In this section, we review the available comparative evidence, focusing on other high-income European and Western nations, to which the UK is close in terms of population structure, mortality patterns and socio-economic characteristics.

European and international comparison have been facilitated by the launch of the *EuroMOMO project as well as by the enlargement of the data pool available in the HMD. The former is* a surveillance network for monitoring weekly 'real-time' all-cause age-specific mortality across participating European countries, using a standardised analytical approach allowing analysis of pooled and comparative mortality trends across an increasing number of European states. The latter is a repository of harmonised mortality information and estimates for large number of countries.
Research exploiting EuroMOMO data has shown that high excess winter mortality in some years has not been unique to the UK but has been experienced as a broader region-level phenomenon (Vestergaard et al., 2017; Baker et al., 2018). Looking at the post-2008 period, for instance, Franklin et al. (2017) reported slow-downs in mortality improvements in most European countries, including countries that had pre-2008 rates of improvement similar to the UK, e.g. Switzerland, the Netherlands and Belgium. Raleigh (2019) showed that gains in life expectancy for men were smallest for the UK, France and Germany in the period 2011-2016 and that, especially in the UK, female life expectancy over the same time period showed practically no change.

If we focus on the 2014-2015 period, numerous studies showed that the irregular mortality observed in the UK coincided with similar fluctuations in most European countries (PHE, 2018b; Newton et al., 2017; Eurostat, 2016; Raleigh, 2019). EuroMOMO reported a considerable increase in the weekly number of excess winter deaths among individuals aged 65 years or more between December 2014 and February 2015 in 14 European countries compared to previous years. Above baseline mortality was first observed in England, the Netherlands, Italy and Portugal. Like in the UK, older people, especially women, were most affected by these excess deaths in France, Germany, Italy, Poland and Spain (Newton et al., 2017). The annual change in life expectancy at birth was negative in 19 out of 28 EU states (reduced period life expectancy of women in 23 and of men in 16 states) and even more countries experienced reduced life expectancy at age 65 (this occurred in 25 European countries for females and in 21 countries for males). Only Ireland, which was among the most-affected by the post-2008 economic crisis, some Baltic and Scandinavian countries showed life expectancy improvements in 2015 (Eurostat, 2016).

As in the UK, no particularly remarkable trend was observed in the year following the first anomalous peak of 2015 and life expectancy rose again in most European countries. Yet, above-range spikes in mortality were identified in the winters of 2016-2017 (Vestergaard et al., 2017) and 2017-2018 across European states (EuroMOMO, 2018), with the exception of Scandinavian countries. Despite being relatively descriptive, this array of evidence suggests that factors causing the spikes in mortality in the UK in 2015 and 2017 and the general slowdown in life expectancy were also found in many other European countries and suggests a widespread Western European phenomenon.

It has further been noted that the reduction in rates of improvement have occurred beyond Europe (Ho and Hendi, 2018; Raleigh, 2019). Academic contributions using a wide array of data on life expectancy at birth showed that the pace of gains in life expectancy have slowed down in recent years at the global level (Cardona and Bishai, 2018). A recent publication from the ONS (2018d), which compared trends in mortality in 20 countries to the trends observed in the UK using HMD data, similarly established that rates of mortality improvement, particularly for those aged 80 and over, have slowed down in high income countries across the globe between 2011-2016. Improvements though were also reduced at lower ages: UK males aged 65 to 79 years experienced an improvement of 5% in SDRs over this period (compared to the 31% improvement occurred between 2001-2011), but equivalent or lower improvements were also observed in the U.S. (2%), Germany (3%), Belgium (5%) and France (5%). However, the UK experienced large slowdowns in life expectancy, especially among the oldest age groups and females, second only to the U.S.

In the U.S., after some years of declining improvements in mortality, the first actual annual fall in life expectancy since the 1993 HIV/AIDS epidemic was recorded in 2015 (Murphy et al., 2016; CDC, 2016; Xu et al., 2016) and then again, unlike many other European countries, in 2016 (Murphy et al., 2017), followed by a further fall in 2017 (Murphy, Xu, Kochanek, & Arias, 2018). In the ONS report (2018d) as well as in Ho and Hendi (2018), the U.S. is at the bottom of the rankings for both male and female life expectancy trends in the chosen countries, primarily as a result of increasing mortality among middle-aged adults. Although mortality improvements are still taking place at all ages, preliminary data from Statistics Canada show a general slowdown in life expectancy for both men and women. These data have been supported by the most recent report into the Old Age Security Program mortality experience, which showed life expectancy increases over 2010-2013 had been lower than experienced over the previous decade (OCA, 2016).

At the population level, Canada and the U.S. share fairly similar profiles in causes of death as the UK and have experienced broadly similar influenza seasons (Institute and Faculty of Actuaries, 2017). It has been shown that in the U.S. the worsening of mortality was particularly acute among the male working-age, non-Hispanic white population (mainly aged under 60) (Case and Deaton, 2015; 2017; Woolf et al., 2018; Ho and Hendi, 2018), possibly suggesting that the impact of influenza most likely played a contributory factor only. Increases in mortality among young adults have also been reported in the UK (see section 1.2.1). The austerity responses in Canada and in the U.S. were different and not as severe as in the UK. In the U.S., President Obama campaigned on taxing the wealthy and investing in social services, and when he came to office in 2009 the U.S. followed the path of stimulus with the American Recovery and Reinvestment Act (UNT Web Archive, 2017). In the former, cutbacks to social assistance benefit and declines in housing funding were introduced in 2012, but in a less substantial way as compared to the UK. These policy differences might in part contribute to the difference in population experience in life expectancy trends at old ages between the U.S. and the UK, as cuts to the national health system are expected to have a stronger detrimental effect on the old, and to a degree explain the lower slowdown in life expectancy in Canada.

Overall, reduced improvements in mortality have been widespread among the countries identified here. The fact that the slowdown in population life expectancy improvements has been seen across different countries provides insight into reasons for the recent UK trends and their future path that are not only country-specific, but also broader cross-national factors are likely to have contributed to the observed increase in mortality in the UK. This would suggest that economic or health service factors unique to the UK do not provide the complete answer. Nonetheless, despite some similarities with other countries, the UK remains peculiar in its experience in that the slowdown in mortality improvement has been more rapid here than in other European settings and deserves particular attention given that UK life expectancy is still lagging behind that of many Western European countries with large populations.

Summary and conclusion

After decades of progress, mortality and life expectancy improvements in the UK have experienced a slowdown. Although this phenomenon has been observed elsewhere outside the UK and the European Union, the UK has fared worse in terms of mortality improvements than most other comparator countries in this decade. In addition, inequalities in mortality appear to have widened over time.

This review of the available literature overall reveals that explanations for the observed mortality patterns in the UK have centred on few distinct causes, with analyses generally tending to be methodologically constrained by data availability and often temporally-limited. Studies have been largely concentrated on the austerity-effect estimation, but have often been limited to few time-points and have relied on different and, often not precise, definitions of ‘austerity’, which overlaps with discussion of the extent to which recent policy changes have borne down more heavily on the more disadvantaged in British society. Research on influenza is mainly based on ecological correlations between mortality and influenza-linked time series, which cannot prove any causal link, and are more likely to explain short-term fluctuations rather than the observed long-term decline in mortality improvements. Alternative explanations, including the influence of artefactual effects (for example quality of data especially mortality denominators or tempo effects), the contribution of other risk factors on the golden cohort and following cohorts such as obesity and changing lifestyles have not yet been clearly articulated. We note that the explanations are not likely to be independent. A more holistic and multifactorial approach which considers longer time periods is thus needed for a greater understanding of mortality in recent years. We seek to discuss and provide evidence on trends and possible explanations in the following sections.

Section II – The UK context: data analysis and evidence

In the previous section, we summarised what has been so far written on recent changes in life expectancy and mortality trends in the UK and presented the available alternative views on what has possibly driven such transformations, including virologic and policy-related factors. In this section, we present additional analysis which elucidate the phenomenon. This is needed because existing research has provided multiple potential and sometimes contradictory explanations and evidence for the stalling of mortality improvements in the UK. However, it has so far failed to clearly define the problem in relation to long-term trends (1950s onwards) by largely focusing on mortality peaks in selected years, e.g. 2015. We thus here employ several indicators of mortality, including SDRs and life expectancy (see footnote 3 for more on these measures) to investigate the consistency of previous findings on longer-term trends in terms of sex, age and timing. Since about 2010, overall improvements in mortality have fallen sharply and if continued, would soon be approaching zero, as has already happened for some sub-groups. We therefore consider the downturns not only in older people, but also at some young ages. Some commentators have argued that recent trends have had a more negative impact on women than on men, since changes in life expectancy for women tended towards zero in the most recent years.

Long-term trends in mortality since 1950

Figures 1a and 1b show SDRs and annual rates of SDR[24] improvement in the UK and constituent countries since the 1950s. Improvement in parts of the 1960s were close to zero, which led some experts at that time to assume that the highest possible life expectancy had been achieved. For example, projections at that time by the Office of Population Censuses and Surveys (now ONS) assumed that there would be no further improvements in mortality, as did some other international agencies. In the event, mortality started to improve at generally increasing pace throughout the rest of the century to achieve the highest ever-recorded rates of improvement. This pattern continued in the early part of the 21st century. Mortality initially improved strongly with average improvements of about 2% to 3% per annum in SDRs in the early years of this century, but more recently improvements have fallen very steeply approaching a value close to zero in the recent period (Figure 1b). The change since about 2010 appears particularly substantial.

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[24] Whichever indicator is used, standardised death rates or life expectancy and whether these referred to the whole population or some specific age group, there are alternative ways of estimating the rate of improvement of mortality.
Year-to-year changes are largely uninformative because of substantial year-to-year fluctuations in the observed values. In order to identify underlying patterns, some form of smoothing o averaging of rates is usually employed.
Standard ways of measuring trends include use of moving averages and/or regression coefficients. These are equivalent since regression coefficients can be formulated as linear filters. This approach is simple and intuitive but has two main disadvantages. The first is that it is not up-to-date, providing an average value over an extended period. The second is that high weight is given to values at the ends of the fitting period since slopes are largely determined by these values.
To overcome these deficiencies, we estimate rate of change as the first derivative of the logarithm of a spline fitting function that can both make current estimates and has reduced sensitivity to the specific observation. Figure 1(a) presents such results, expressed as a percentage. Note that estimates at the end of the series are still less precise than those in more central positions since current estimates are subject to revision because additional later values may clarify whether the particular estimate reflects a blip or part of emerging trend. The most recent estimates must therefore be treated with caution although it must be recognised that these are often the ones of highest interest.

Figure 2 shows the corresponding values for the alternative widely-used age-adjusted indicators of mortality, period life expectancy at birth. While not showing exactly the same trends, these are very similar and the sharp drop in mortality improvement is again clear-cut. Northern Ireland has a rather different trend in the early years, but all constituent countries show deterioration in the current decade. The recent period therefore exhibits a particularly sharp decline in the rate of long-term improvement in overall mortality. In the next sections, we consider whether these recent trends are similar or distinct across various population sub-groups, such by sex and age.

Sex-specific trends

Sex differences have remained largely similar, with females initially exhibiting a rather higher rate of improvement until around the 1970s, and males showing a rather greater level of long-term improvement subsequently. The sex differential in mortality increased and then declined for life expectancy both at birth and at older ages (Figure 3) as the large gap that opened up in the earlier period started to decline. This was particularly associated with substantial improvements in CVD, which historically have had a greater impact on men, for reasons including much higher levels of smoking among men than women in the early period, followed by greater reduction in smoking for men than women and fewer men employed in high-mortality occupations.[25]

This trend is well-recognised, but our focus is on whether there has been a change in the current decade. As Table 1 shows, there has been little if any improvement in mortality among women in the period 2011-16, whereas males have continued to improve albeit at a slow rate. However, this does not necessarily indicate that women have done relatively worse than men in the most recent period as compared with earlier periods. The conclusion depends on whether we look at absolute or relative metrics.

Table 1 Changes in life expectancy at birth by sex in the UK (years) – 2006/11, 2011/16 and 2006-2011

Period	Males	Female	Difference
2006-11	1.66	1.24	0.42
2011-16	0.40	0.13	0.27
Difference	-1.26	-1.11	-0.15

Source: HMD; Own calculations

[25] These results are based on HMD data because these data are available to two decimal places and give a number of differenced series are presented, this is to minimise rounding errors in calculations. The method of calculation of life expectancy differs slightly between HMD, Eurostat and UK official life tables, but the differences do not appear substantive.

Figure 1a Long-term changes in SDRs, UK and constituent countries by sex.

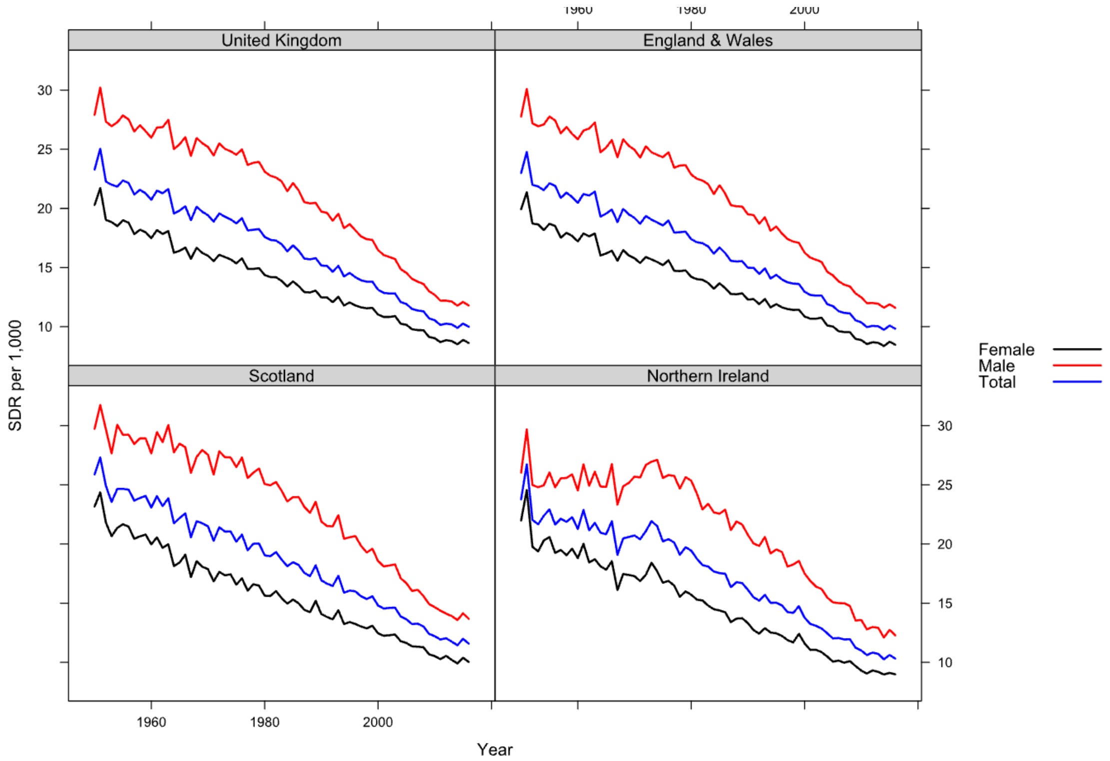
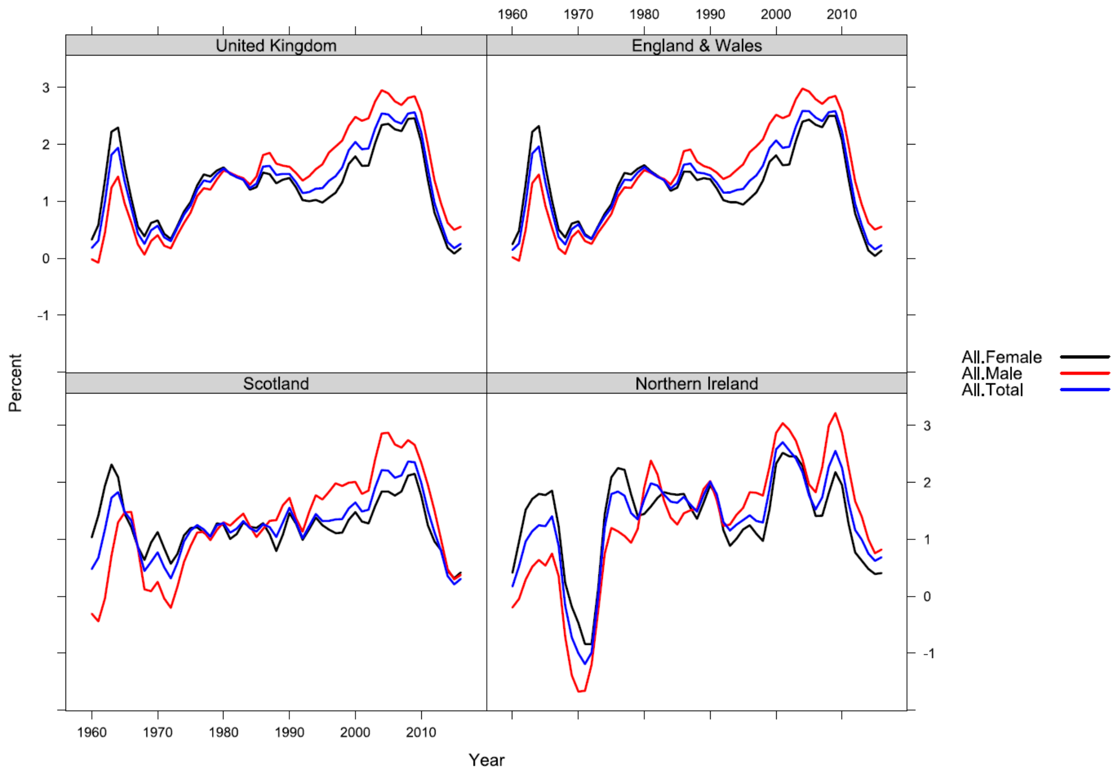
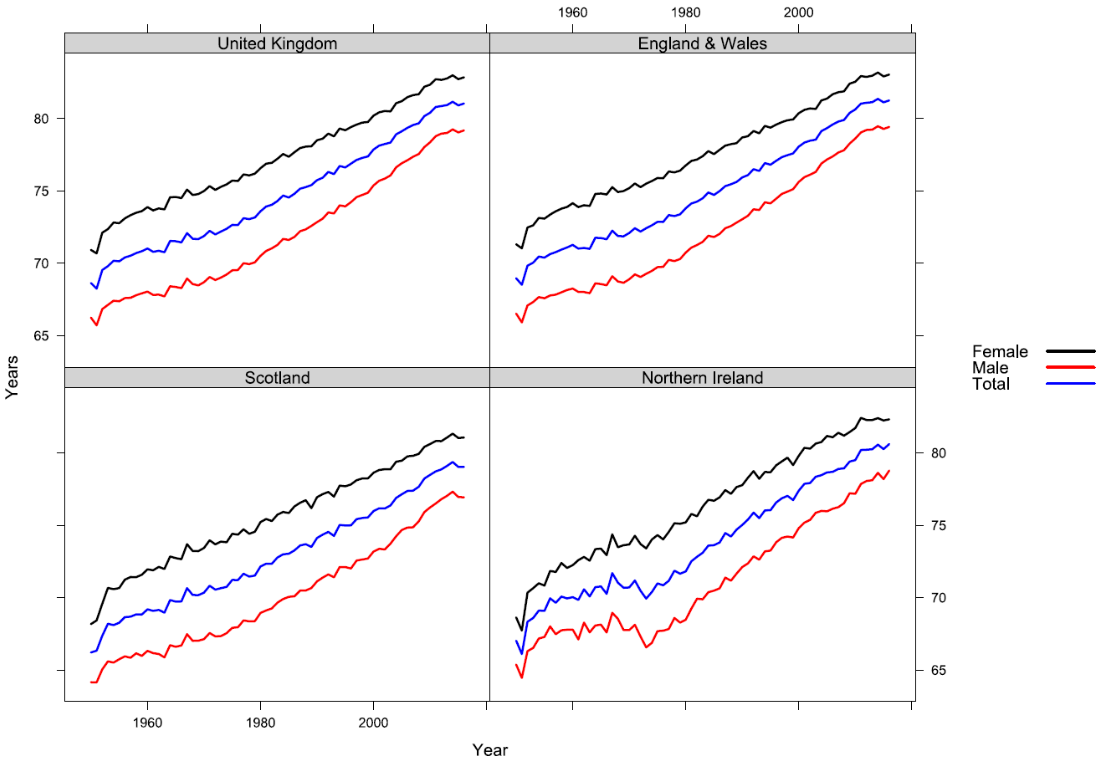


Figure 1b Long-term percentage changes in SDRs, UK and constituent countries by sex



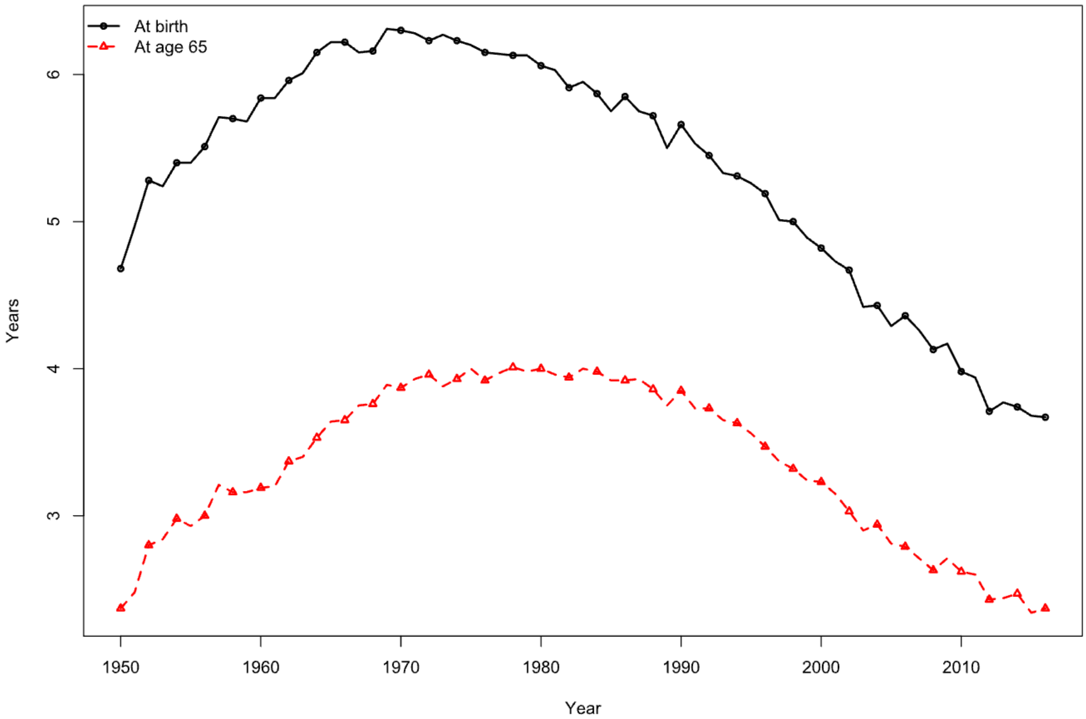
Source: HMD; Own calculations

Figure 2 Period life expectancy at birth, UK and constituent countries by sex.



Source: HMD; Own calculations.

Figure 3 Male-Female differences in Life Expectancy at birth and age 65, UK 1950-2016



Source: HMD; Own calculations.

Both sexes showed a substantial decline in improvement in the second period, with the increase in female life expectancy being only one third of that for men (Table 1). However, the deterioration between 2006-11 and 2011-16 was greater for males, 1.26 years compared with 1.11 for females. This might appear surprising since, for example, life expectancy increased substantially less for women than men in 2011-16, it is sometime assumed that women have been more affected. However, such differentials are not directly relevant to the question of whether men or women have fared relatively better or worse in the most recent period since a similar finding has been observed in earlier periods as sex differentials in mortality decline.

The main conclusion is that rates for men and women have moved in a very similar way over the whole period, although female improvements have been slightly less than for men. There is no evidence that the deterioration in mortality improvement in the recent period has been greater for women than for men at the overall national level. While this may be so for some particular sub-groups of women, this will be offset by greater male disadvantage in other sub-groups.

Age-specific trends

Table 2 presents information on change for different age groups. Specifically, here we present age standardised deaths in each age group rather than rates, because this directly shows the relative contribution of deaths in each age group to overall age-standardised mortality. The other mortality measure used so far – life expectancy – is not well-suited for comparing different age groups, although methods such as decomposition (e.g. Arriaga, 1984) may be used.

Table 2 Standardised deaths by sex and age, 2006, 2011, 2016 and changes, UK (using 2013 ESP population with size 1,000)

	All ages		Age 0-49		Age 50-69		Age 70-84		Age 85-99	
	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female
Year										
2006	14.04	9.79	0.70	0.41	2.49	1.57	5.82	3.93	5.04	3.88
2011	12.20	8.69	0.61	0.37	2.12	1.40	4.92	3.38	4.55	3.55
2016	11.79	8.62	0.61	0.37	2.06	1.37	4.66	3.27	4.47	3.62
Between years difference										
2006 to 2011	-1.84	-1.09	-0.09	-0.04	-0.37	-0.17	-0.90	-0.55	-0.49	-0.33
2011 to 2016	-0.41	-0.07	0.00	0.00	-0.07	-0.03	-0.26	-0.11	-0.09	0.07
2006-11 and 2011-16	-1.43	-1.02	-0.09	-0.04	-0.30	-0.14	-0.64	-0.44	-0.40	-0.40

Source: HMD; Own calculations

Improvements in the first period were particularly concentrated in the 70-84 age group, accounting for about half of total change, and for a substantial part in the much smaller decrease in the second period. This is largely because more deaths occur in this age group, and similar rates of change are apparent in all groups (see footnote 6). In the first period, all groups' values declined by about 10%, but changes were close to zero in the second period for all age groups. Both sexes aged 85 and over experienced a reduction of 0.4 standardised deaths between the two periods. However, since the initial value for women was below 0.4 the result was an absolute deterioration in mortality between the two periods, whereas men were initially just above this value, so they continued to show an improvement, albeit at a much-reduced rate. An absolute increase in standardised deaths for women at these old ages does not mean that women have fared worse than men in the recent past, since the longstanding lower rate of improvement for women will inevitably mean that they are likely to cross certain thresholds earlier than men. With both sexes experiencing the same rates of deterioration, women will reach the point where mortality starts to increase before men do. This is not to say that there are no sex differentials, and these will be noted elsewhere but at present, these appear to be second-order effects in relation to the underlying changes that affect both sexes equally.

This similarity in stalling of mortality improvement across sex and age groups suggests that explanations for recent trends will need to account for more than those which are heavily concentrated in specific sub-groups, such as dementias for older people.

Section III – International comparison: data analysis and evidence

The previous sections confirmed that mortality improvements have been stalling in the UK since about 2010. Comparison of mortality trends with other countries is important to provide additional insight into trends observed in the UK. If trends are very similar, explanations that relate directly only to UK conditions would have less weight; if the trends were similar but not identical, then explanations for the general trends would need to be general, and local explanations examined to explain the national deviations from the wider pattern. In this section, evidence is provided to explore differences and similarities between the UK experience and settings with similar socioeconomic structures and mortality levels. For cross-national European comparison, we mainly use the set of high-income countries largely located in the western side of Europe and therefore ones that provide the most appropriate comparators for the UK. These countries are the European countries defined as "developed economies" according to the MSCI World Index[26] (the fuller set of EU and neighbouring countries is given in Appendix II). Since the determinants of trends in the Eastern European countries and very different, we do not include them in most analyses, but we include relevant non-EU countries such as Switzerland and Norway. Since the 15 countries included are too many for detailed analysis, we will particularly concentrate our comparisons to countries neighbouring to the UK, such as France and Netherlands, since they might be expected to be closest in economic, social, political, climatic and geographical aspects. Using a changepoint analysis, we show that overall changes in mortality have been very similar in comparator Western Europe countries. However, evidence shows that, since 2010, annual improvements have been greater in many European countries than in the UK. Some findings, e.g. increased adult mortality, resemble mortality patterns that are not equally present in other European settings, but that have already been observed in the U.S.

Long-term mortality changes in high-income countries

A more gradual shift from historically very high rates of improvement in mortality to much lower ones has been observed in a number of high-income countries in Europe and elsewhere (Figure 4 shows annual percentage rates of improvement, see footnote 24)[27].

For the countries shown in Figure 4, improvement rates tending towards zero are confined to the UK, U.S.A., West Germany and the Netherlands[28], although France and Belgium show a similar but

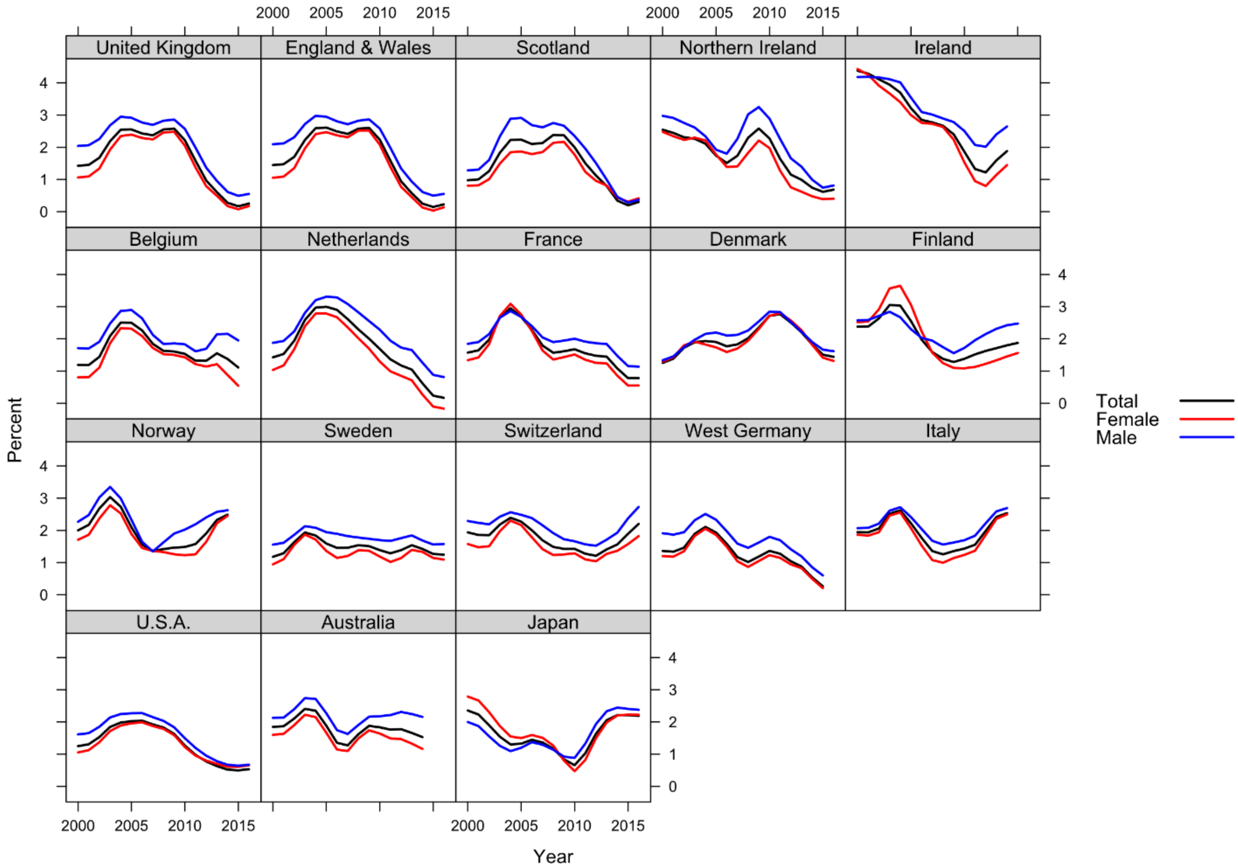
[26] For more, see: https://www.msci.com/market-classification

[27] Following the literature review, comparison here is mainly made with high-income countries, especially in Western Europe as set out above. We use HMD data here which ae not available for all countries, but do include data separately for England and Wales, Scotland and Northam Ireland treated in a consistent way with the other countries shown. We have not included countries of Eastern and some in Southern Europe, which exhibit different patterns and where a number of different factors are likely to operate. We also exclude a number of small countries since values are often volatile and therefore tend to be uninformative. We draw on various sources including United Nations Population Division, Eurostat, World Health Organisation, and Human Mortality database.

[28] Note that there are concerns about the accuracy of German population estimates since Germany did not hold censuses in the period before 2011 (since 1987 in the East and 1989 in the West),) and the 2011 Census estimates were found to be substantially lower than the estimates that had been used to construct mortality statistics. German trend data should therefore be interpreted with caution. U.S. is shown because there has been considerable interest in comparative trends, although the explanations for these trends are different. Australia and Japan are examples of high-income countries from other parts of the globe.

attenuated trend. The Scandinavian countries along with Switzerland and Italy, show a much less pronounced pattern with rates of improvement around 1% per annum and a tendency for rates to be improving in the most recent period (although they had already slowed down before 2010 – see below). A notable point, however, is not just the more pronounced similarity of current patterns, but rather the similarity of trends in the early years of this century. In the great majority of cases, there were local and often absolute maxima in recent decades in the rates of improvement in the period.

Figure 4 Annual percentage changes in standardized death rates, selected countries



Source: HMD; Own calculations.

A general slow-down in mortality improvement is widespread and real. Figure 5 shows a changepoint analysis from 2000 to around 2016 using HMD data (which therefore includes non-European HICs and separate UK constituent countries) that identifies whether there has been a trend change under the assumption that the series may be approximated by a piecewise linear spline and the point at which it takes place in the period since 2000. This approach has been used widely including in ONS (2018d). All countries (apart from Denmark) showed a decline in the rate of improvement during the period, although in most cases these did not achieve statistical significance at 5% level. In addition, the estimated breakpoint varied. Most of the national breakpoints were around 2005, and therefore earlier than in the UK (and constituent countries). The UK constituent countries show a very similar pattern with, for example, Northern Ireland being closer to Great Britain values and Ireland closer to the continental European pattern.

Figure 6 shows SDR values for the UK, France and the Netherlands in more detail. The levels of mortality in the UK and the Netherlands are very close over the whole period, and the location of the breakpoint and the magnitude of the change in trend at the period are very similar. The trend in France was broadly similar, although the level was considerably lower, and the breakpoint occurred somewhat earlier, as was the case for most European countries.

Care is required to avoid over-interpreting such results: these analyses in fact show the best-fitting piecewise linear trends over the selected period. Other specifications may produce different results, as could alternative mortality indices (including alternative sources of life expectancy data) and the choice of fitting period. Results should be treated as indicative: for example, the method will identify a changepoint in a simple exponential curve such as $y = \exp(t)$, where there is obviously no structural change by construction. However, the conclusion that there was a general slowdown in rate of overall mortality improvement around 2005-10 suggests that UK patterns can only be usefully interpreted in conjunction with those of comparator countries.

This slowdown in mortality improvement is particularly apparent in this set of high-income countries largely located in the western side of Europe and therefore ones that provide the most appropriate comparators for the UK shown in Table 3 (the fuller set of EU and neighbouring countries is given in Appendix II). The increase in overall life expectancy over the period 2011-16 was less than in the period 2006-11 in 14 of the 15 the countries shown, with the exceptions being Norway, together with Italian males. The low rates of improvement in UK life expectancy at birth in period 2011-16 for both males and females is in strong contrast to the previous period 2006-11, where UK improvement rates were amongst the highest; indeed, although starting from a lower base level, UK females had the largest improvement of all countries shown in period 2006-11. Most of the other countries tend to show a decline in rates of improvement from high points around 2005-10, and values at the end-point around 2015 are often broadly similar to those around 2000 (Figure 4). None of these countries had the sustained period of high improvement of the UK in the early 2000s. While a reduction in rates of improvement is widespread, a consequence of the particularly high initial rates of improvement means that the UK exhibits a more marked change of trend.

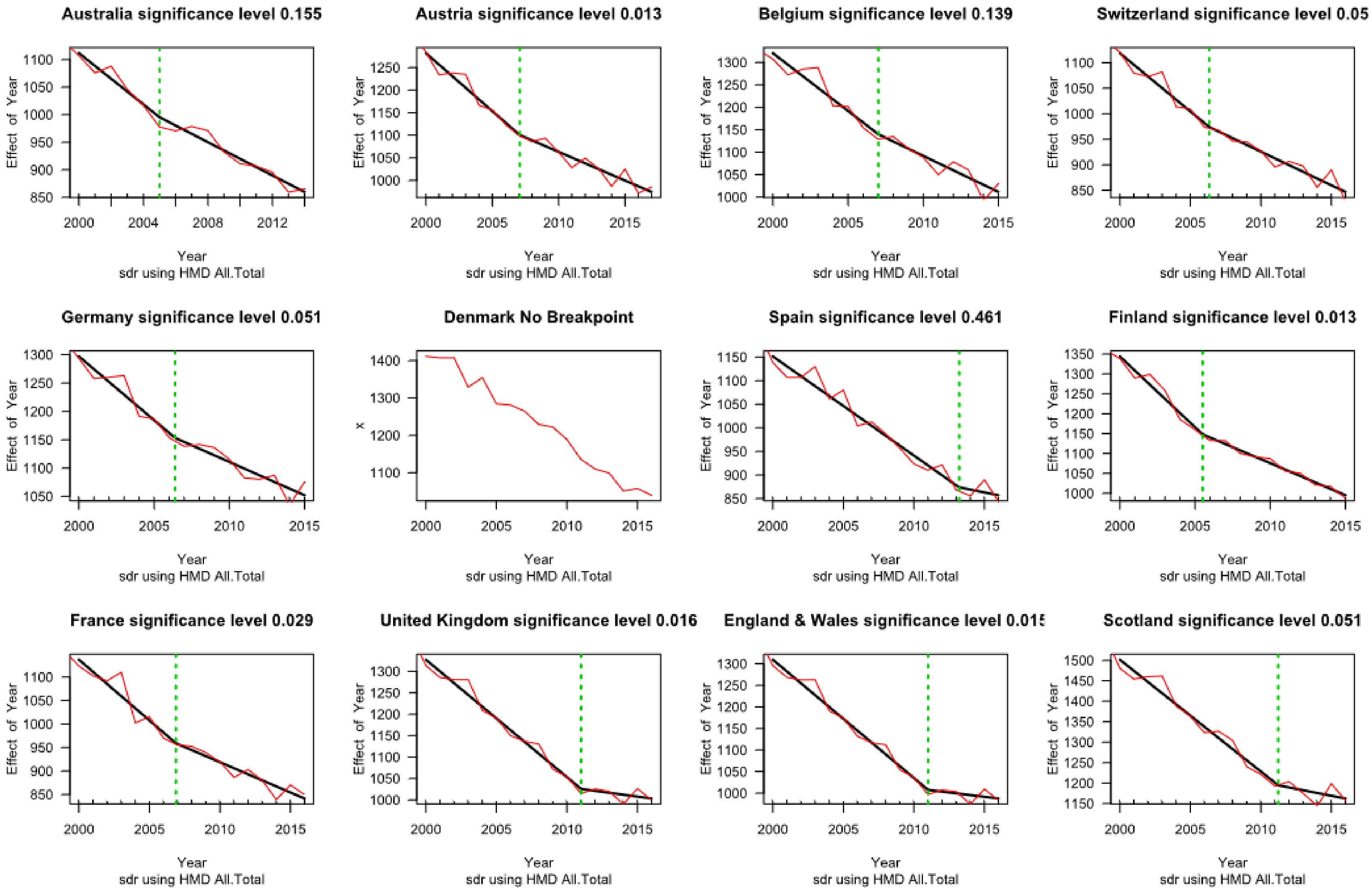
Over the whole period 2006-16, the UK has improved more than countries such as Sweden and Germany and at a similar rate to many other countries in Table 3. If the UK is compared with close, long-standing rich industrialised counties such as France or the Netherlands, the difference in life expectancy increases over period 2006-16 is 0.1 years for France (a difference averaging 4 days per annum for period life expectancy at birth) and zero for the Netherlands. The UK has performed in a similar way to other countries shown over this 10-year period, apart for three countries with large improvement that had historically low levels, Spain, Portugal and Ireland that reflects an element of “catching up”, and the anomalous case of Denmark, which has been discussed by Christensen et al. (2010).

What is distinctive about the UK is its temporal pattern. Improvement was more concentrated in the first part of the 10-year-period compared to the other countries shown. For this reason, explanatory variables that changed more substantially within the whole period 2006-16 in UK than in other parts of Europe would appear to have greater potential ability to explain this trend than those which exhibited more similar trends across countries. It should be noted that the particularly sharp decline in UK in 2011-16 as compared with 2006-11 is due in part to the fact the breakpoint around 2011 meant that the comparison is between a wholly "good" period with a wholly "bad" one, whereas in European countries where the breakpoint was usually somewhat earlier, the period 2006-11 would contain some "bad" years, and indeed in a number of cases, there were more "bad" (i.e. post-change point years) than "good" years in this period[29].

Therefore, the case for UK exceptionalism that has been so widely reported and commented on in official publications, academic papers, and blogs and media reports (and even in the recent Leader of the Opposition's Budget reply statement in October 2018[30]) may be less strong than sometimes suggested if this pattern may be due in part to a shift within the interval. On the other hand, if the current particularly negative UK mortality trends were to continue into the future, this would have major implications. The identification issue of the causes underlying both the more widespread international trends and for the differences between UK and comparator countries is crucial for assessing the implications of these trends.

[29] A pre -and post-change point analysis could also be performed for each country to determine the magnitude of the change in trend, if one is interested in one single country. This would allow identifying more precisely the time period chosen for each country.
[30] For more, see: https://www.parliament.uk/about/how/role/check-and-approve-government-spending-and-taxation/the-budget-and-parliament/

Figure 5 Changepoint analysis in mortality rates of selected high-income countries



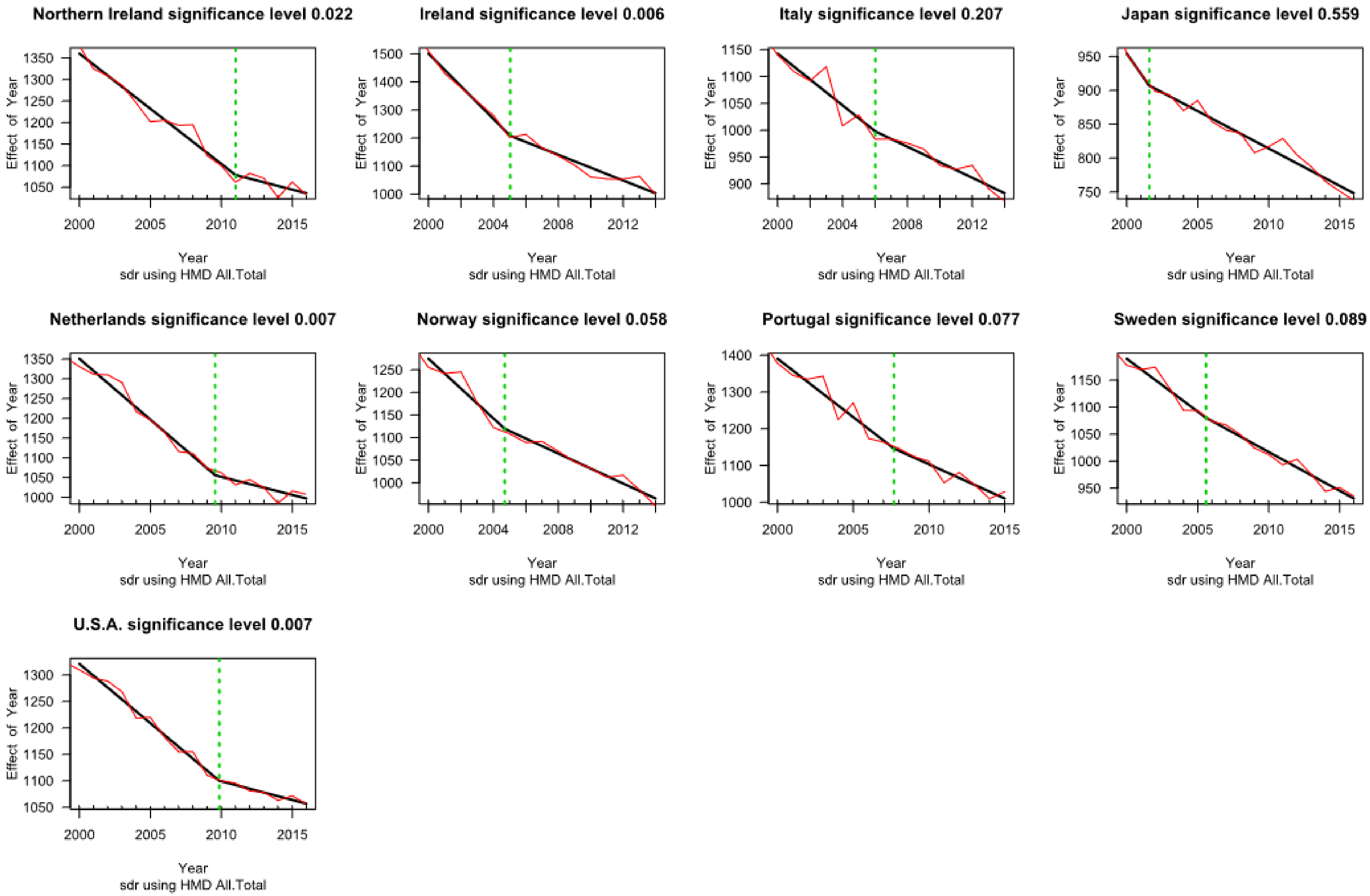
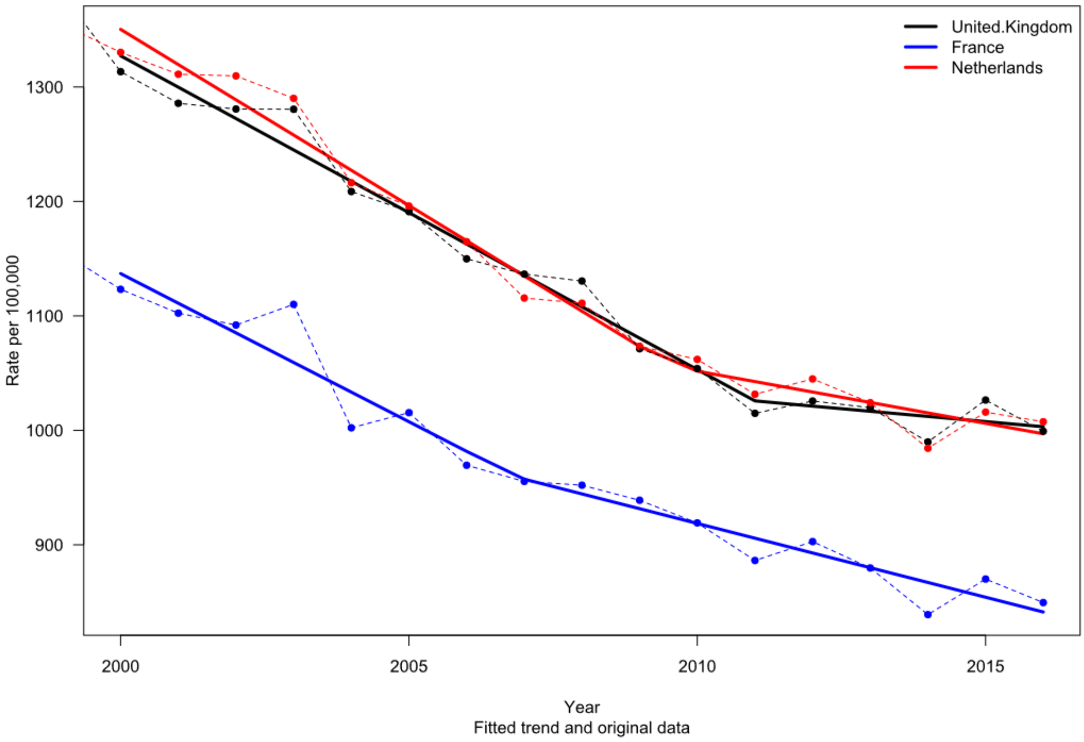

Northern Ireland significance level 0.022
Effect of Year
Year
sdr using HMD All.Total
Ireland significance level 0.006
Effect of Year
Year
sdr using HMD All.Total
Italy significance level 0.207
Effect of Year
Year
sdr using HMD All.Total
Japan significance level 0.559
Effect of Year
Year
sdr using HMD All.Total
Netherlands significance level 0.007
Effect of Year
Year
sdr using HMD All.Total
Norway significance level 0.058
Effect of Year
Year
sdr using HMD All.Total
Portugal significance level 0.077
Effect of Year
Year
sdr using HMD All.Total
Sweden significance level 0.089
Effect of Year
Year
sdr using HMD All.Total
U.S.A. significance level 0.007
Effect of Year
Year
sdr using HMD All.Total

Figure 6 SDR changepoint analysis 2000-2016, the UK, the Netherlands and France



Source: HMD; Own calculations.

Table 3 Changes in life expectancy at birth, 2006/11, 2011/16 and 2006-2011, selected European countries

	Total			Males			Females		
	2006-11	2011-16	2006-16	2006-11	2011-16	2006-16	2006-11	2011-16	2006-16
Belgium	1.2	0.8	2.0	1.4	1.0	2.4	1.0	0.7	1.7
Denmark	1.5	1.0	2.5	1.7	1.2	2.9	1.2	0.9	2.1
Germany	0.7	0.4	1.1	0.7	0.7	1.4	0.7	0.4	1.1
Ireland	1.6	0.9	2.5	1.7	1.3	3.0	1.3	0.6	1.9
Spain	1.5	0.9	2.4	1.7	1.0	2.7	1.2	0.7	1.9
France	1.4	0.4	1.8	1.4	0.8	2.2	1.2	0.0	1.2
Italy	1.0	1.0	2.0	1.1	1.3	2.4	0.7	0.8	1.5
Netherlands	1.3	0.4	1.7	1.7	0.6	2.3	1.1	0.1	1.2
Austria	1.0	0.7	1.7	1.2	1.0	2.2	1.0	0.3	1.3
Portugal	1.7	0.6	2.3	1.8	0.8	2.6	1.3	0.5	1.8
Finland	1.1	0.9	2.0	1.4	1.3	2.7	0.7	0.6	1.3
Sweden	0.9	0.5	1.4	1.1	0.7	1.8	0.7	0.3	1.0
UK	**1.5**	**0.2**	**1.7**	**1.7**	**0.4**	**2.1**	**1.4**	**0.0**	**1.4**
Norway	0.8	1.1	1.9	0.9	1.6	2.5	0.7	0.6	1.3
Switzerland	1.0	0.9	1.9	1.3	1.2	2.5	0.8	0.6	1.4

Source: Eurostat. Note: These countries are the European countries defined as “developed economies” according to the MSCI World Index

The reason for the greater deterioration in the UK within this period than in other countries shown (Table 3) may be because the UK was more successful in postponing deaths in the period before 2010 and therefore creating a larger pool of frail, more vulnerable individuals in the following period. These deaths have thus been shifted into years following 2010. However, any reduction in mortality for a particular group will lead to additional later deaths since those alive at any point must die at some stage. This would mean that the sharper UK deterioration arose from a particular set of circumstances around that time rather than indicating a divergence that might be expected to continue into the future. We discuss mechanisms and possible causes that have been pointed out in the literature, as well as some neglected factors, such as TE, in more detail in Section V.

Sex-specific trends

Sex differences have remained largely similar across these countries, with males continuing to show a rather greater level of long-term improvement than females in the most recent period. In all countries and both periods, the improvement in male life expectancy at birth was higher than that for females, with the result that the average gap declined by just under one year on average over per period 2006-16, with about half of this occurring in each quinquennium. While there were substantial differences in the extent to which the sex gap closed in this period, ranging for 0.3 years in Germany to 1.4 years in Finland, there does not appear to be a markedly different pattern between the sexes emerging in the most recent period, although the trend for women has approached zero.

Age-specific trends

When assessing the impact of mortality change, absolute or relative (i.e. proportionate) changes in both rates and deaths can be used. Absolute changes in mortality rates are high at the oldest ages, but relative rate changes may be highest at young ages where death rates are very low. In contrast, absolute changes in deaths may be largest in intermediate age groups where deaths are most common. Different indicators may give more emphasis to one age group rather than another, which may account for the different conclusions drawn. The following discussion is based mainly on proportionate rather than absolute changes.

Mortality at younger ages

Deaths at ages under 40 account for only a small fraction of deaths in Europe (2.5% in the UK in 2017). Since deaths tend to be concentrated around age 80, the trends among those around this age will dominate overall mortality trends, but comparison of trends by age may help to identify underlying causes and possibly priorities for further work.

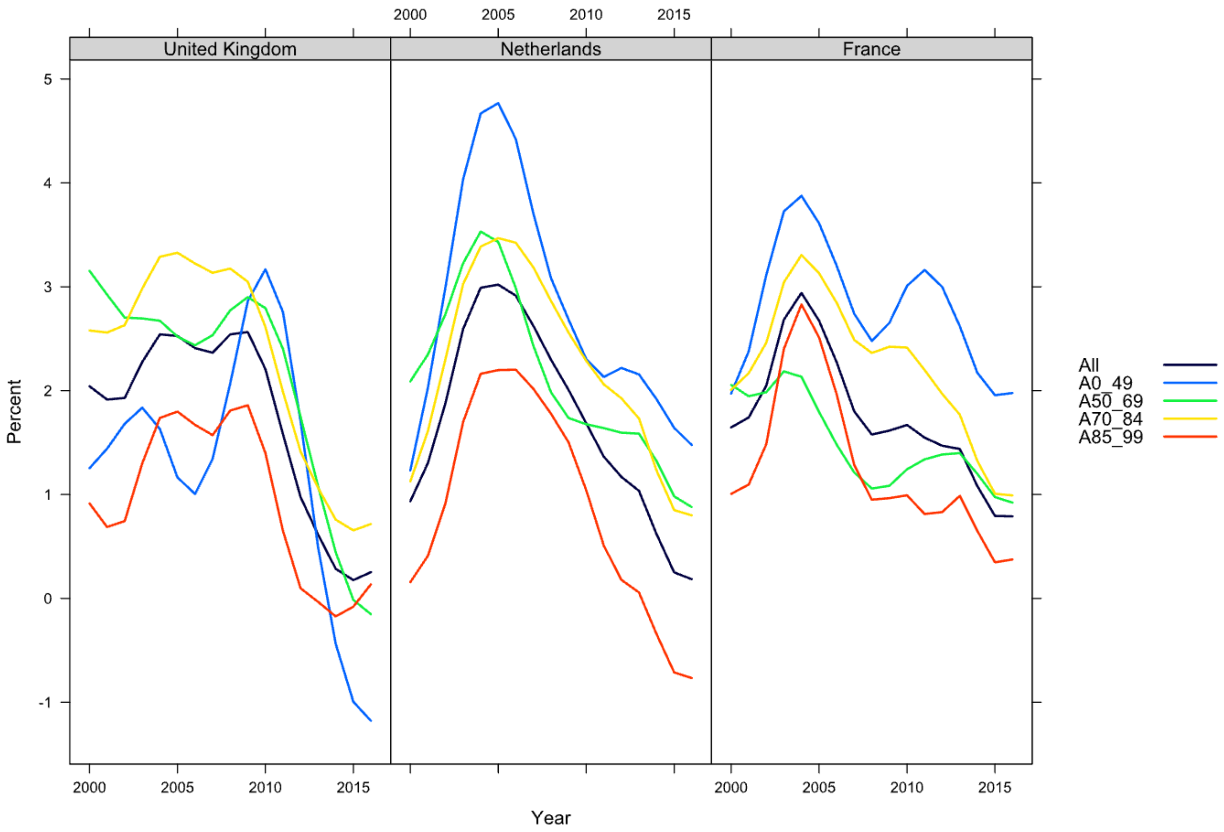
Figure 7 shows smoothed estimates of the rate of improvement in different years for the two selected neighbouring countries to the UK – France and the Netherlands – that might be expected to provide useful comparisons for reasons set out above.

Trends in the current decade at all ages above 40 are very similar in most cases and to the overall value, but mortality under age 40 is distinctly different in the UK from the other comparator countries shown. While mortality at these young ages is currently improving at about 2% per annum in the other two countries, it is deteriorating in the UK. This is in line with what PHE (2018a) has observed. Since the main causes of death – and by implication reasons for death – differ across age groups, this suggests a different pattern in the UK at earlier ages, one more similar to U.S. as noted by Ho and Hendi (2018), where "deaths of despair" (Case and Deaton, 2015) involving substance abuse and other forms of self-harm have led to more substantial increases in mortality at younger ages in contrast to mainland Europe, where mortality at young ages is generally continuing to improve.

Mortality at older ages

At later ages, the drop in improvement rates is apparent in all age groups. Trends are similar in general, although the levels are different. In almost all cases, levels of improvement at ages 80 and over are the lowest, but there is little evidence that differentials between age groups are increasing or decreasing over time. Therefore, using relative rather than absolute measures, there is no strong evidence that the recent downturns in mortality improvement have disproportionately affected the oldest age groups, in contrast to what has been sometimes claimed. As with sex differences, the factors driving these trends appear to be of broadly similar magnitude across all ages above around age 40, suggesting that common factors across age groups rather than specific factors are at work.

Figure 7 Changes in SDRs by age, UK and neighbouring countries by sex, 2000-2016.



Source: HMD; Own calculations.

Life expectancy

As noted earlier, changes in life expectancy over the period 2006-16 have been very similar in the UK and its direct comparator countries, such as the Netherlands and France, but with the UK improving by about 0.2 years more in the first half, and 0.2 years less in the second half of the period than the Netherlands and France. To examine how changes in mortality, the focus of this report, are related to levels and, in particular, whether the position of countries at the lower end of the life expectancy distribution, including the UK, have improved or deteriorated in the period of stalling of mortality improvement and whether the findings for males and females are similar.

The UK has remained towards the bottom of the life expectancy distribution of the more developed Western European countries (Figure 8); the full set of values for EU and neighbouring countries is given in Appendix II. While the UK's position has fluctuated, this has been in a rather narrow band apart from two years, 2009 and 2015, around which they were sharp changes in the number of excess winter deaths and it is well-recognised that the magnitude of this effect differs across

Europe with the largest values being observed in countries of Southern Europe and the UK.

Overall, the UK has been overtaken by Belgium and Finland, but especially by Ireland which has shown the greatest improvement of all countries. In contrast Germany has shown the most substantial and persistent declines (although there are problems with the interpretation of German trends[31]). While Ireland was one of the countries most affected by the post-2008 crisis, Germany was one of the least affected. If allowance is made for population size of the countries included, UK females' relative position remained static; it was lower than the values of 82% of women in these countries in 2000 and 2010, and 83% in 2017. In contrast, males' position deteriorated in the recent period; UK males' life expectancy was surpassed by 35% of the overall male population in 2000, 36% in 2010, but 54% in 2017.

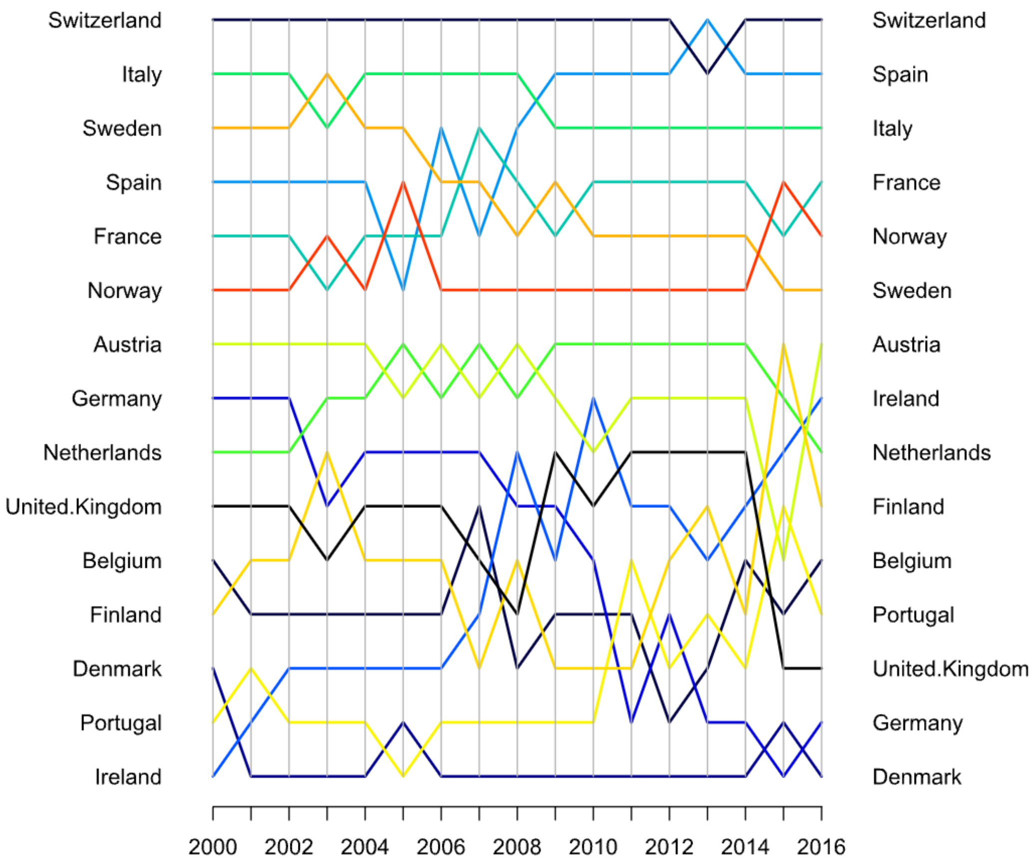
An alternative way of indicating the relative position of UK men and women is given but the difference between life expectancy for the UK and the average of the countries in Figure 8 weighted for population size (Figures 9 and 10). These results confirm that the recent mortality stalling had had little impact on sex differentials apart from a small additional penalty for men in relation not only to earlier periods in UK, but also in relation to comparator countries. In 2000, UK males were 0.1 years below the average, but improved slightly to zero in 2010 before falling to 0.3 years lower by 2017. While women's level remained lower than the average, the relative position of 1.4 years below in 2000 reduced slightly to 1.3 years in 2010 and 2017.

These results confirm that the recent mortality improvement stalling had had little impact on sex differentials apart from a small additional penalty for men in relation not only to earlier periods in the UK, but also in relation to comparator countries.

Although the UK performed better than comparable countries in the period before 2011, it did worse afterwards, there is no indication that its relative or absolute position or level is related to the magnitude of subsequent change.

[31] See footnote 28.

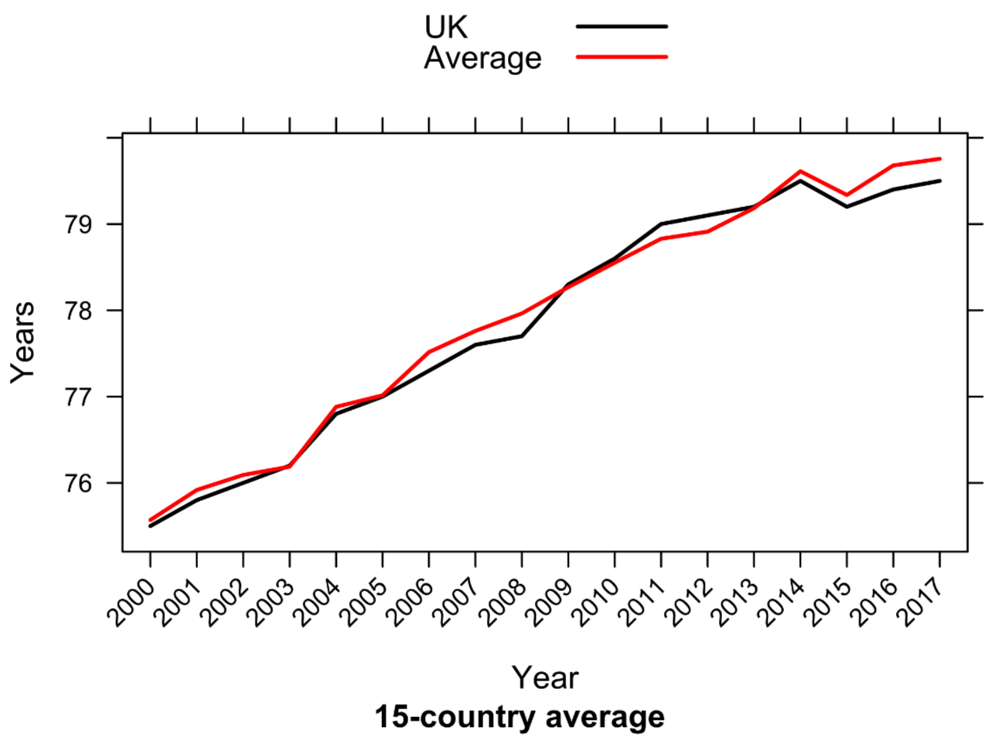
Figure 8 Ranking of life expectancy at birth, selected EU countries (both sexes)



Source: Eurostat; Own calculations.

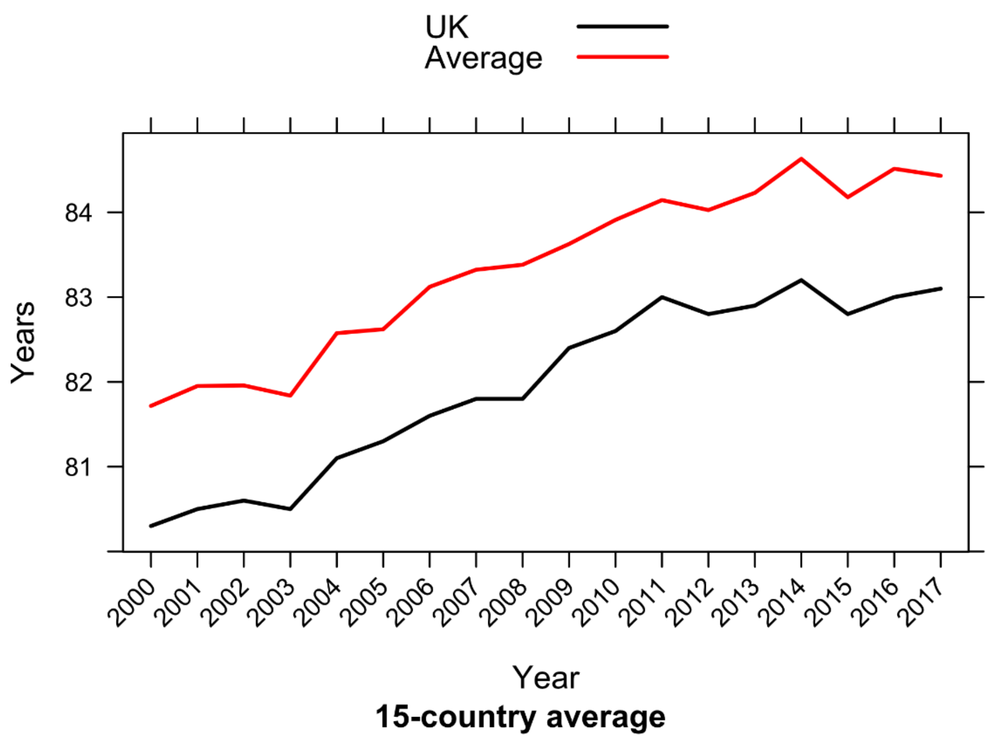
Figures 9 and 10 show UK values for males and females, together with the weighted average of the countries in Figure 8. Although UK had high rates of improvement in the earlier part of the period, and low rates subsequently, the movement in relation to the average of comparator countries, as with ranking, showed little change over time.

Figure 9 UK and average life expectancy at birth, selected EU countries (males)



Source: Eurostat; Own calculations

Figure 10 UK and average life expectancy at birth, selected EU countries (females)



Source:Eurostat; Own calculations

Section IV – Explaining short, medium and long-term patterns

So far, we have provided evidence on the stalling of mortality improvements in the UK and placed them in the broader European and international context. This section concentrates on the potential determinants of the observed patterns. Drawing on the literature synthesised in Section I, here we draw a clear distinction between long- and short-term trends[32] and comment individually upon each potential explanation in detail. We argue that short-term fluctuations in annual mortality, such as the “spike” in 2014-15, have distinct determinants from the long-term underlying trends. While flu has definitely contributed to such annual fluctuations, there is no direct evidence proving that recent levels of flu-related mortality are greater in magnitude than before. Austerity may appear to be a credible explanation for longer-term UK trends, but since mortality improvement stalling is not unique to the UK, it is unlikely to be the sole answer even for the sharper pattern of deterioration observed in the UK. Stalls in improvements in CVD mortality and cohort-effects are also likely to be contributing to slowing improvements. Such explanations are likely to be intertwined, acting concurrently at different levels.

Overview

The issue of slowing mortality improvements has generally attracted limited interest in other countries[33] apart from the U.S., where the patterns have been long debated[34]. UK analysis has focused on a number of possible explanations, especially UK-oriented factors (Hiam et al., 2107b; ONS, 2018a; PHE, 2018a; Raleigh, 2019; Ortiz-Ospina & Ritchie, 2018) often concentrating on a series of individual explanations. In some cases, analysis of these possible explanations has been undertaken for completeness rather than because they are thought to be likely reasons, but this has the benefit of limiting the range of potential explanations and therefore the variables that may be involved. Less evidence exists on the importance of wider supra-national factors that have more general implications. Yet, as noted earlier, if recent trends are driven by a combination of local and general factors, any useful model will have to include both types of factors.

Drawing on Section I of this report, we summarise possible explanations in Table 4, classifying them by whether these have been analysed as UK-level or wider factors and by the extent to which their impact was considered to be large in the literature. Explanations based on population ageing, increases in dementia and migration appear unlikely to have much explanatory power, although some will have affected the number of deaths, or the overall distribution of deaths by cause. However, it is useful to be able to dismiss these and concentrate on the remaining ones that are not easily rejected. The possibility that some of these might contribute a small amount to recent trends and could reinforce more important variables needs to be acknowledged. In addition, variables such as migration (both international and internal) might have more effect on sub-

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[32] For instance, short-term annual fluctuations are heavily influenced by communicable diseases, such as influenza and therefore might be expected to exhibit similarities in neighbouring countries, as would the effects of extreme temperatures. This does not imply that the responses to such challenges will necessarily be uniform either across time or space.
[33] For more discussion, see the report of our survey of European Statistical Offices in Appendix II.
[34] In the U.S., mortality has attracted more attention since the deterioration of mortality trends occurred earlier and in a more substantial way than elsewhere (e.g. Case and Deaton, 2015). It has thus generated a wide literature. Factors contributing to U.S trends, such as abuse of opioids have not so far been considered major factors in the UK in the period following 2011.

national trends and/or work through other causes such as the contribution of recent migrants to the working of the health and social care systems.

Table 4 Potential explanations for UK and European mortality improvement stalling

Potential driver	Scope	Impact	Comments
Data artefact	National	Small	Revisions to older age groups following 2011 census not considered.
Increase in Alzheimer's disease and dementias	National	Small	This could also be considered a data artefact. Largely a consequence of increased discovery and changing coding practices, together with population ageing in unstandardized measures. Increase overall prevalence will tend to increase annual fluctuations in deaths, ceteris paribus. Large reported increases affect interpretation of CVD effects.
Migration (recent)	National	Small	Information on mortality by country of birth not generally available. Recent migrants in low-mortality groups so very limited possibility to influence overall values. Healthy migrant and salmon bias effects not considered (latter relating to UK-born returning migrants).
Migration (general)	National	Small	Not considered, but e.g. disadvantage may be observed in second generation rather than first generation migrants. Also, emigrants are selected for good health.
Influenza epidemics	International	Large for annual fluctuations, small for long-term trends	While occasional studies dismiss this, there is substantial evidence supporting the role of influenza, but precise magnitude of annual impact is not established.
Weather trends	National	Small	No evidence for secular shift, individual year effects are small, Excess mortality (especially among deprived older people linked to temperature such as cold homes and fuel poverty have received less attention in recent years.
Population ageing	National	Small	Has impact on numbers of deaths, but no direct influence on age-standardised measures. Compositional changes will affect unstandardized overall values if improvement at older ages is inherently lower than at younger ones.
Increasing inequality	National	Probably small	This is too broad to be examined empirically without refining research question.
Austerity	National	Plausibly large for differences between UK and comparator countries	Broad term that includes numerous components including standard of living; changes in benefit systems; and social care and health care services. Analysis of differential impact on distinct population groups is required.
Cohort effects	National	Potential large impact on shifts in timing of deaths	Multiple factors are potentially involved. Sufficient data to identify cohort effects in short time periods are lacking to date.

Specific role of CVD	International	Large	Slowing down of CVD mortality improvement appears to account for a substantial fraction of overall stalling but problems with recent cause-specific data (see below). Explanations for a sharp change in trend have not been advanced.
Choice of reference period	International	Large	The relative and absolute magnitude of mortality improvement stalling depends substantially on the choice of reference period, e.g. 2006-11 vs. 2011-16 vs. 2006-16. The interpretation of results is particularly sensitive to the anomalous patters observed in the first decade of this century.
Period tempo-effects	International	Potentially large	The interpretation of period statistics that are interpreted as relating to actual populations can be affected by shifts in timing of events between periods.

It is generally accepted that the observed patterns may arise from a combination of factors, none of which would necessarily be sufficient on their own, but whose combined effect could be substantial. However potential explanations have mainly been examined on a topic by topic basis and while qualitative conclusions have been drawn, neither quantitative estimates of the relative magnitude of competing explanations have been made. Discussion has principally focused on two main distinct sets of causes: the cumulative effect of UK Government austerity policies from around 2010 on longer-term trends and on Excess Winter Deaths (EWD) owing to general outbreaks of influenza, on short-term fluctuations but which also influence general trends. Both analyses draw heavily on the experience of winter 2014-15. These are not completely independent, but they arise for very different reasons and they have very different policy implications. Studies on the role of austerity have particularly concentrated on cross-sectional geographically disaggregated data, while those on influenza are largely based on estimation of the contribution of influenza to mortality based on correlations between mortality and influenza-linked time series.

To our knowledge, there has been no attempt to consider these approaches together, and they have sometimes been treated as mutually exclusive. Hiam et al (2017b) argued that influenza was unlikely to be an explanation for the 2014-15 winter spike because the circulating strain A(H3N2) had not produced a similar level of excess mortality when it was the prevalent strain in an earlier year. Therefore, austerity emerged as the preferred explanation by a process of elimination. Around the same time, PHE also gave less emphasis to the role of infectious disease and argued that there was nothing exceptional about that period and population ageing was identified as the main reason (Newton et al., 2017).

A third factor that has been advanced for mortality improvement stalling is the lack of continuing improvement in CVD mortality. However, little specific analysis directly linking these in the post-2011 period has been undertaken, in particular, to quantify the contribution of this factor to recent trends. Moreover, although the role of cohort factors and increasing inequality have been mentioned by Chan et al. (2019), more research is needed to identify how these have been distinct from, for example, changes in CVD in the recent years.

Overall, there does not appear to have been any clearly articulated alternative potential explanations such as the contribution of a broad range of other risk factors such as obesity, diabetes, anti-microbial resistant strains, vaping, air pollution, diet and lack of exercise, although these are all known to have potentially important influences on population health in general (apart from vaping). A notable absence in possible factors is the general area of wider societal pathologies that come under the general heading of “deaths of despair” by Case and Deaton (2017) or Marmot’s Social Determinants of Health framework (World Health Organisation, 2003). Some variables such as opioid or other substance abuse have been examined, but these contribute little to explanation of overall trend change since 2011.[35]

The proposed explanations are not independent, and they may include explanations of the same factors but at different levels. Cause of death trends from cancers, cardiovascular and respiratory diseases are in part a consequence of determinants such as smoking patterns, so examining these three causes separately may provide less insight, especially for identifying policy options, than examining smoking *per se*. At a deeper level, there is the question of why people smoke, how far this is socially patterned and the reasons why substantial socioeconomic differences in smoking exist and appear to be increasing. Mental health is rarely even mentioned in the debate about mortality improvement stalling but, like smoking, it would be expected to have effects across a number of causes, age groups etc. Some of these identified areas are major themes in research on the determinants of health and mortality, but the focus of this project is the extent to which it is possible to identify factors that could lead to an apparently sharp reversal of long-term trends in mortality improvement in recent years. Any particular variable identified as the primary cause of mortality improvement stalling in the UK, should be able to explain the difference between the UK and similar countries’ trends, over the periods <u>before</u> and <u>after</u> 2011 rather than UK patterns since 2011, or alternatively be able to explain why different countries experienced changepoints at different time points.

In order to structure discussion of the proposed causes, it is useful to have a framework that is based on the assumption that the current level of mortality is determined by long-term trends, seasonal patterns and short-term fluctuations as in the classical composition of time series. We thus use such framework to evaluate each potential explanation.

The role of influenza

Influenza continues to be identified as a major factor: it was the hypothesised cause that received particular emphasis in PHE (2018a) and Raleigh (2019). However, as Appendix I shows, there is little direct evidence that seasonal influenza can produce the sort of changes seen in the UK and elsewhere in Europe[36]. While, there is no doubt that influenza is implicated in year-to-year fluctuations, there is no evidence that the magnitude of recent levels of flu-related mortality are so much greater than in recent periods that influenza could account for a substantial fraction of

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[35] For instance, PHE (2018a) estimated that the increase in mortality from substance abuse reduced life expectancy for male and female adults (aged 20-44) by -0.06 years and -0.11 years respectively between 2011 and 2016.
[36] In the U.S. where life expectancy has now fallen for three years in a row, influenza receives little attention as a possible explanation.

observed trends. Year-to-year changes especially between 2014 and 2015 have been given undue prominence and do not provide any evidence for a step change in the role of winter excess mortality/influenza since 2011. The pattern of mortality change likely to be associated with seasonal epidemics is not consistent with observation. Mortality trends in non-winter months are very similar to overall values leaving little scope for winter values to contribute to overall trends.

If the short-term annual fluctuations, whatever their underlying cause, do not appear to offer much in the way of explanation for recent mortality improvement stalling, attention needs to be focussed on factors acting over extended timescales of many decades in the case of smoking, and definitely before 2010 for any hypothesised explanation since the focus is on the change between the period before and after 2010. We consider such variables in the next sections.

"Austerity"

The debate about the contribution of "austerity" to stalling of mortality improvements has become highly polarised in recent years. This was originally centred on the reason for the 2015 "spike", but as noted in Section I, this led to a confused debate based on the annual change in number of deaths between the year with lowest-ever recorded winter excess mortality and a following year with above-average values.

The criticisms of austerity largely centred on the fact that although the stalling of mortality improvement started in the UK around 2011 shortly after the change in government and substantial reductions in welfare, social services, police funding, social care as well as health services (Table 5), that correlation did not prove causation (Milne, 2017b; PHE, 2018a; Raleigh, 2019). It seems unlikely that the mortality trends discussed above would have been responsible for the trends in public expenditure on health and other services, so the remaining options apart from the level of expenditure not directly affecting mortality levels might be simple coincidence or both are the result of a third variable or set of variables.

Table 5 Annual average real growth rates in UK public spending on health, selected periods

Period	Financial years	Average annual real growth rate
Whole period	1949–50 to 2016–17	3.70%
Pre-1979 (various governments)	1949–50 to 1978–79	3.50%
Thatcher and Major Conservative governments	1978–79 to 1996–97	3.30%
Blair and Brown Labour governments	*1996–97 to 2009–10*	*6.00%*
Coalition government (Cameron and Clegg)	*2009–10 to 2014–15*	*1.10%*
Cameron and May Conservative governments	2014–15 to 2016–17	2.30%

Source: Institute for Fiscal Studies and the Health Foundation, in association with NHS Confederation.

The PHE Report (2018a) did not include the word “austerity” in the text. Most references are only in relation to health and social care funding rather than to the whole range of changes that come under the heading of “austerity” (although the Report did acknowledge that further work in required).

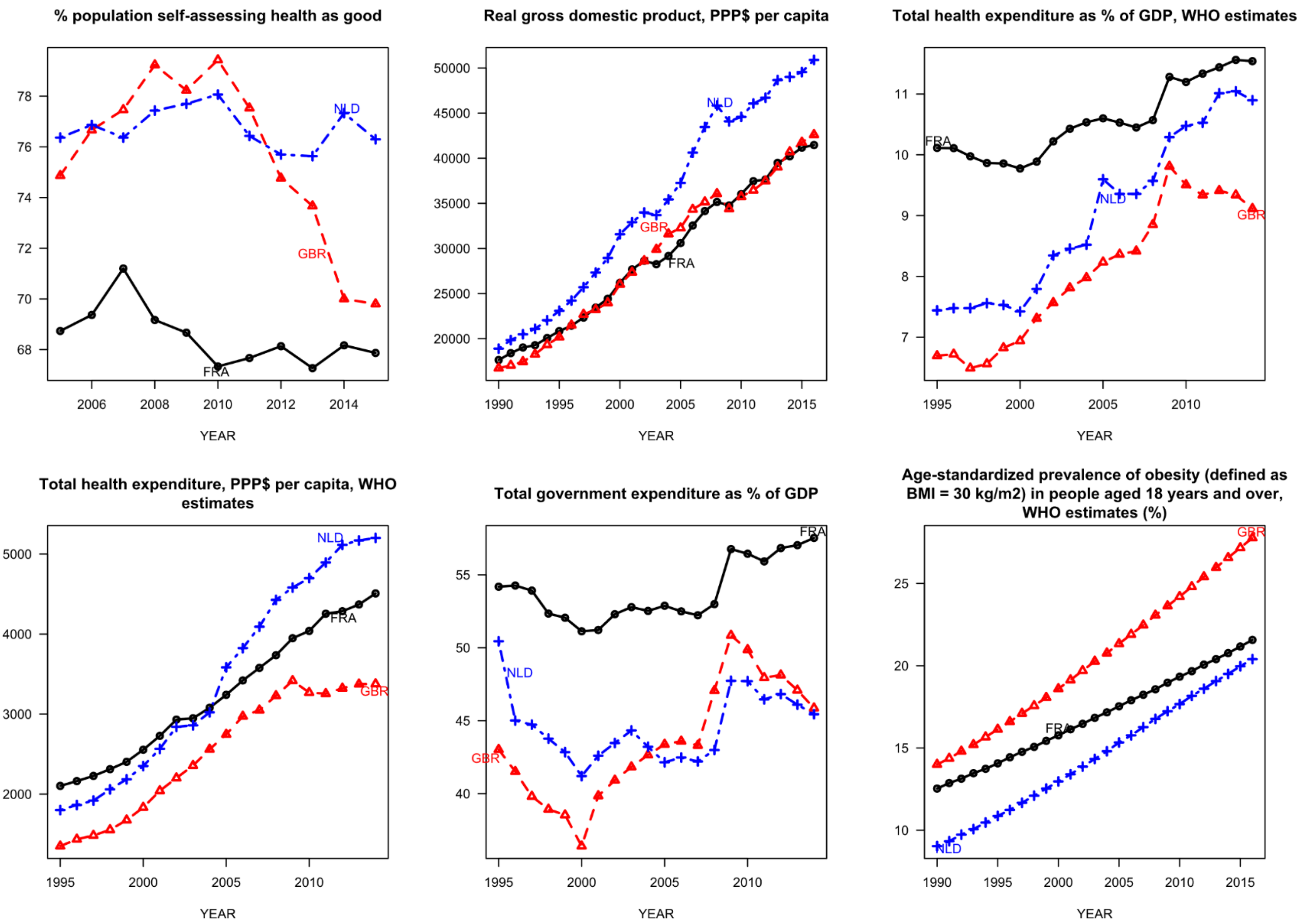
The criticisms that such studies are “descriptive” apply with equal or greater force to some of the other explanations put forward. However, explanations stressing the role of UK austerity should address the fact that mortality improvement stalling is not unique to the UK, and therefore UK austerity cannot provide a complete answer and possibly not for the different and sharper pattern of deterioration observed in the UK. While Figure 6 showed that in the UK and the Netherlands, the levels, magnitude and timing of changes are very similar[37], yet the social environment over recent years has been very different (Figure 11). Note that although the WHO HFA database shows a substantial deterioration in reported self-assessed health, this finding is not replicated in a number of UK national data sources.

Particular attention has been given to the role of austerity for health services, although it covers a much broader area including social care, social services, and welfare changes that have received less attention (Watkins et al., 2015). On a number of indicators, austerity was much less pronounced in the Netherlands and France than in the UK, and in particular, the Dutch health system which is judged to be of higher quality than the UK system showed little deterioration since the 2008 banking crisis in contrast to the UK and continued expansion both as a proportion of GDP and real per capita expenditure.[38]

[37] Although we note that there are considerable differences at ages below 40, although these have little effect on overall values.

[38] The Commonwealth Fund (2017) Report ranked NHS as the best overall health service among 11 countries studied, but rated UK 10th out the 11th countries on Health Care Outcomes, the indicator that might be regarded as the most relevant to this report (Schneider et al., 2019). On a more detailed ranking of health systems across Europe, the Euro Health Consumer Index, the Netherlands was first-ranked in nine of the last 10 years, with UK being ranked in the middle of the 35 countries included (Björnberg and Phang, 2019).

Figure 11 Comparison of austerity-related variables in the UK, the Netherlands and France, 2000-2016



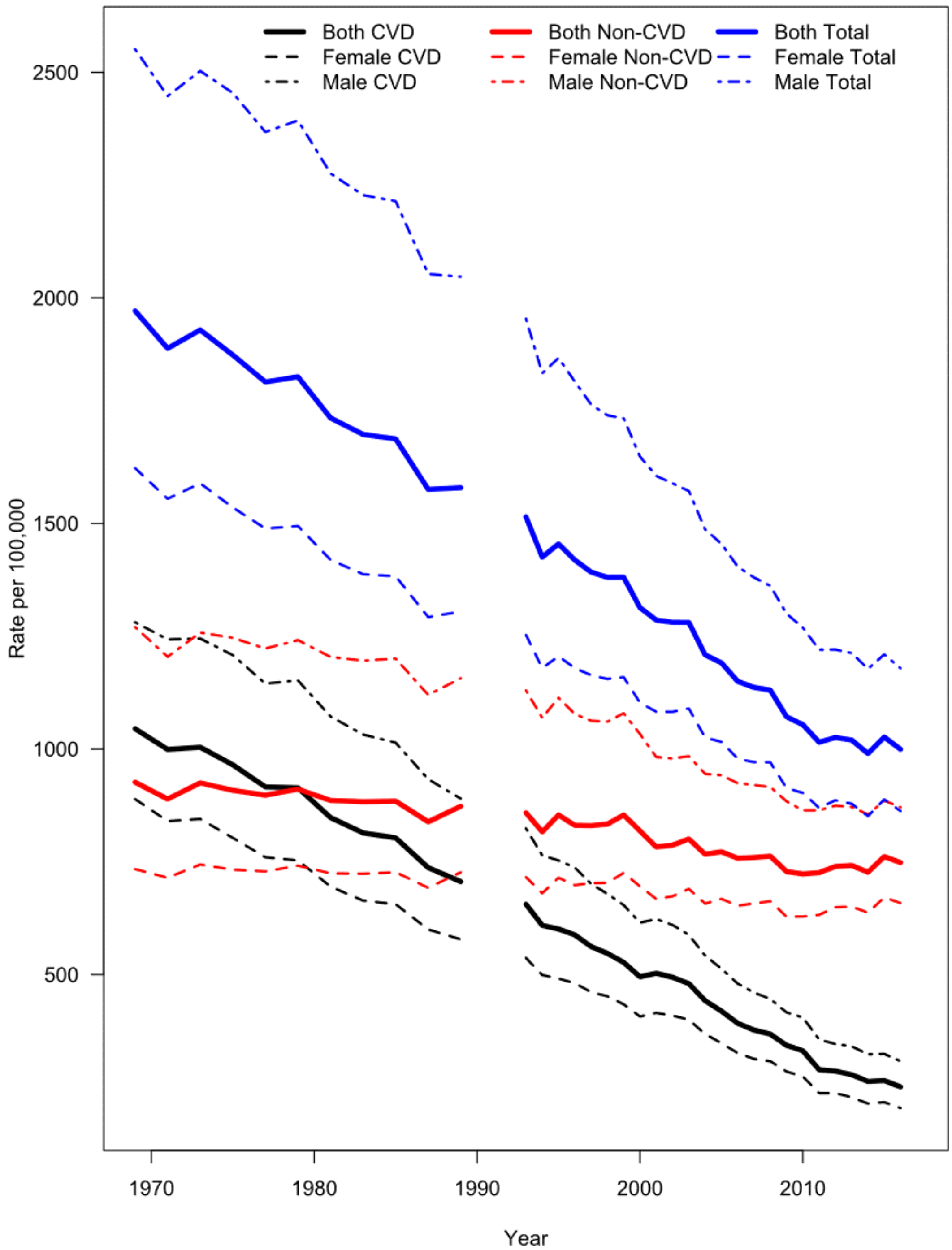
Source: based on WHO HFA. Available at: http://www.euro.who.int/en/data-and-evidence/databases/european-health-for-all-family-of-databases-hfa-db

Lack of improvement in CVD mortality

Causes of death provide some useful information of possible reasons for the changing patterns of mortality improvement. One suggested reason for the stalling of mortality improvement in recent years across a number of countries focuses on the role of reductions in rates of improvement in circulatory system deaths (ICD 10 I00-I99).

Figure 12 shows long-term SDR trends for CVD, all causes, and non-CVD causes in the UK from 1969 using data from the British Heart Foundation (BHF) based on ONS data. CVD SDRs declined by 77% for men and 76% for women over the period up to 2016, at an average rate of decline of 3.1%. per annum. In the case of women, in particular, there has been little change in non-CVD mortality, declining by only 0.2% per annum over the past half-century. Clearly CVD mortality reduction has had a dominant effect on overall mortality improvement over the past half-century, and it is highly unlikely that this would cease to be the case from about 2011.

Figure 12 SDRs CVD and non-CVD and Total in the UK, 1970-2016



Source: BHF

While cause of death analysis in the very old is inherently problematic due to multi-morbidities, in Britain this has become more difficult since changes have led to substantial increases in deaths recorded as due to Alzheimer's disease/dementias in recent years (see Section I). Some increase in numbers would have been expected due to ageing of populations as a greater fraction of people would be in the high age groups where dementia is much more common. However, reported age-standardised values also increased sharply and changing population structures account for only a small fraction of the increase of 74% for males and 92% for females between 2006 and 2016 in England (PHE, 2018a). For both sexes, the proportions of age-standardised mortality attributed to dementia more than doubled over that 10-year period in England. There is increasing recognition of dementias' contributing role in the sequence leading to death, e.g. malnutrition, increased risk of falls and in the added vulnerability that it brings to those with comorbidities (Bunn et al., 2014). However, direct evidence on age-specific dementia prevalence and incidence suggest that these were probably falling in recent years (Matthews, 2013).

These changes mean not only that trends in reported dementia deaths could be misleading, but also that death rates from other causes will be spuriously reduced since these deaths would have been recorded to various different causes in the past if consistent allocation procedures had been used. This effect is substantial given that dementia deaths are sometimes presented as the largest single cause of death (although this depends, for example, on whether CVD deaths are treated as a single group of disaggregated into separate heart disease and stroke components). While recorded causes of death are now more accurate than in the past when dementia was under-recorded, the inevitable consequence of such developments is that estimates of change are less accurate.

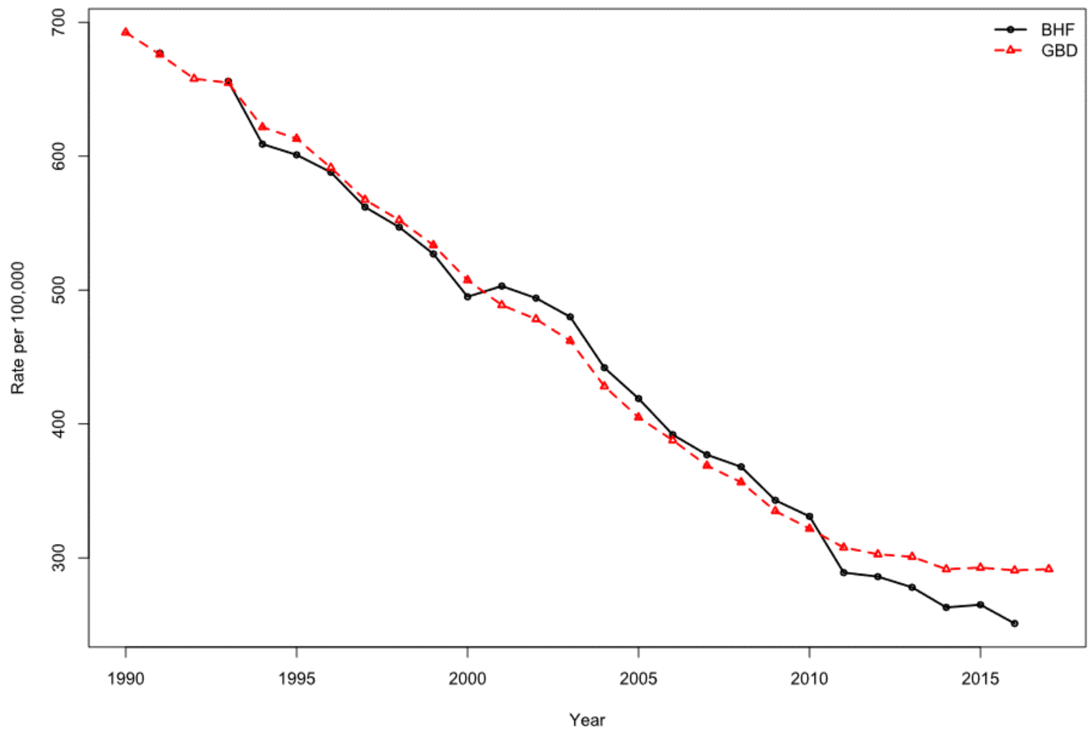
Alternative evidence on cause of death is also available for the Global Burden of Disease (GBD) programme (IHME, 2019). The GBD estimates do not show the age-standardised increase in Alzheimer's disease/dementias in national statistics and are more in line with our understanding of how Alzheimer's disease/dementias trends should evolve since age-specific incidence and prevalence of dementia do not appear to be increasing.

Figure 13 shows data from the two alternative series, both standardised using 2013 European standard population, from 1990 when GBD data became first available.. While very similar in the first two decades, they diverge in the most recent period, not only because GBD data are smoothed modelled estimates, but also because GBD data do not show the sharp increase in Alzheimer's disease/dementias reported in the UK and some other countries' statistical systems in recent years. Both series suggest rates of CVD SDR improvement increasing at about 3% per year around 1990 to 5% or 6% in the first decade of this century, before falling back from about 2010. However, in the following period, GBD data show a more substantial slowdown in CVD mortality improvement of around 1% compared with a value of about 3% in ONS data.

It should be stressed that GBD data are not without problems. The results are based on statistical modelling of national data including smoothing, giving a much smoother trend, but even the estimated annual number of deaths does not match official values, so, for example, major year-to-year changes such as between 2014 and 2015 cannot be usefully analysed using GBD data.

Figure 14 disaggregates overall change simply into CVD and non-CVD mortality using GBD data. Results are also shown for the Netherlands and France for comparison. Both levels and smoothed annual changes are shown.[39] The declines in improvement in CVD are apparent as is the fact that they have been substantially responsible for the improvements in mortality in all countries over the whole period. However, the contribution of CVD has been more substantial in the UK than in other countries since 2010. The trend of non-CVD mortality improvement was both much lower and much flatter over an extended period until about 2010 so the long-term improvement in mortality was driven overwhelmingly by CVD trends. However, some non-CVD mortality causes, especially respiratory diseases appear to be subject to the same issue of the increasing use of dementia as cause in death coding, and even unadjusted respiratory rates have actually increased in the UK in the most recent period. Cancer mortality, which forms a substantial fraction of non-CVD mortality has exhibited low rates of improvement for most sites. Similar results are found using national data and presented by WHO, but based on a different standard population, so results are not shown to avoid confusion.

Figure 13 SDRs for CVD in the UK 1990-2016



Source: GBD (2018) and BHF estimates based on ONS data; Own calculations.

There are two processes at work determining the contribution of CVD to overall trends. The first is the relative change of CVD and non-CVD mortality, and the second is the proportion overall

[39] Note these are rates of the raw series rather than logarithms so the impact of CVD and non-CVD can be directly compared.

mortality that CVD accounts for. These are linked in that the high rates of decline in CVD mortality means that its contribution to overall mortality is declining over time, so higher and higher rates of CVD improvement would be needed for CVD to retain the same effect on overall mortality decline. Both factors are working to reduce the current impact of CVD on overall mortality.

The sharp but temporary rapid improvement in CVD mortality starting around 2000 once more emphasises the special role of that period. Widespread introduction of statins[40], which became much cheaper around that time may have been a factor in the particularly sharp drop in CVD mortality as some deaths that would have occurred in that period were shifted to later periods. Comparison of later trends with a baseline that was temporarily out of line with long-term trends will mean that changes from that date will appear to be particularly large, in the same way that comparisons of 2015 with 2014 deaths will overstate the importance of what is happening in the latter year.

The reduction in CVD mortality improvement has been emphasised as a major factor in the stalling of mortality improvement in the UK since about 2011, but there do not appear to exist any studies that identify the reasons for the change in CVD mortality improvement stalling. It seems unlikely that cohort factors associated with lifestyle changes were responsible and lack of other factors such as “one-off” gains from introduction of new drugs and/or treatment regimes may be responsible. If there have been fewer such innovations (beyond changes in clinical guidance on who to treat and at which level), this may be a substantial part of the reason for the lack of improvement. If high rates of improvement depend on identifying and responding to a series of new opportunities this may be challenging to achieve. Clearly it is more difficult to identify the lack of substantial innovations.

On a simple arithmetic level, whatever happens to CVD mortality, even if it were to become zero, rates of mortality improvements of around 2% per annum cannot be achieved unless there are substantial improvements in non-CVD mortality, with the historical trends emphasising the challenges inherent in this. The fact that fast-improving causes will contribute less and less to overall values means that the remaining causes must improve more for the overall value to remain constant. This may occur because there are a series of one-off advances, some of which may be difficult to predict, but there is an argument that this has happened in the past and therefore that there is no reason to expect that this will not be the case in the future. On the other hand, some argue that similar improvements may be less likely, with, for example, the emergence of Anti-Microbial Resistance and the lack of success in developing new products to cope with such emerging threats. While it is tempting to concentrate of existing factors that may account for current trends, the need to take account of what is not happening may be crucially important.[41]

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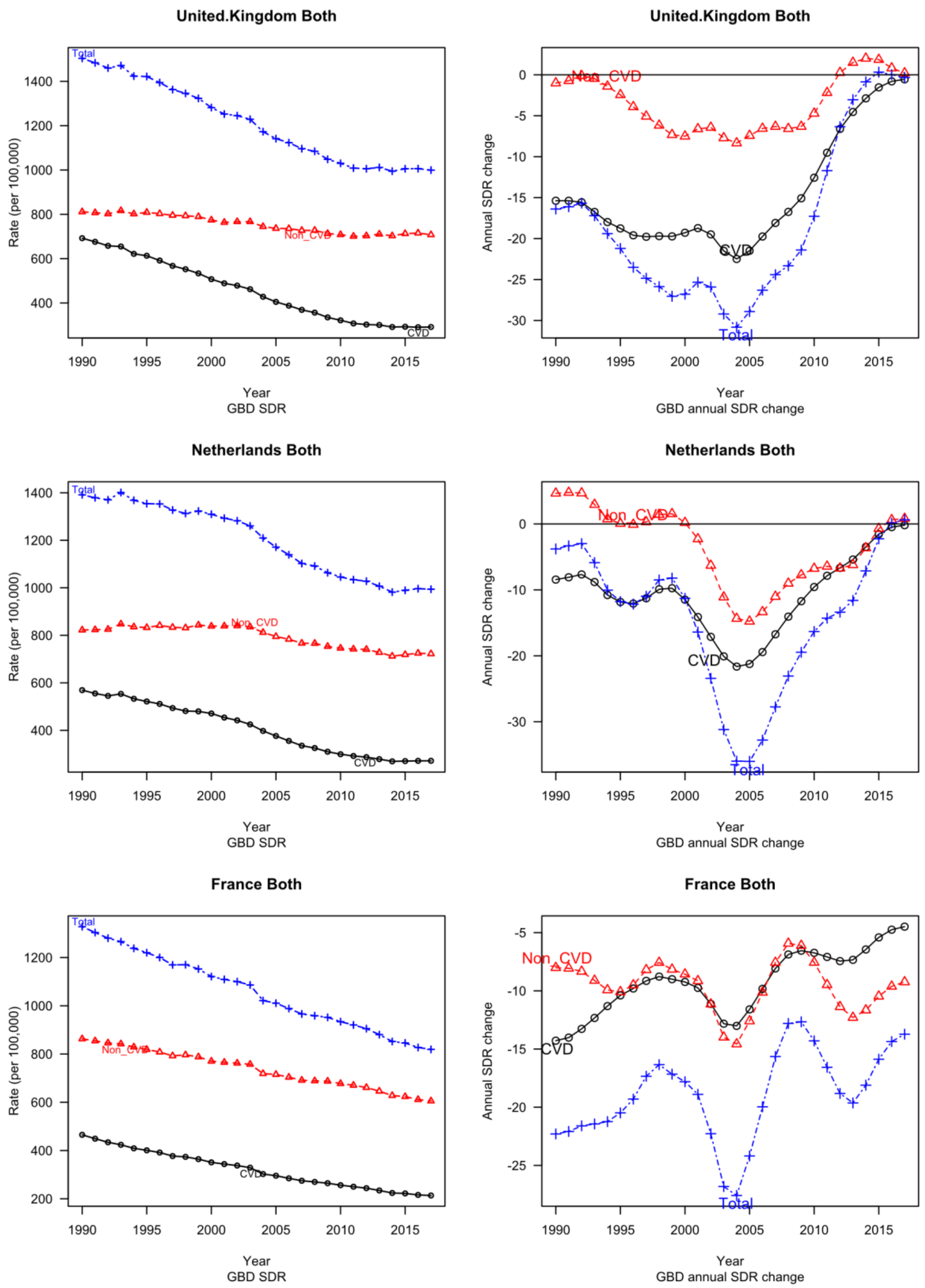
[40] In 2014, the National Institute for Health and Care Excellence (NICE, 2014) published guidance for statins usage among the elderly and recommended its wider use for prevention of CVDs. Under NICE guidelines, General Practitioners are advised to "consider people aged 85+ to be at increased risk of CVD because of age alone", and to offer statins for primary prevention of CVD in patients "who have a 10% or greater 10-year risk of developing CVD".
[41] A similar example is the role of dark matter in current cosmological models.

Figure 14 SDR for CVD in the UK, the Netherlands and France 1990-2016 (Both sexes)



Source: GBD (2018) Own calculations.

Inequality as a driver of mortality slowdown

The literature suggests that mortality improvement stalling has been widespread but has been more pronounced among the more disadvantaged in this decade. The PHE (2018a, p. 67) Report concluded "*whatever* is causing the reduction in the rate of improvement, it is affecting the most deprived areas more than the least deprived areas, and that widening health inequalities has exacerbated the slowdown in improvement". If mortality inequality indicators are measured by the spread (e.g. standard deviation) of mortality across socio-economic or other groups around the average value, then inequality in health outcomes could increase because those at the upper end of the scale do particularly well compared to the average (which would simultaneously increase the average value) or because those at the bottom of the scale do particularly badly (with consequent reduction in the average). In the former case, increased inequality could be interpreted as improving the average, but in the alternative case as reducing it. The answer depends on the underlying mechanism responsible for increasing inequality in outcomes, which is the primary question of interest. An alternative and more clearly causal mechanism is where inequality can affect not only those directly affected in a particular group, but it may have a general societal effect even on those not directly concerned as argued by, for example, Wilkinson and Pickett (2010).

A second question is whether there has, in fact, been an increase in inequality since 2011, or more precisely those aspects that influence health outcomes. Inequalities can be operationalized in many ways, but the most widely-used measure such as the Gini coefficient suggests a decrease in inequality rather than the reverse in recent years (World Bank, 2018; McGuinness and Harari, 2019), although there are problems with the accuracy and treatment of the wealthiest, since inequality can decrease because the nominal wealth of a small group of the very wealth declines, which would not be expected to have population-level consequences.. In addition, older people gave been better-protected from the effects of the 2008 recession than other vulnerable groups with the triple lock on state pensions.

The reverse question is whether stalling mortality improvement would be likely to lead to increased inequalities in health, rather than inequality causing mortality improvement stalling. This is more in line with our expectations about the social determinants of mortality (World Health Organisation, 2003). There is evidence that inequalities between social groups have increased at both the ecological and individual level in recent years (Centre for Analysis of Social Exclusion. 2010; National Academies of Sciences, Engineering, and Medicine, 2015). As pointed out by a number of authors in other contexts, correlation does not imply causation, but it would appear more plausible that the factors responsible for low mortality improvement would bear more heavily on the more deprived, with a widening of the mortality gap rather than the reverse, but this is clearly an area that requires further investigation. It is therefore welcome that two major long-term detailed analyses are in train. The Health Foundation has commissioned Sir Michael Marmot to update his 2010 Report[42] and report by 2020. The Institute for Fiscal Studies (IFS) launched the most

[42] See here for more: https://www.health.org.uk/funding-and-partnerships/our-partnerships/health-equity-in-england-the-marmot-review-10-years-on

comprehensive scientific analysis of inequalities yet attempted chaired by Nobel Laureate Professor Sir Angus Deaton and funded by the Nuffield Foundation in May 2019.[43] The five-year enquiry will include analysis of mortality trends as a major area of study.[44]

Cohort effects

As in other countries, mortality improvement for population projections is usually formulated in period terms, with current levels assumed to move towards these rates in the long-term. UK official projections in recent years have assumed this long-term rate of improvement would be about 1% per annum. A similar value has been used by the Actuarial profession in their Continuous Mortality Investigation. Although both bodies are well-aware of recent trends and discussed then extensively, neither had decided to amend the long-term assumption, which is typical of the average values over the past half century or so, but between the high rates of improvement of the early 2000s and the current low rate of improvement.

Cohort effects have been suggested as a possible contributor to these trends. The most discussed group is the so-called “golden cohort”, those born between 1925 and 1934. Compared to prior and later generations, this generation has been characterised by particularly high levels of mortality improvement over time (Murphy, 2009). These cohorts have been identified as of high interest for a considerable period of time, and have been included explicitly in UK official population projections between base years 2002 to 2014 by assuming that these cohorts’ mortality would continue to improve at a rate about 1.5% per year above the values assumed for all others at any future period. The recent debate about changes in life expectancy in the UK has been based in part on the fact that the 2016 ONS projections of life expectancy were lower than those published for 2014 (Ortiz-Ospina and Ritchie, 2018) This change was due in part to the fact that the 2016 revision modified the assumed mortality rate improvements for the golden cohort would not, in fact, continue. In recent years the positive health experience of this cohort seems to have reduced substantially (Figure 16), if not disappeared entirely, and its mortality improvements now appear closer to other population subgroups.

The sorts of mechanisms that might lead to a cohort influencing period trends would be, for example, lower period rates during those times when this cohort was contributing high numbers of deaths. These cohorts would have been about age 70 in 2000, when overall improvements started to improve, and these cohorts were starting to make noticeable contributions to period mortality trends. However, since deaths are most common around age 85, these cohorts would be expected to make their maximum contribution to overall mortality estimates in the current decade when improvement rates were dropping rapidly.[45]

A number of hypotheses have been put forth to explain why the golden-cohort mortality improvements have slowed down in recent years (Goldring et al., 2011; Shindler, 2018; Ortiz-Ospina

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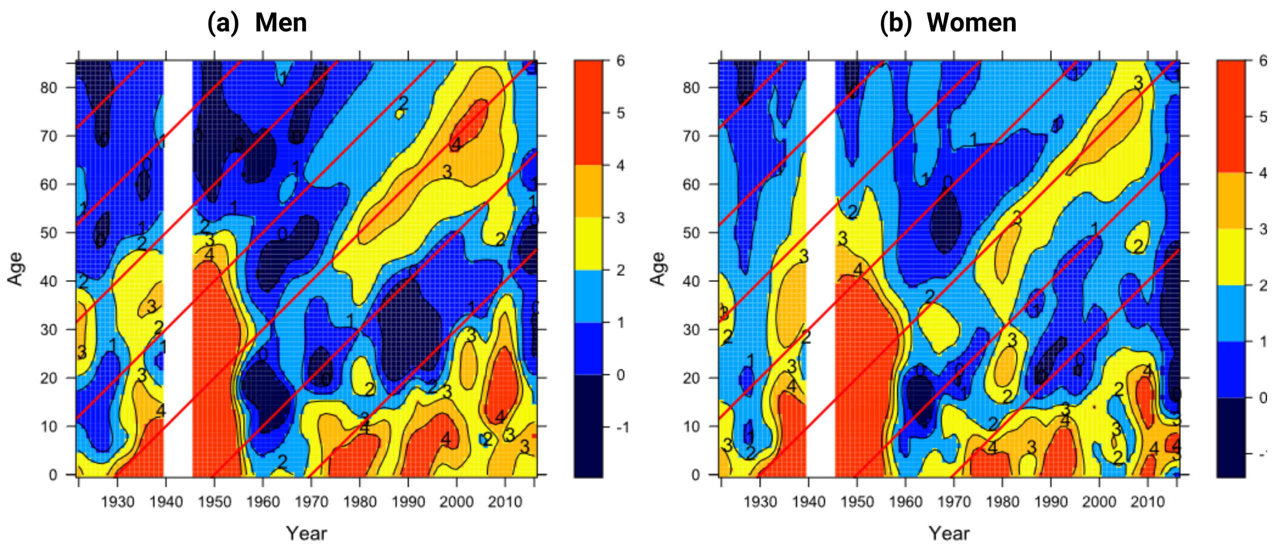
[43] See here for more: https://www.ifs.org.uk/publications/14109
[44] See here for more: https://www.bbc.co.uk/news/education-4822903
[45] Based on comments from ONS, declining numbers in the golden cohorts has been suggested as a possible reason for the recent slowdown (Wilson and Coghlan, 2018).

and Ritchie, 2018). However, it is noteworthy that no convincing explanation has been established for the unusual patterns of this intensively-studied population that have underpinned national population projections for a decade and a half, emphasising the likely challenges in obtaining a definitive answer to the drivers of the current mortality slowdowns, when data on many of the potential drivers are not yet available.

Figure 16 Annual smoothed mortality improvement (percent) by age and period, UK



Source: HMD; Own calculations.

Section V – The Role of Tempo Effects

The previous sections of this report demonstrated that many potential explanations for the trend change in life expectancy in recent years and for the decrease in life expectancy in 2015 have been discussed and empirically assessed. Nonetheless, despite of all these efforts of researchers, a large fraction of the change in trends and the 2015 decrease in life expectancy remains still unexplained. The last section of this report deals with a so-far ignored factor that might be the missing link that connects all the potential drivers and fills the empirically unexplained fraction of the changes in life expectancy: the so-called “tempo effects” (TE).

What are tempo effects in mortality?

We use the simple illustration of Luy (2008) to demonstrate TE in death rates.[46] Consider a hypothetical population A in which all births occur intermittently at intervals of 0.2 years and in which all deaths taking place during some base year occur at exactly the midpoint of a single year of age. Suppose that, at the end of the base year, age at death within a certain age group begins to increase linearly at the rate of 0.2 years per year for all persons and cedes increasing at the end of the year. The Lexis diagram in Figure 17 shows this scenario for age 62 as an example. The life lines of each cohort are represented by an arrow moving through time and age. In the base year t0, all deaths at age 62 occur exactly at age 62.5. During year t1, the age at death increases linearly with the given annual rate, from 62.5 to 62.7. The latter level is reached in year t2 and remains constant from then on. Assume further that the annual numbers of births to the population have been constant and that the proportion of deaths at a certain age is constant over all cohorts (i.e., unchanged mortality conditions until year t0). These two assumptions imply that each dot in Figure 17 represents the same number of deaths and that each arrow represents the same number of persons surviving until age 62.5. Let us assume that 20,000 individuals of each cohort reach age 62 and that 1,000 of them die at this age. Thus, according to the old mortality conditions until year t0 there are 5,000 annual deaths at age 62. The age-specific death rate for age 62 in year t0 is then given by 5,000 deaths divided by 97,500 risk years lived:

$$M_{62,\,t0} = 5{,}000 \;/\; 97{,}500 = 0.05128$$

The number of risk years lived can easily be derived. If all individuals survived until age 63, the number of risk years lived was 100,000 since each individual lived exactly one person year at age 62. Since the 5,000 deceased individuals live only 2,500 person years at age 62, the total number of risk years lived reduces to 97,500.

Now let’s consider what happens with the number of deaths in year t1, the year of changing mortality. The five cohorts in t1 reaching age 62.5, the exact age at which those who do not survive

[46] A similar example can be found in Feeney (2010).

the given age group die according to the old conditions, are marked with the letters A to E. Thus, cohort A is the oldest cohort reaching age 62.5 in year t1 and cohort E is the youngest. Due to the assumed changes in mortality conditions during year t1, the age at death of cohorts A to E increases steadily and cohort E is the first to reach the new age at death level of 62.7 years. Since each of the five cohorts lives longer than the preceding one, the intervals between the deaths become larger than they are between the births (note that both intervals are identical before the year of changing mortality conditions t1). Consequently, the deaths among the five cohorts which reach age 62.5 during year t1 are spread over a period exceeding one year. As a result, the deaths of persons belonging to cohort E are shifted to year t2, shown by the thick grey arrow in Figure 17. Consequently, the number of deaths in year t1 declines by 1,000 compared to the scenario before the change in mortality conditions. This is demonstrated in Figure 17: only four black dots are located in year t1. Had mortality not changed during that year, there would have been five dots in year t1, as demonstrated by the unfilled dots representing the age at death of cohorts according to the old mortality conditions until year t0. Due to the reduced number of deaths and the risk years gained in year t1, the age-specific death rate for age 62 decreases to:

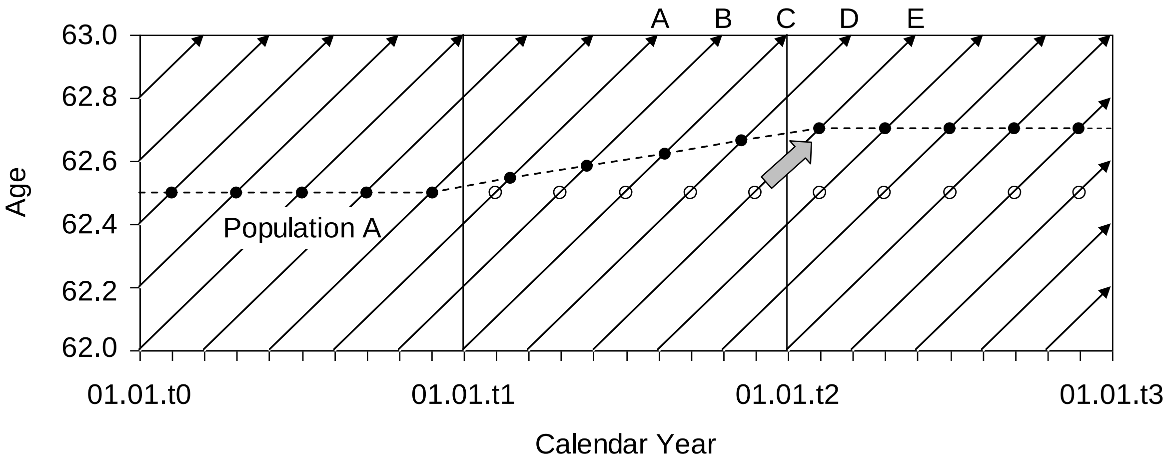
$$M_{62,\,t1} = 4{,}000 \,/\, 98{,}400 = 0.04065$$

The mortality decline is reflected in the decreasing age-specific death rate. Note that the death rate decreased approximately by 20 percent, i.e., almost exactly the proportion of decrease in the number of deaths.[47] Figure 17 shows that the decline in the annual number of deaths is transitory in that it disappears when the age at death stops rising. From year t2 on, the intervals between births and deaths are identical again and there are 5,000 deaths in each subsequent calendar year, leading to the age-specific death rate:

$$M_{62,\,t2} = 5{,}000 \,/\, 98{,}500 = 0.05076$$

[47] In fact, the death rate decreased by 20.7 percent. The slight deviation from the 20.0 percent decrease in the number of deaths results from the fact that numerator and denominator of the rate are affected differently by the shift of deaths. Whereas the number of deaths in the numerator decreases by exactly 20.0 percent, the risk years lived in the denominator increases by 1.0 percent.

Figure 17: Mortality tempo effect illustrated in the Lexis diagram



Source: Luy (2008, p. 207)

Since the number of deaths in the numerator increases relatively stronger than the number of risk years lived in the denominator (25.0 percent versus 1.0 percent), the period death rate for year t2 increases compared to the period death rate for year t1. This increase in the period death rate occurs albeit the average age at death is higher in t2 than in t1. Following Bongaarts and Feeney (2002), such a discrepancy between the development of mortality conditions and its representation in period death rates represents a TE. The logic behind this argument is neither limited to the simple assumptions of this example (constant number of births, birth intervals of 0.2 years) nor is it restricted to one single age group. If we increased the number of age groups and assumed that the ages at death in these groups rise at different rates, then different numbers of deaths would be shifted and the magnitude of the TE would vary from one age group to another (for more details, see Feeney, 2010).

Naturally, a mortality change as described above affects life expectancy accordingly because life expectancy is derived from age-specific death rates. In our hypothetical example, life expectancy would increase between years t0 and t1, thus reflecting the actual decrease in mortality and age-specific death rates. Note, however, that life expectancy would decrease between years t1 and t2 despite all cohorts living in the years t1 and t2 experience only increasing lifetimes. Since period life expectancy is generally seen as an indicator for period mortality conditions, such a decrease is likely to be interpreted as an increase in mortality. However, Figure 17 shows that there is nothing like such a mortality crisis: all cohorts, i.e. the “real people”, experience only decreasing mortality. This is the bias which TE can cause in period life expectancy when mortality is changing during the analysed calendar year.

Bongaarts and Feeney (2002) demonstrated this bias with another hypothetical scenario based on a stable population with a life expectancy of 75.0 years (see Figure 18). In a stable population (i.e., under unchanged mortality conditions), period life expectancy is identical to cohort life expectancy, and thus is the same as the average lifetime of all cohorts living in a particular year, what

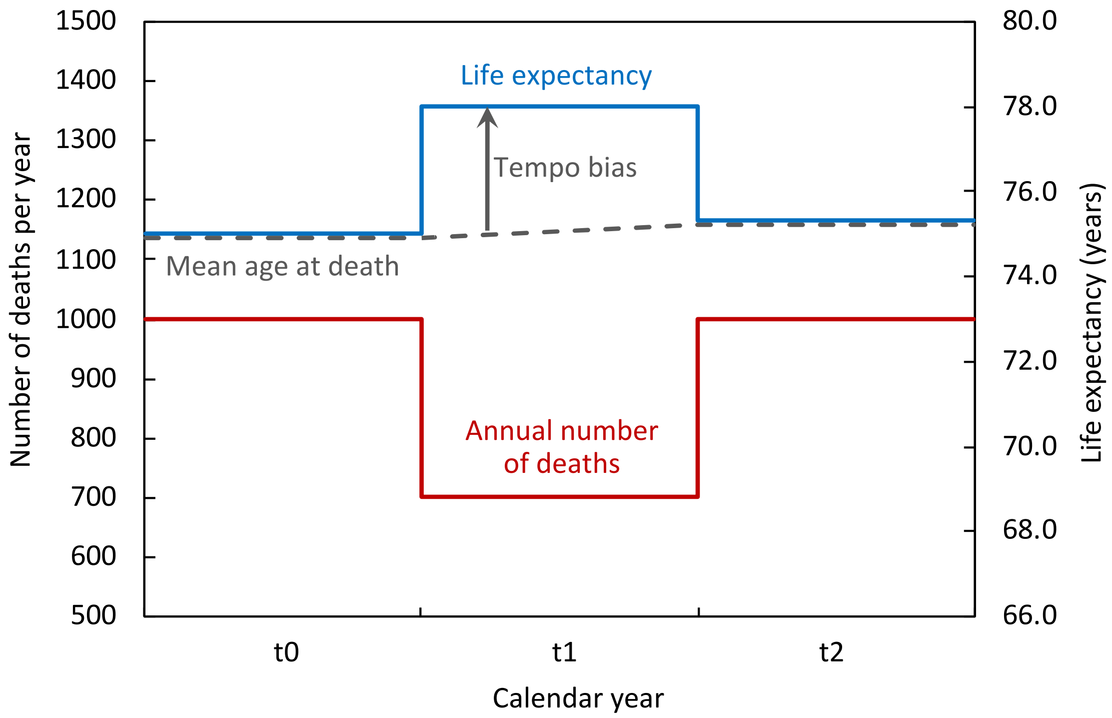
Bongaarts and Feeney termed “mean age at death”. Then, they assumed that during a year t1 – and only in year t1 – mortality is decreasing in a way that the mean age at death is rising to the level of 75.3, at which it remains constant from year t2 onwards. Albeit this change in the mean age at death is only small and gradual, it leads to huge jumps in period life expectancy: first, an increase from 75.0 to 78.0 in year t1, and then a decrease from 78.0 to 75.3 in year t2. These jumps are caused by the shift of deaths from year t1 to year t2 as a consequence of the decrease in mortality. As we have shown above, such shifts have a much stronger (relative) effect on the numerators of the death rates then on their denominators what boosts the rates—and consequently life expectancy—disproportionately in year t1. This hypothetical example leads to two central messages:

1. Changes in the mean age at death—or in other words, changes in mortality—during the observation period can inflate period life expectancy, and
2. Period life expectancy can decrease without an actual increase in mortality (decrease in the mean age at death), but as consequence of shifted deaths.

Figure 19 shows the actual empirical numbers for women in the UK in the same graphical manner. The similarity to the theoretical example of Bongaarts and Feeney in Figure 18 is striking: the empirical data for the years 2013 to 2015 closely resembles the hypothetical scenario of Bongaarts and Feeney. This leads to two conclusions:

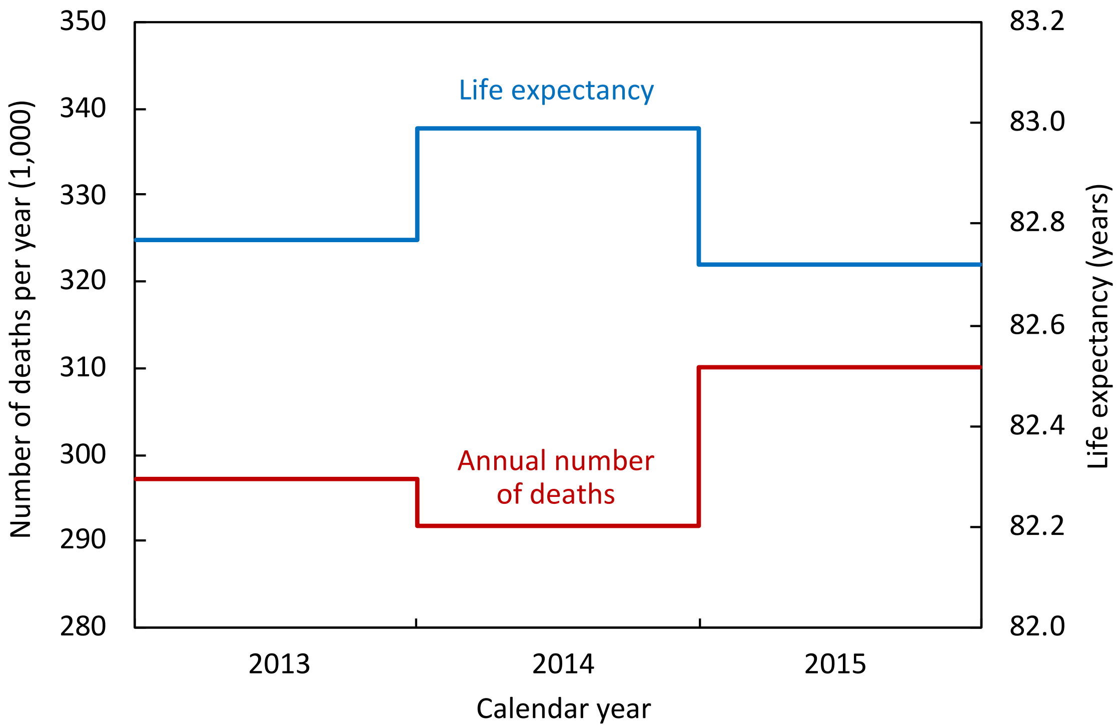
1. A large fraction of the decrease in life expectancy between 2014 and 2015 might be caused by TE, as a consequence of the tempo-inflated life expectancy increase in 2014 and the tempo-inflated decrease in 2015, and
2. The increase in the number of deaths in 2015 is largely a consequence of the low mortality in 2014, what led to a shift of deaths from 2014 to 2015.

Figure 18: Trends in total number of deaths and life expectancy, hypothetical scenario of changing mortality



Source: Bongaarts and Feeney (2002, p. 19); Own replication.

Figure 19: Trends in total number of deaths and life expectancy, empirical data for women of UK, 2013-2015



Source: HMD; Own calculation and illustration.

Tempo effects in UK mortality

To test the possible extent of a tempo bias in life expectancy trends, we assessed the level of TE in the UK for the years 2009 to 2015 with the "Total Mortality Rate" (TMR). The TMR represents the cross-sectional sum of cohort deaths in a particular calendar year – adjusted for the size of birth cohorts – and equals 1.0 when mortality remains unchanged during the year of observation. As soon as some or all currently living cohorts experience a change in mortality (i.e. a shift in deaths to earlier or later calendar years), the TMR leaves unity and becomes higher than 1.0 in the case of increasing mortality and lower than 1.0 in the case of decreasing mortality (Sardon, 1994)[48]. As recommended by Bongaarts and Feeney (2006), we restricted the estimation of TE to ages 30 and older because the assumptions behind their adjustment-model (which is applied below) do not hold for younger ages. To estimate the TMR we reconstructed the complete longitudinal life time survival for each cohort alive during the observation years 2009 to 2015 from the age-specific death rates retrieved from the HMD. We then determined the cohort-specific proportion of deaths occurring in these calendar years and derived the period TMR (from age 30) for each calendar year by summing up the corresponding proportions across all cohorts (more details about the calculation of the TMR can be found in Guillot, 2006).

Figure 20 illustrates the trends in period life expectancy in the UK between 2009 and 2015 (see black lines of the graphs with the values relating to the left y-axis) and the corresponding levels of the TMR (grey dotted lines referring to the y-axes on the right-hand side). The graph reveals that the fluctuations in the trends of life expectancy and TMR are strongly correlated. Most importantly, stalls or decreases in period life expectancy are always associated with an upward jump in the TMR. This holds not only for the reductions in life expectancy between 2014 and 2015, but also for the decreases and stalls in previous years, such as between 2011 and 2012 among women and between 2012 and 2013 among men.

Finally, we estimated tempo-adjusted life expectancy for the years, 2009-2015. Four different methods have been developed to adjust period life expectancy for TE (Bongaarts and Feeney, 2003). These methods are, however, only variants for performing mortality tempo adjustment and arrive essentially at the same estimates (Luy, 2010). We applied the TMR-method tempo adjustment which utilises the property of the TMR to directly reflect the level of TE in a particular period[49]. The age-specific death rates for ages 30 and older were thus adjusted by division with the corresponding annual TMR values. For ages 0-29 we used the unadjusted DR, implying that no TE occurred at ages below 30. Bongaarts and Feeney (2003) have demonstrated that this assumption is justified for contemporary populations from industrialized countries.[50]

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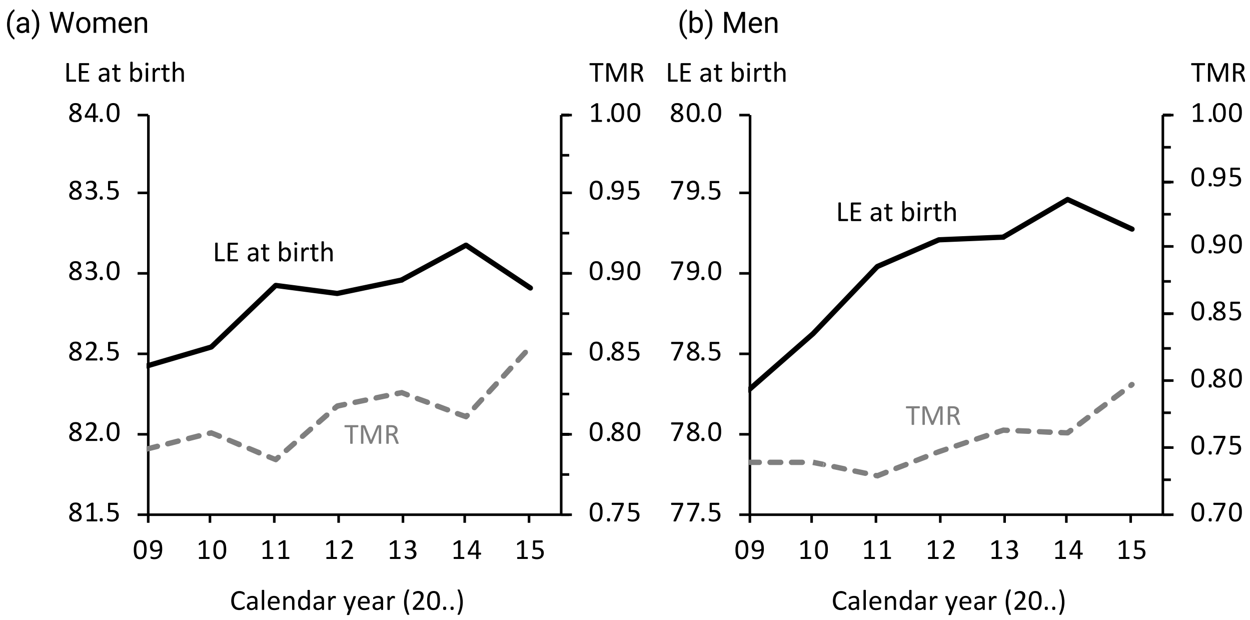
[48] What makes the TMR so interesting in the context of our study is that it deviates from 1.0 exactly by the proportion of deaths that are shifted out of or into the period of observation, relative to the hypothetical situation of constant mortality (for details see Guillot, 2006; Luy, 2010).

[49] See footnote 48.

[50] The methods for tempo adjustment imply that the schedule of age-specific death rates shifts proportionally across all ages. This assumption is violated during the changes between, 2014 and, 2015. In some age groups, death rates increased in, 2015 compared to, 2014, in other age groups they decreased. Nonetheless, we performed test simulations which revealed that the estimations are not affected by the constant shape assumption of the Bongaarts and Feeney model.

Figure 21 shows the trends in Bongaarts and Feeney's tempo-adjusted life expectancy (LE*) and Nicolas Brouard's cross-sectional average length of life (CAL), which is an alternative measure for period longevity which is also free of TE. The graphs show the changes in conventional life expectancy since 2009 in blue (with the decrease in, 2015), tempo-adjusted LE* in red, and CAL in green. The results illustrate the potentially strong impact of TE on the fluctuations in period LE in the UK: both, LE* and CAL continued to increase in 2015 without marked fluctuations. Thus, once TE are taken into account, we find no indication of any health crisis that has affected the mortality conditions of the current population. This is made even more evident by the fact that the TMR for the year 2015 lies below 1.0 in both women and men (see Figure 20). This means that even in the year of declining period life expectancy, mortality has still been decreasing rather than increasing.

Figure 20 Trends in life expectancy at birth (left axes) and the Total Mortality Rate (right axes), the UK 2009-2015

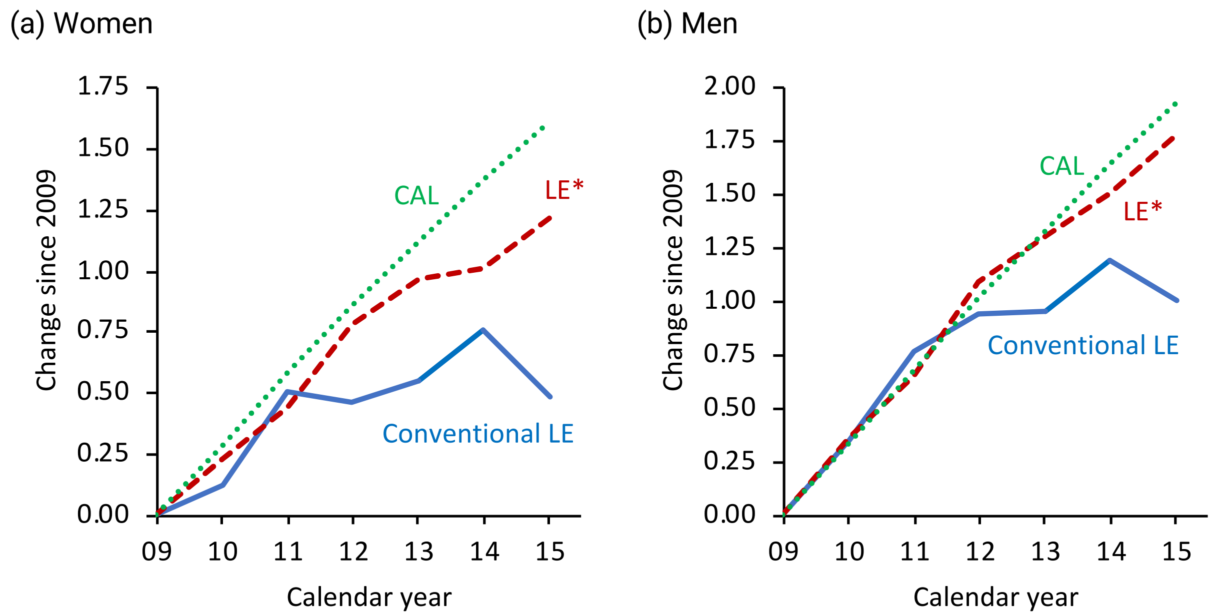


Source: HMD; Own calculations.

The decisive factor that caused these distorting effects on the conventional life expectancy indicator is that the level of TE – i.e. the extent of mortality improvements – decreased in 2015 compared to 2014. This becomes apparent from the fact that the TMR becomes closer to 1.0 between 2014 and 2015. This means that the decrease in life expectancy between 2014 and 2015 was caused by changes in mortality in both years, and not only in the year of decreasing life expectancy (see also Fig. 19).

It is important to note, however, that these results should be seen only as indicators for the strong impact of TE because the existing techniques for tempo-adjustment of life expectancy include assumptions which allow only approximate estimations. Thus, the extent of TE in the life expectancy of the UK could be over– or underestimated. These methodological limitations do not hold for the TMR, however. This rarely used mortality indicator is free of theoretical assumptions. The TMR is highly valuable because it reflects directly the extent and the direction of TE prevailing in a particular calendar year. The fact it lies below 1.0 in all analysed populations and years reveals that the life expectancy values for both 2014 and 2015 are boosted upwards by TE. These boosts are to such an extent larger in 2014 compared to 2015 that they cause an increase in age-specific death rates between the two years what, as a consequence, contributed to the decrease in the conventional period life expectancy. This explanation entails a very different message compared to the alarming reports about an increase in mortality derived from conventional period life expectancy which strongly influenced the perception of actual mortality trends. A deceleration of mortality improvements implies a still ongoing decrease in mortality in 2015 among the real cohorts, just at a reduced pace. The reduction of the pace in mortality improvements led to an accumulation of deaths in 2015 compared to 2014. This particular situation occurred because the stronger mortality improvements in 2014 shifted deaths from 2014 into 2015.

Figure 21 Changes in life expectancy at birth, tempo-adjusted life expectancy and the cross-sectional average length of life, relative to, 2009 in the UK 2009-2015



Source: HMD; Own calculations.
Notes: LE = life expectancy, LE* = tempo-adjusted life expectancy; CAL = cross-sectional average length of life

The data for 2016 provide further support for our interpretations. As shown in the previous sections, European countries experiencing the life expectancy decline in 2015 experienced an increase in life expectancy in 2016. This applies likewise to the UK.

Clearly, decreasing life expectancy in the UK and several populations of Europe causes great concern for public health researchers and officials. However, it is essential to keep in mind that this information is derived from a demographic period indicator. This represents by definition the lifetime experiences of a hypothetical cohort of people which have only limited validity for the real population. TE are one element of period indicators which do not exist in the life time experiences of real cohorts. It is likely that the actual decrease in life expectancy is to some extent attributable to these TE, rather than being the consequence of factors related to a severe health crisis. Public health researchers and officials should remain open for all possibilities, including a TE-caused bias in the actual trend of life expectancy.

Section VI – Summary and Conclusions

Main UK mortality trends in retrospect and prospect

Mortality in the UK has broadly followed the patterns of other high-income European countries over the 21st century and has largely retained its position over that whole period, especially for females but with a slight deterioration for males. In the early part of this century, UK mortality rate improvements were amongst the highest recorded since WWII. However, rates of improvement deteriorated sharply since about 2010. This has also occurred in some other European high-income countries in this current decade, but the pattern has been particularly prominent in the UK. If this deterioration were to continue, current low levels of mortality improvement will turn into relative and potentially absolute decline (although the most recent trends seem to be more optimistic). However, in the set of 15 comparator countries included earlier, the rate of change in life expectancy between 2010 and 2017 was equivalent to an increase of one year or more per decade for 14 out of the 15 countries shown (the exception being Germany) – and one third of these countries had historically strong increases of two or more years per decade. In our view, it is unlikely that countries that have long-standing and increasing economic, cultural and demographic links would start to develop long-term divergences in mortality trends without a clearly-identified reason, such as the exceptional divergence in mortality between Western and Eastern Europe for about half a century from the 1960s and we have been unable to identify such a single factor or set of factors that would lead to continuing divergent patterns in European HICs.

The last period in the UK of sustained low improvements or even reversals in mortality improvement was around 1970, when projections at the time assumed no further improvement in mortality. This period was followed by a long and substantial period of mortality improvement. In the more recent period, Japan showed little improvement in mortality in the first decade of the 21st century, when other countries at similarly high levels of development were improving rapidly. However, in the most recent period Japan has shown very high rates of mortality improvement (Figure 4 and ONS, 2018d). Examples of sustained poor performance are rare, although, in recent years, the U.S. has experienced this in relation both to earlier periods and to other high-income countries. U.S. life expectancy has fallen in each of the three latest years for which data are available, from 2015 to 2018 (Murphy et al., 2018), an event that has occurred only once in the past century, and that the exceptional period 1915-18.

The assumption of a reduction in rate of improvement from historically high levels had been built into population projections made by various agencies including ONS, Eurostat, United Nations and U.S. Census Bureau. However, the speed and magnitude of the decline has been unexpected in many countries, but so far there is a consensus that there is no evidence that require long-term assumptions need to be altered substantially, or that overall rates of improvement are likely to become negative.

We emphasise that there have been no cases of long-lasting substantial increases in mortality recently in European developed countries apart from the special case of the Soviet Union in the period 1960-95. In most European countries, current rates of improvement are similar to those experienced in the 1990s. While some concern has been expressed about this reduced rate of improvement as compared with the early 2000s, the key question is whether this deterioration will continue or stabilise. This requires a better understanding of the factors that are responsible for these trends and how these variables may evolve in years to come.

The importance of these findings varies according to the uses of such data. For those concerned with providing day-to-day services, information on variability and predictability of demand may be the priority, whereas in areas such as pensions, understanding the drivers of long-term trends is crucial. While the past is “nice to know”, the future is “need to know” and the key question is whether current trends, which give information on the current performance of population health in general, represent a long-term shift from recent values in the first decade of the 21st century, or whether these improvements are likely to have been driven by “one off” factors that cannot continue; for example once smoking rates are low and uptake of statins is high, their impact on rates of mortality improvement will disappear. Such changes may have influenced past trends, but they would need to be replaced by the emergence of other drivers to maintain high rates of improvement.

The Government’s 2018 Industrial Strategy sets out four Grand Challenges. One of which is “ageing society”[51] with the mission of “to ensure that people can enjoy at least 5 extra healthy, independent years of life by 2030[52], while narrowing the gap between the experience of the richest and poorest”. This is at a time when if the increases in UK total period life expectancies over the most recent period of 2009-11 to 2015-17 were continued until 2035, total male life expectancy would have increased by 2.1 years and female life expectancy by 1.1 years. Healthy life expectancy tends to improve at an even smaller rate, and the latest UK figures show an increase of 0.4 years for males and a decrease of 0.3 years for females in the period 2009-11 to 2015-17, so if the trend over the past 6 years were to continue, male healthy life expectancy would increase by only 1.1 years and healthy female life expectancy would actually worsen by 0.8 years by 2035. The ageing society Grand Challenge would appear to be an aspiration that is unlikely to be achieved, and emphasises the need for a framework for structuring discussion of future mortality trends, drawing on recent experience. Understanding of the mechanisms underpinning current trends is crucial for planning and policy purposes. The experience of an earlier but much more extreme case of mortality deterioration, the Russian mortality crisis 1990-94 serves to highlight the difficulties that may be faced.

The 1990-94 Russian mortality crisis

Why a very substantial sharp and sustained deterioration in mortality trends without an obvious determinant such as war, pandemic or large-scale civil insurrection in a modern society can occur has been examined in Russia and in some other parts of the Former Soviet Union, as well as lesser but still substantial increases in some countries in the former Communist bloc.
Life expectancy in Russia for males fell from 63.8 in 1990 to 57.7 years in 1994, and the

[51] See for more: https://www.gov.uk/government/publications/industrial-strategy-the-grand-challenges/industrial-strategy-the-grand-challenges
[52] The same document elsewhere gives the target date as 2035.

corresponding figures for women were from 74.4 to 71.2. The additional number of premature deaths around this period in the Soviet Union was estimated at seven million (Men et al., 2003). The collapse of the Soviet Union was relatively peaceful and unsurprisingly attracted much attention as to how and why such a catastrophic fall in longevity could occur. Initially, as with current discussions of mortality improvement stalling, the question of whether these were artefacts due to data collection system problems were raised but quickly rejected. At an early stage, excess mortality was found to be particularly high among working age men, but infants and children appeared to be much less affected. The causes of deaths mainly responsible were identified as CVD together with external causes of accidents and violence (although since external causes accounted for a smaller fraction of total deaths, their contribution was much lower than CVD). Alcohol consumption was identified as another possible key factor – life expectancy had increased substantially following Gorbachev's short-lived anti-alcohol campaign in 1987 – emphasising the importance of needing to include earlier periods to understand later ones. However, there was initially some resistance to a key role for alcohol since the drivers of CVD mortality were mainly seen as long-term life course factors and, in any case, there was a widely-held view that alcohol was cardio-protective. It later became clear that binge drinking was a major risk factor to cardio-vascular disease and alcohol was substantially implicated (McKee and Britton, 1998). The lack of change in cancer mortality was used to argue that the primary mechanism underlying the increase in mortality was not the collapse of the health system as some had argued.

More attention was given to drinking patterns, especially binge drinking together with increased use of potentially dangerous home-prepared spirits ("zapoi"), and obviously dangerous sources of surrogates such as anti-freeze, window cleaning fluids and after-shave lotions. This did not address the question of why highly-dangerous drinking practices increased and the explanations concentrated on the deteriorating social; and economic environment with formerly highly-respected groups like heavy industrial workers particularly affected. Finally, attention was given to the role of political decisions such as mass privatisation of state enterprises that led to widespread economic hardship, while enriching a small group of oligarchs and the role of, for example, western and international agencies who have been pressing for such structural adjustment policies in Russia as elsewhere. After a quarter of a century, there are still disagreements about the underlying reasons for the Russian mortality crisis (Gerry et al., 2010; Azarova et al., 2017), and the same is true for the more recent U.S. stalling of mortality improvement.

There are a number of lessons that can be drawn from the Russian mortality crisis that are relevant to the debate about current UK trends. In terms of cause-specific analysis, concluding that CVD was the primary reason for the deterioration in Russian mortality in the early 1990s, although true, provides little insight into process, although it may provide some signposts for areas that need investigation - "to understand the dynamics behind the recent slowdown in improvements, we must look beyond cause of death data" (SwissRe, 2018, p.1). It is clear that cancer trends were highly insensitive to the wider societal transformations and suggests that there is less scope for initiatives to affect cancer mortality in the short-term.

When looking at the drivers of CVD increase, alcohol was a major factor, but this also affected a range of other causes, especially external causes through accidents in the home, work-place and street as well as through violence, including domestic violence. Concentration on individual causes may obscure the role of drivers such as alcohol or smoking that act across multiple causes. While alcohol may provide additional insight into what's happening, the same may be said about the role of opioids in the U.S. – in both cases, disadvantaged groups have sought out something available that would help them to cope with their current situation.

Finally, there is question of why people resort to such behaviours – this may include passive behaviour in that people are less inclined to seek treatment and to adhere to medication, or that greater stress may add to vulnerability. Clearly the further the determinant is from the event, the more difficult it is to identify causality, and the need for careful research with sound theoretical and empirical underpinnings.

Bearing in mind the difficulties faced in determining the causes of this extreme event we now consider what frameworks for assessing potential causes and additional work may be appropriate.

A framework for analyzing recent mortality change

The PHE Report (2018a, p. 5) was rightly cautious about the extent it was possible to identify, never mind quantify the contribution of various hypothesised causes of mortality improvement stalling: "It is not possible, however, to attribute the recent slowdown in improvement to any single cause and it is likely that a number of factors, operating simultaneously, need to be addressed". A similar conclusion was reached in an international context by SwissRe (2017). We have noted above that two large-scale studies concerned with inequalities have been established in the UK emphasising the extent to which gaps are recognised to exist. The need for in-depth analysis may be illustrated by the example of the role of obesity that has been identified as a possible factor in on recent mortality improvement stalling. Obesity was examined by a wide-ranging expert panel in a government Foresight study in 2007, and the *Tackling Obesities: Future Choices* report concluded that obesity was unlikely to lead to a reduction of even one year in life expectancy by 2050. In an update in 2017, it was noted that in the meantime rates of obesity were much lower than had been anticipated, estimated as 10% lower in 2030 [53]. However, one of the papers given in support of a possible contribution of obesity to the stalling of mortality improvement since 2011 presented two key studies over periods 1980−2000 and 1979-2011 respectively (Mensah et al., 2017). A similar in-depth investigation would be necessary for the large number of other potential explanations. This reinforces the need for a framework to identify the structure for a coherent future work programme.

One of the first issues to consider is whether the hypothesised causes could plausibly produce the observed patterns. To test such hypotheses, it is important to establish a framework that considers separately (i) long-term improvements in mortality, (ii) medium-term sharp change in the pace of that improvement and (iii) short-term year-to-year fluctuations around these trends. This report has attempted to do so, highlighting also that the drivers of these trends should preferably: be capable

[53] For more information, see: https://foresightprojects.blog.gov.uk/2017/10/04/dusting-off-foresights-obesity-report/

of affecting a broad range of age and sex groups; be likely to have a greater impact on more deprived groups; and be consistent with observed cross-national differentials. While it is tempting to concentrate on specific factors relevant to particular subgroups and, by default, attribute any similarities to coincidence, the generalised pattern across age and sex groups which have, for example, different of causes of death suggests that wider underlying factors may be required to explain the observed similar variations across different sub-groups.

We argue that short-term influences – in practice now often identified with seasonal influenza – have had little if any impact on longer term trends (for more detail see Appendix I). This means that attention can be focused on other, longer-term changes.

Long-term trends are driven by extended processes and the substantially monotonic nature of improvement over periods with time-scales of multiple decades suggests factors such as generalised improvements in standard of living and human capital, good governance, improved health and social care leading to better prevention and treatment of disease all play a role and these factors are, in any case, not independent. Another example would be the smoking history of cohorts that can influence their mortality rates decades later. More recent cohorts show increasingly better risk profiles, and an 85-year-old in 2019 would have experienced one year more of the hostile environment to smoking than an 85-year-old in 2018 and so on. This environment would include more anti-smoking public health messages, legal restrictions, increasing cost and public disapproval. While initial levels and responses to these messages may not be uniform between different social groups and this can be a factor in increasing socio-economic differentials. These trends would be expected to be incremental and long-lasting (two successive cohorts will have spent the great majority of their lives in a common environment). In addition, any mortality advantage of later birth cohorts will be dispersed across extended period of time as any reductions in mortality are likely to be spread over many decades of their life course. This will further tend to smooth out the effects of cohort factors while simultaneously making it more likely that trends will be monotonic and relatively smooth. While potentially accounting for the long-term trends, cohort factors appear to be poorly-suited to explaining what we describe as a middle-term patterns, the change in trend from around 2011 in the UK and in attenuated form in a number of other countries around 2005-10.

This is particularly relevant to the possible contribution reductions in CVD mortality to current trends. Changes in overall mortality trends due to CVD mortality can be divided into three main components, the first is simply arithmetic – higher rates of improvement in any case will inevitably lead to that variable contributing less to the overall value and the overall rate of improvement will decline as a consequence even if rates of improvement of all variables remain constant. If the overall value is to remain constant, the rate of improvement of some of the remaining substantial variables will have to increase. The second is the role of cohort factors determined by experiences before the study period, such as smoking and high fat diet. As pointed out above, these would not be expected to lead to sharp trend changes. For socio-economic differentials, long-term changes could temporarily reduce socio-economic differences if, for example, higher incomes may facilitate more smoking or higher animal fat diet for a time, but over time these differences would be expected to reverse as smoking becomes more common in lower socio-economic groups. However, these long acting factors – both positive and negative – are unlikely to result in an apparent increase in differentials as seen in the UK in 2011.

This leaves contemporary factors that include improved medication and treatment, crucially in early years of the century. There are well-validated widely-accepted models for allocating changes in CVD mortality to specific risk factors, such as the IMPACT model (Ural et al., 2004). This model estimated that about 60% of the decline in England and Wales in the period 1981-2000 was due to improvements in risk actors and about 40% to improvements in medication and treatments. Changes in deprivation accounted for only 4% of the decline, and obesity led to an increase of 3.5%. We are unaware of similar analyses specifically for the changes in the current decade. However, quantifying the effect of various drivers requires a substantial modelling exercise and relevant data to drive the model, but there is clearly scope for further detailed work to investigate this issue. While there are opportunities to reduce CVD mortality further, and especially its social gradient, major improvements will also be needed to occur in non-CVD mortality to achieve the substantial improvements in overall mortality observed a decade ago. While stalling of CVD mortality improvement had been identified as a factor in the recent downturn of mortality improvement, even if this had not occurred, some reduction in improvement would have been expected in any case.

Tempo-effects in recent period mortality indicators, instead, seem to have had an influence on the actual decrease in life expectancy observed in 2015 in the UK. This once again supports our view that short-term fluctuations are to be expected and should always be contextualised with prior periods characterised by stronger mortality improvements to avoid excessive alarmism.

Since there appears to be no plausible short-term or long-term mechanism identified that would lead to the discontinuity in trend as it appears to have occurred in the UK around 2010, this leaves contemporary factors that includes improved medication and treatment, but also reductions in health and social care services crucially in relation to comparison with early years of the century, and TE in the most recent period. The variables that may plausibly account for the change in trend around 2010-2011 are contemporaneous or nearly contemporaneous period factors.

Of the remaining hypotheses, austerity is an explanation closely linked to the current environment. Work in this area has been criticised for methodological and presentational failings (O’Dowd, 2017; Milne, 2017b, Steventon, 2017) and, in particular, for over-interpretation (PHE, 2018a; Raleigh, 2019). There is empirical evidence for an association between austerity and mortality improvement stalling and a plausible pathway for a causal relationship. Bradford Hill (1965) set out a framework for assessing whether there was likely to be a relationship between cause and effect, which was applied to austerity by McCartney and Fischbacher (2018) and also by Hiam et al. (2019). Austerity is not incompatible with the two main other hypotheses, seasonal influenza and CVD trends. As emphasised earlier, a debate structured around one single explanatory factor being mainly responsible for recent patterns would be short-sighted and fail to acknowledge the inevitable interactions between factors. Worse conditions (which may lead to less inequality as conventionally measured) may bear harder both economically and psychologically on the less well-off and increase inequalities in mortality together with lower mortality improvements. The introduction of austerity in the UK is more consistent with the sharp and sustained deterioration in the UK trend. However, this is on a balance of probability rather than beyond reasonable doubt basis, mainly because it might be expected to account for the more pronounced change than found in comparator countries. Unfortunately, the concentration on 2015 and the headline figure of a decline in life expectancy in 19 of the 28 EU countries as compared with 2014 may have led to less attention being given to the fact that changes across the 2010 decade have been highly variable across Europe with current underlying rates of mortality improvement often similar to those of the 1990s, and with the early 2000s period appearing anomalous.

Identifying and attempting to explain the divergences of the UK for other high-income countries will require more robust evidence, both in relation to other countries' experience, what is to be explained; the change since 2011 or the relative sharpness of the change relative to comparator countries – and which are the relevant comparators. Analyses undertaken at lower geographical level, such as by Watkins et al. (2017), where outcomes can be related to local variations in conditions and service provision would provide more variability and permit the effect of variables such as individual and areal indicators of socio-economic status to be estimated (if appropriate data are available). In such cases, statistical models can remove the effect of common unmeasured variables and provide less biased estimates.

Overall, the UK is facing a mortality improvement stalling problem that has led to calls for action but many of the basic facts to underpin useful actions are not available. Some, such as improving influenza vaccine coverage and surveillance, and attempting to improve vaccine effectiveness would clearly be welcome and undisputed, even if they had little effect on long-term mortality trends. However, attempts to reduce deaths due to poor housing conditions or fuel poverty would be more controversial: fuel subsidies are expensive and the question of universal or restricted benefits is politically charged; it would bring the area of additional deaths among the more deprived as a result government (in)action to the forefront; subsidising fuel use would conflict with other Government policies on climate change; and more pressure for expenditure on public housing construction and maintenance.

The PHE Report (2018a, p.73) set out a range of sensible additional analyses that could be undertaken to elucidate the causes and consequences of recent trends. These were further research on causes of death, especially heart disease and stroke; links between mortality and public expenditure, including that on health and social care; and the role of excess mortality especially in relation to health inequalities among deprived older people. Raleigh (2019) recommended availability of additional disaggregated data, especially those on cause of death, but came to the firm conclusion that it would be premature and inappropriate to make recommendations about policy interventions.

There is a need for better information in areas such as availability of longer and more consistent and timely data series. For example, France published life expectancy estimates for 2018 in February 2019; before UK data for 2017 were made available. UK life expectancy data are first made available as 3-year averages, so that for example, in making comparisons between the most recent figures for 2015-17 and the previous figure for 2014-16 published in September 2018 are actually comparisons between years 2014 and 2017 since 2015 and 2016 are common to both. SDR data for England in 2018 are already available and, like life expectancy, are based on age-specific mortality rates. The latest published information in early 2019 on the most widely used indicator of mortality inequality trends, by deprivation deciles is for period 2014-16 so the latest possibly change analysis is between years 2013 and 2016 (2015-17 data were released in March 2019). Comparable constituent and complete UK data are very frequently not available, complicating intra-national and international comparisons.

However, while improved routine macro-level data would provide a better basis for monitoring, informed debate and hypothesis generation, they are inadequate for theory-driven research or for identification of causal pathways. Information on individual-level data is needed to complement the mainly ecological data currently used and, in particular, there is a need for more cross-national analysis to identify, sharpen and validate hypotheses.

In terms of additional work, a number of variables such as on obesity, type 2 diabetes, and air pollution have been suggested. However, these have not been examined for plausibility, such as whether the magnitude and likely time frame of such variables can account for observed trends since, for example, contemporary increases might not be expected to show up in mortality statistics for many years in the future. In terms of major additional variables that might help to explain these trends, population-level mental health possibly associated with a sharp decline in self-reported health has received little attention. Ultimately the objective should be to understand the underlying processes.

The difficulties in making progress should not be underestimated. The case of interpretation of cause of death data is discussed earlier. The inherent problems are clear if one thinks of example such as: an older person with a chronic heart problem and Alzheimer's disease is admitted to hospital with symptoms of influenza but treatment was delayed because, for example, social care provision was inadequate or pressures in the health system meant the person did not receive prompt treatment. The person subsequently died of a bacterial infection. All these factors could be said to have contributed to mortality. However, not all will appear on the death certificate. Identifying the selected underlying cause can be problematic, and there are challenges in extracting useful information from multiply-coded death certificates. An additional complication is that differences across time in overall mortality could be due, for example, to changing proportions of people with chronic disease, proportions of people who are diagnosed as having Alzheimer's disease, the circulating strain of influenza and vaccine effectiveness, and finally the quality and quantity of social care and services available at different time points. Separating out the contribution of each component will clearly be difficult. Yet this is only a first step, since as the case of Russia shows, decisions about the pace and type of societal transformation and the way in which they were implemented is where key policy decisions are made.

In the U.S. where the stalling of mortality improvement is of longer standing and of greater magnitude, variables such as influenza and CVD, have attracted little attention. Possibly the most influential study by Case and Deaton (2017, pp. 3, 4) concluded:

> "We propose a preliminary but plausible story in which cumulative disadvantage from one birth cohort to the next – in the labour market, in marriage and child outcomes, and in health – is triggered by progressively worsening labour market opportunities at the time of entry for whites with low levels of education. This account, which fits much of the data, has the profoundly negative implication that policies. Deaths of despair come from a long-standing process of cumulative disadvantage for those with less than a college degree. The story is rooted in the labour market, but involves many aspects of life, including marriage, child rearing, and religion. Although we do not see the supply of opioids as the fundamental factor, the prescription of opioids for chronic pain added fuel to the flames, making the epidemic much worse than it otherwise would have been".

These authors were not able to clearly identify specific causes, but rather to attribute these trends to a generally deteriorating social environment, bearing down particularly hard on the most disadvantaged. There has been a tendency to assume that U.S. experience (and the readily-available explanation of easier access to both prescribed and non-prescribed synthetic opioids) is not relevant to the UK[54]. However, our report not only highlights that that the UK shares similarities with patterns observed in U.S., but also, as Case and Deaton (2017), we stress the importance of learning from and applying an approach which investigates "the cause of the causes" (Marmot, 2018) in the long-term, instead of just focusing on single explanatory mechanisms. This endeavour would highly benefit current and future research on the issue and would guide appropriate policy responses. It is therefore particularly welcome that both Marmot and Deaton are leading major in-depth enquiries into factors associated with mortality improvement stalling, and in particular on the extent, causes and consequences of what appears to be increasing inequalities. There is also a strong case for a similar initiative to investigate the role of changing disease patterns on mortality, especially if this adopted an explicitly international focus.

[54] Although a very recent OECD Report suggests that may be changing (https://www.oecd.org/health/addressing-problematic-opioid-use-in-oecd-countries-a18286f0-en.htm).

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Appendix I - The contribution of winter excess mortality, seasonal influenza and the 2015 “spike” to stalling of mortality improvement in UK since 2011

Introduction

There are three main components of mortality change over time:

1. short-term (year-to-year) fluctuations
2. medium-term changes
3. long-term trends.

The boundaries between these, especially points two and three are not well-defined, but the distinction helps to clarify identification of the sorts of factors that may be relevant to explaining recent trends.

Figure 1b in the main report shows that there has been a long-term trend of improving longevity in the period around 1970-2010. Figures 4 and 5 show that there was an apparent change the magnitude of improvement around 2011.

In this Appendix, we will start by examining the role of short-term fluctuations on trends in recent decades. We argue that these have had little effect on the slowdown in mortality improvement in the UK or elsewhere. Although there has been some increase in the volatility of year-to-year variability in the recent past, there is no evidence for an increase in the magnitude of such fluctuations nor a plausible mechanism that would reproduce the observed patterns.

As discussed in Section I, in the UK, considerable attention has been focused on the high number of deaths in winter 2014-15 and year 2015 in general. This has been defined as exceptional in official reports (ONS 2016a), academic papers (Hiam et al 2017a,b), blogs (Newton et al., 2017; Raleigh 2017) and other outlets such as letters to journals. The fact that the increase in annual deaths between 2015 and the previous year was the highest percentage increase year on year since 1968 led to considerable public attention and controversy. In part, this was because the rise in excess deaths was attributed to NHS cuts and to austerity more generally in an influential paper by Hiam et al. (2017b). This paper reached this conclusion after reviewing various factors that might be responsible and rejected a number of these such as artefacts due to data problems, and, in particular, the authors rejected the role of seasonal influenza on grounds such as the fact that similar levels of excess mortality were not observed when the same A(H3N2) strain circulated in previous years. Around the same time a report in the BMJ stated that the “sharp rise in the annual number of deaths recorded in England and Wales in 2015 has left public health experts grasping for answers”, and that this needed investigation (Hawkes, 2016).

In response, PHE argued that the peak in deaths in 2015 is not a complete mystery, and that fluctuations were known to occur due to extremes of weather and circulating infections (Newton, Pebody and Fitzpatrick, 2017). A statement from the Department of Health (DoH) said that annual fluctuations have always occurred and the trend at the time was similar to earlier years. However, since mortality had been improving at a fast pace in earlier years, an apparently sudden reduction in the previous improving trend became a topic on interest. Discussion of the reasons for the increase in deaths in 2015 became so controversial, that an anonymous DoH spokesman told the BMJ that the paper by Hiam et al (2017b) was "a triumph of personal bias over research" (O'Dowd, 2017) [55].

An ONS Report on the increase in deaths between 2014 and 2015 concluded that increases in dementia and flu particularly among older people were responsible for the increase in deaths in 2015 in England and Wales since 86% of these extra deaths occurred in people over 75, and 38% were in people over 90 (ONS, 2016a)[56].

Around this time, discussions started about a general slow-down in mortality improvement from the rapid levels of the first decade of the 21st century. Influenza was identified as a factor in this emerging trend since it was argued that the pattern observed in the winter of 2014-15 was not necessarily an isolated event. An increase in mortality was observed more widely, such that period life expectancy at birth was lower in 2015 compared with 2014 in the majority of EU countries, which was documented by Ho and Hendi (2018) as well as in an ONS Report (ONS, 2018a). Moreover, the 2015 "spike" (as it came to be called) was identified as more than an isolated "one-off" event, and of wider importance because "similar 'flu' effects were apparent in the subsequent two winters also (in the UK and Europe). As the 2015 spike can provide clues to mortality trends more generally" (Raleigh, 2017). We therefore repeat the key points in Jasilionis' (2018) editorial in BMJ in commenting on Ho and Hendi's (2018) paper concerned with changes between 2014 and 2015 stated forcefully (our emphasis in italics):

> "This universal spike in mortality has often been attributed to the direct and indirect effects of severe flu epidemics, particularly among older people. The fact that modern healthcare systems in the most advanced high-income countries were unable to cope with this unexpected challenge, resulting in the *first reductions in longevity for decades, is striking and might signal more profound problems*. [...] Evidence suggests that discontinuities in secular trends can lead to prolonged health crises – *they are warning signs of fundamental and longstanding societal and health problems*."

There was also a sharp increase in deaths in the first part of 2018, which led to a BMJ Editorial by Hiam and Dorling (2018) entitled "*Rise in mortality in England and Wales in first seven weeks of 2018*. *Health chiefs are failing to investigate a clear pattern of worsening health outcomes*". This editorial explicitly rejected the roles of influenza and cold weather as relevant to the increase and a related News item was headlined "*Government must investigate rising excess deaths in England and Wales, experts warn*" (Iacobucci, 2018). This was followed by a decision by the Government to commission a report on recent mortality trends by PHE, which was published in December 2018

[55] For more, see: https://blogs.bmj.com/bmj/2019/03/08/lucinda-hiam-and-martin-mckee-the-deepening-health-crisis-in-the-uk-requires-society-wide-political-intervention/

[56] While deaths recorded as Alzheimer's disease deaths have been rising sharply, this has been substantially due to changes in discovery and recording practices), see Sections I.2.3 and 4.1.3.

(PHE, 2018a). However, 2018 subsequently turned out to have the second-lowest level of SDR ever-recorded (ONS, 2019).

After reviewing the evidence, usually based on comparison of changes observed in the period 2011-16 with those in 2006-11, the PHE Report assessed possible reasons for recent patterns: some such as data artefacts and international migration were rejected, and others identified as possible factors, see Sections I and IV. The Report emphasised that a slowdown in improvement from heart disease and stroke mortality had a significant impact on these trends, but the role of EWD/influenza was central in the discussion about the longer-term stalling of mortality improvement. Flu received the greatest attention in the section on possible explanations for the stalling of mortality improvement since 2011. "*The size and frequency of recent winter peaks in mortality, determined by the intensity and dominant type of influenza circulating, flu vaccine uptake and effectiveness, and which is sometimes exacerbated by cold weather, has contributed to the fluctuations in the annual age-standardised rates and the slowdown in improvement*" (PHE, 2018a: p.5).

The King's Fund in commenting on the Report also gave prominence to the role of influenza in the stalling of mortality improvement: "*Public Health England's report is a welcome, if somewhat overdue, start to understanding why life expectancy is stalling in England. It paints a complex picture but confirms that a slowdown in improvements in mortality from heart disease and an increase in winter deaths from flu and other respiratory diseases are significant factors.*" [57]

Given the emphasis to influenza as a factor on recent mortality trends, and the fact that any responses to this slowdown will need insight into causes in order to formulate appropriate policy responses, we will consider trends in EWD and the 2015 spike in particular since this event has been prominent in setting the agenda for discussion of mortality improvement stalling. While the winter of 2017-18 has attracted considerable initial attention based on deaths counts in early 2018, but later more relevant data suggest that 2018 was less extreme than suggested, indeed it turned out to have the second-lowest ever SDR value in England and Wales. In any case, the winter of 2017-18 does not have any relevance to the change in trend that was identified as occurring around 2011.
The following sections will therefore examine three closely-related areas: (a) the contribution of winter excess to overall mortality trends, (b) links between seasonal influenza and winter excess mortality, and (c) the contribution of the 2015 "spike" to stalling of mortality improvement in the UK since 2011.

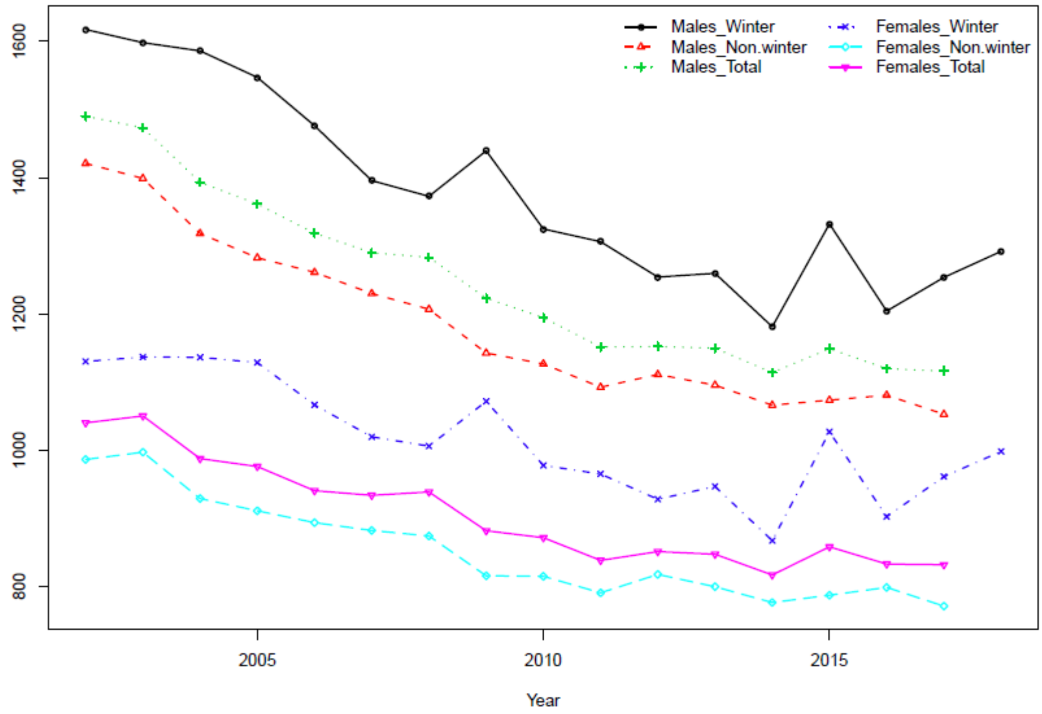
Trends in winter non-winter mortality

Using data of Figure 5J in PHE (2018a), Figure 22 shows trends in SDRs by sex in England separately for winter months (December to March inclusive) and non-winter months (April to October inclusive, measured as average of the two 4-month periods surrounding the winter period) from 2002 to August-October 2017 and April-July 2018 and therefore including the periods 2006-11 and 2011-16 which have been of the greatest interest. While not without criticisms (Hajat and

[57] For full text, see: https://www.kingsfund.org.uk/press/press-releases/kings-fund-response-phe-life-expectancy

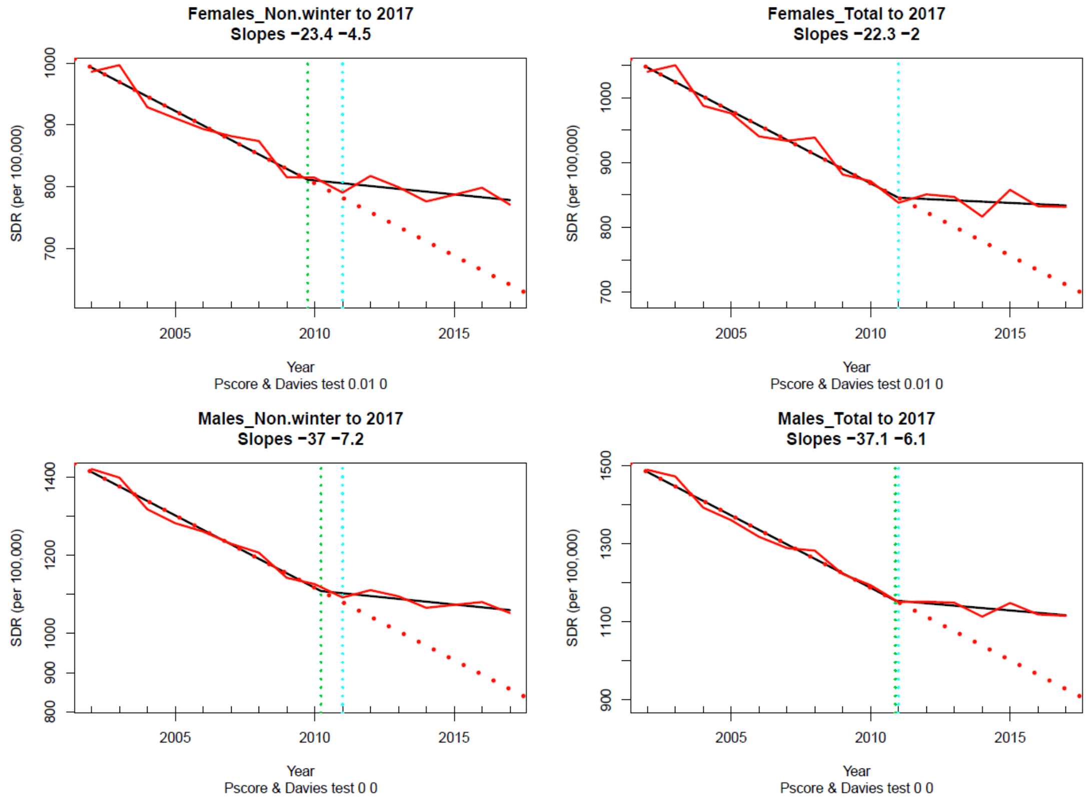
Gasparrini, 2016), the contribution of winter excess mortality has been central to recent discussion about mortality trends. Non-winter months do not include excess winter deaths and therefore provide trend estimates net of such effects. The underlying trend is much clearer when winter values are excluded, and this allows the question of the extent to which winter excess mortality has been a factor in the recent downturn in mortality improvement in the UK to be addressed.

Figure 22 Total SDRs, winter and non-winter months, England 2002-2017



Source: based on PHE (2018a)

Figure 23 Changepoint analysis for total SDR and non-winter month SDR, England



Source: based on PHE (2018a)

Figure 22 shows that, as expected, mortality in winter months is more volatile than in other months, but this period accounts for a minority of deaths. The non-winter month levels are lower than the overall ones, but the underlying trend appears to be very similar. The possibility of spill-over effects needs to be considered. This may include the fact that some winter events such as a seasonal flu epidemic may have a flatter distribution and still be observable outside the conventional December to March inclusive period used to define winter excess, leading to a continuing number of excess deaths in the subsequent non-winter months. Another possible mechanism is scarring – those affected in the winter period may remain more vulnerable and more likely subsequently to die from unrelated causes. Alternatively, there is the opposite effect of “harvesting”, whereby the most vulnerable who might have survived in a more benign winter but would have died shortly afterwards, died in winter so deaths in the following period would be reduced. Evidence on this is inconclusive – a recent study by Rehill et al. (2015) concluded that there were neither detectable positive nor negative effects on subsequent number of deaths.

Figure 23 shows results from a changepoint analysis for total SDR and non-winter SDR, a method to identify whether a time series may be usefully modelled as a series of piecewise continuous linear terms and, in particular, to identify the optimal location of these discontinuities in trend (the winter months series could not be adequately fitted by such a model). The changepoint for the non-winter SDR is slightly earlier for both males and females than for the total SDR, but all are located around 2011[58]. To maximise comparability, we also present the estimated coefficient values for the separate linear trends for the series with a breakpoint at 2011. These coefficients are very similar for both males and females in each period, allowing for the fact that SDR values are larger for males than for females. Differences in slopes before and after 2011 are typically about 30 per 100,000 for males and 20 per 100,000 for females, although the percentage values are similar, around 2.5 to 3% per annum (Table 6). In particular, since trends in total and non-winter mortality are so similar, there is no evidence that winter seasonal effects on underlying trends are likely to be substantial. Since seasonal flu is heavily concentrated in the winter months, non-winter period can be treated as largely unaffected by seasonal flu or related epidemics. We therefore conclude that seasonal influenza has had a minor effect on the stalling of mortality improvement in the period since 2011.

Table 6 Slope coefficients of change point analysis for total SDR (per 100,000) and non-winter month SDR (per 100,000), England

	All years	to 2011	2011+
Males Non-winter	-24.1	-36.4	-7.2
Males Total	-25.6	-37.1	-6.1
Females Non-winter	-14.4	-22.6	-3.9
Females Total	-15.0	-22.5	-1.6

While these results suggest that EWD over the whole period is unlikely to provide an explanation for the recent slowdown in mortality improvement. However, the 2015 “spike” has been central to much of the debate about the causes we now consider this topic explicitly.

The 2015 “spike”

The interpretation of the sharp increase in annual deaths between 2014 and 2015 became controversial, and in some cases acrimonious. The discussion was underpinned by the headline fact that the increase in deaths between these two years produced the largest recorded percentage change for half a century.

A large increase could occur for various reasons: For example, a particularly low value in the first year followed by an average value in the subsequent year, or an average first year value followed by a particularly high second year value, or by a low value, but not exceptionally so, followed by an above average value in the following year.

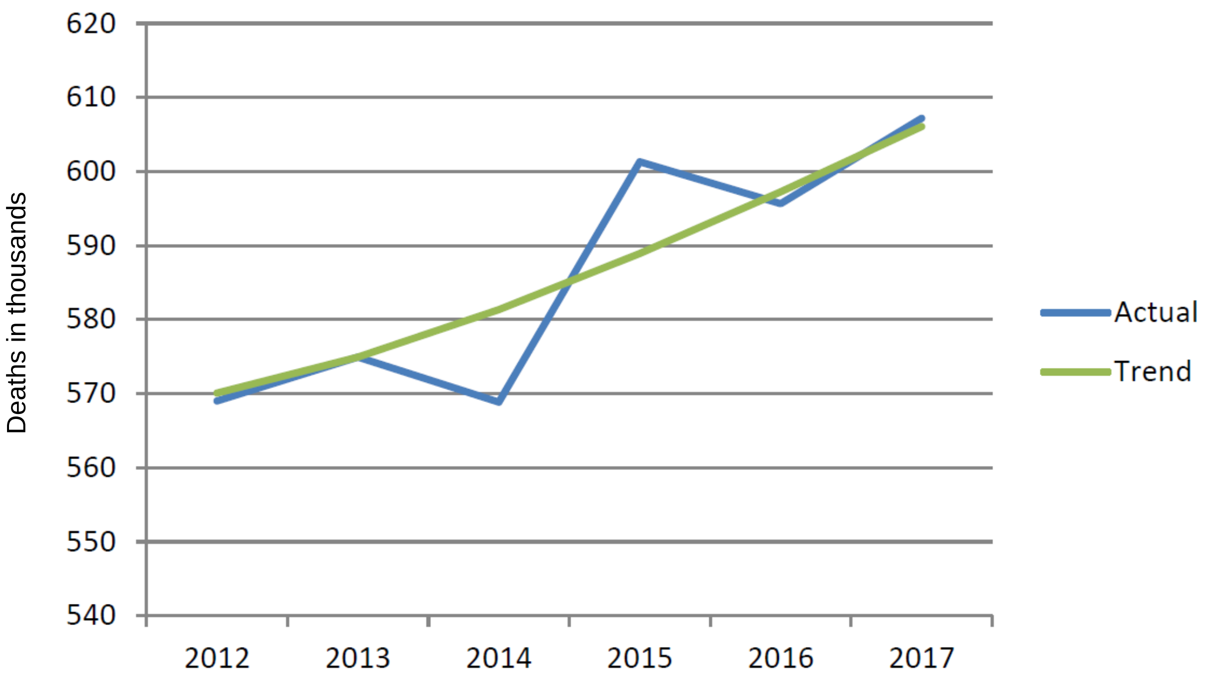
Figure 24 shows annual values in the period around 2015, together with a smoothed trend[59]. Data

[58] The same is true for annual life expectancy series, but seasonal values are not available for this measure.

[59] Alternative trend estimates can be estimated. These are based on a cubic spline fitting, but the results are unaffected by an alternative such as the simpler 5-point moving average used by PHE.

on the increase of 32 thousand UK deaths between 2014 and 2015 are shown in Table 7. There are three components to this increase: the extent to which 2014 was low, the extent to which 2015 was high and the extent to which there was an underlying increase in deaths in that period as reflected by the change in trend, so even if there had been nothing unusual in either year, deaths would have increased anyway.

Figure 24 Annual deaths UK, actual and trend data, 2012-17



Sources: Eurostat, ONS (2018).

Table 7. Actual and trend annual deaths (000s), UK 2014 and 2015

Year	Actual	Difference from actual previous year	Trend	Difference from trend previous year	Actual-Trend
2014	568.84		581.34		-12.5
2015	601.27	32.43	588.9	7.56	12.37

The increase between 2014 and 2015 may be decomposed as

$$32.43 = 12.50 + 12.37 + 7.56$$

Therefore, the components of the 32 thousand change in deaths between 2014 and 2015 are as follows:

1. 13 thousand due to lower than expected value in 2014
2. 12 thousand due to higher than expected value in 2015
3. 8 thousand due to underlying increase in trend between 2014 and 2015.

The higher than expected number of deaths in 2015 was almost exactly matched by the lower number in 2014. The underlying trend increase was responsible for about 23% of the total change between 2014 and 2015, the low 2014 value for 39% and the high value in 2015 for 38%. Therefore, the excess in 2015, as measured by the extent to which the value in 2015 was greater than expected, is well under half of the 32 thousand figure (or sub-national corresponding values) usually quoted in discussion. The 2015 excess measured in this way was the largest since 2003[60], but it was by no means exceptional – larger numbers of such excess deaths had been observed in each of the previous six decades (and higher values expressed as a proportion of total deaths apart from the 1980s decade). The main difference in these other periods was that a "bad" year was not accompanied to the same extent by a preceding "good" year. In fact, the combined number of additional deaths in relation to expected numbers in 2014 and 2015 being close to zero was, as expected, lower than about half of such other adjacent pairs, 27 out of the 56 values between 1961 and 2017. Hence, the combined effect of 2014 and 2015 on overall trends in the period 2011-16 was negligible, and no other values in the period were unusual.[61]

There was an increase in UK deaths in early 2018 that also attracted attention, but more detailed information became available only when official the life expectancy estimates were published in late September 2019, therefore the recent period has had nothing to contribute to life expectancy trends to date[62] (see note in the Introduction for further discussion). If a similar analysis is undertaken using a more appropriate age-adjusted index of mortality, such as SDR or life expectancy at birth (Table 8), results are very similar, but 2015 is somewhat less striking – there were two years where the excess of actual value over trend in each of the 1990s and 2000s decades were greater than for winter 2014-15.

[60] This definition of excess mortality is close to the standard excess winter deaths definition and the EWM Index produced by ONS that also compare winter values with surrounding values, in this case adjacent non-winter mortality values rather than a trend estimated over a longer period.
[61] For annual fluctuations to have an impact on underlying trends since 2011, the values would have to be larger than in the years before 2011. This will be discussed in a later section, the focus here is on the interpretation of change data.
[62] France has already produced provisional life expectancy estimated for 2018 (INSEE, 2019. Available at: https://www.insee.fr/en/metadonnees/source/serie/s1169). As for the UK, it shows mortality in that year was the second-lightest ever.

Table 8 Actual and trend annual SDRs (per 100,000), UK 2014 and 2015

Year	Actual	Difference from actual previous year	Trend	Difference from trend previous year	Actual-Trend
2014	989.9		1010.7		-20.8
2015	1026.5	36.6	1006.2	-4.5	20.3

As with births, the SDR change may be expressed as:

$$36.6 = 20.8 + 20.3 - 4.5$$ [63]

The conclusions are the same as for deaths shown earlier. The main difference is that the trend change due to falling underlying mortality rates in the period was negative whereas the trend in deaths was positive since increasing population size and changing population structure were more than sufficient to offset the fact that the underlying mortality trend was improving at that time, emphasising the potential problems of using death counts to elucidate trends in mortality rates. About one quarter of the observed change in deaths between 2014 and 2015 was inflation due to such structural changes unrelated to mortality change. Since deaths were decreasing for most of the previous 50 years, trend changes would have deflated year-to-year changes in earlier periods.

The use of annual change data in numbers of deaths for identifying excess mortality can be misleading, and it is unlikely that there would have been as much attention to values in 2015 if the excess was presented as 12 thousand rather than as 32 thousand. A similar pattern of low 2014 followed by high 2015 values was widespread and a consequence was that estimated total life expectancy at birth was lower in 2015 than in 2014 in 10 of the 15 countries shown in Table 3 (9 for males and 13 for females). The potential pitfalls in use of change data are broader than presentation. For example, Figure 5K of the PHE report (2018a) presented autocorrelation for year-on-year percentage change in the age-standardised rate between years 1972 and 2017 in England. The correlation between successive values was –0.45, i.e. a large percentage change in one direction is more likely to be followed by a smaller change in the same direction or a change in the opposite direction. This was interpreted as an indication that older vulnerable people survived 2014 and there were therefore a greater number at risk of dying in 2015 (PHE, 2018a, p. 60). However, the use of differenced data induces a negative correlation between successive values. This may be illustrated by the example of a series **x** of independent (i.e. uncorrelated) identically distributed values. For simplicity of presentation, assume the series has mean zero and variance one, although the results hold more generally.

[63] Note that the difference here is due to rounding.

The correlation between adjacent differenced values is:

$$cor\{(x_t - x_{t-1}), (x_{t+1} - x_t)\} = cov\{(x_t - x_{t-1}), (x_{t+1} - x_t)\}/\{var(x_t - x_{t-1})*var(x_{t+1} - x_t)\}$$

since

$$cov(x_t, x_{t-1}) = 0 \text{ and } var(x_t) = 1, cor\{(x_t - x_{t-1}), (x_{t+1} - x_t)\} = -0.5.$$

The observed autocorrelation of -0.45 is therefore close to what would be expected if the annual values were independent, i.e. if the excess value in a given year has no impact on the next year's value. This is consistent with the lag 1 autocorrelation of a non-statistically significant value of 0.11 for the England and Wales Excess Winter Mortality Index (EWMI) values in the same period, which are based solely on values in a single year.

The conclusion is that although the percentage increase in deaths between 2014 and 2015 was exceptional, the largest for 50 years, mortality levels in 2015 could be better-described as unusually large, with an expected level of mortality of a magnitude that might be expected every 10 years or so. Raw death counts are a very poor indicator for measuring mortality levels – even more so than crude death rates that control additionally for overall population size.[64]
The exceptional nature of 2014-15 winter deaths has been over-stressed and to that extent, it appears to have distorted the debate about mortality trends especially since there were a large number of in-depth analyses of this specific period in comparison to the number of studies concerned with longer-term trends.

However, since 2014-15 "spike" has become so entwined with the role of influenza in recent mortality trends, we now review this area.

Flu related deaths and Excess Winter Mortality

Estimates of deaths associated with influenza are available from various sources (PHE, 2018a, EuroMOMO, n.d.). The basis on which they are made and magnitude of these estimates varies substantially. A recent worldwide study published in the Lancet (Iuliano et al. 2018) estimated between 291 to 645 thousand influenza-associated respiratory deaths globally. Another model from the Institute of Health Metrics and Evaluation (IHME) estimated between 55 and 122 thousand global deaths (Dawood et al. 2012).

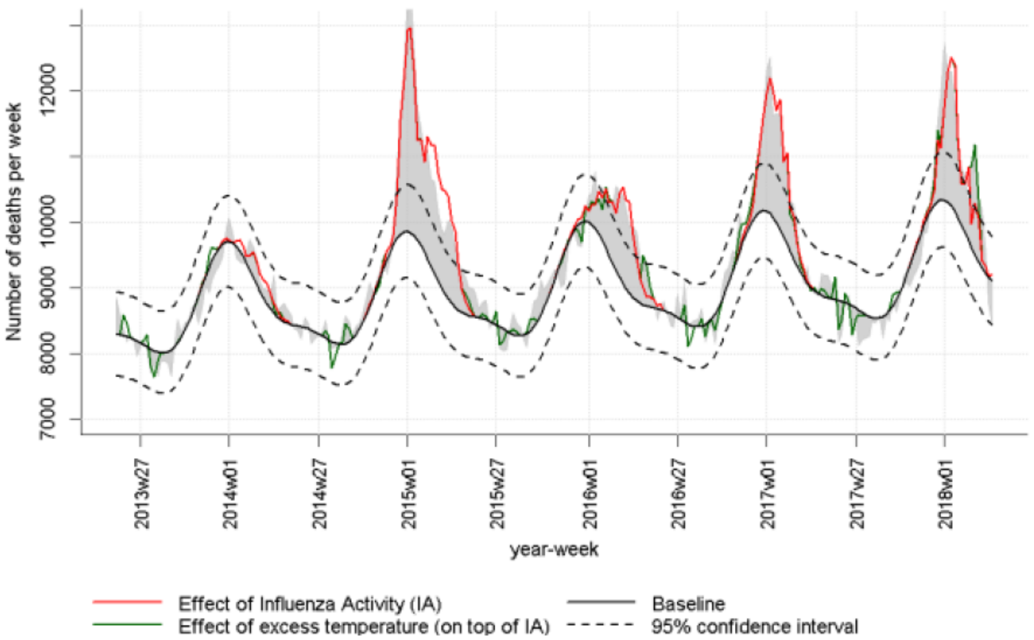
The difficulty of interpretation of cause of death data is discussed in Section 1.2.3. UK analyses usually use estimates that start from 2009 produced by the EuroMOMO network, although estimates of flu-related deaths are only available from winter 2012-13 based on their FluMOMO model[65]. Figure 25 shows a chart of these values[66] (the data which are used for these charts are not publicly available

[64] The Institute of Actuaries have recently started to publish age-standardised weekly mortality rates that provide a better basis for such analysis. (https://www.actuaries.org.uk/learn-and-develop/continuous-mortality-investigation/other-cmi-outputs/mortality-monitor).
[65] For more, see: http://www.euromomo.eu/methods/flumomo.html
[66] Data are the same as those used in Figure 5F of PHE (2018a)

and therefore following discussion is based mainly on visual interpretation of such charts). The FluMOMO model is based on three macrolevel time series. The first is simply weekly recorded deaths by age-group, which is regressed on a series of is ILI (influenza like illness) consultations with GPs, and an indicator of weekly "extreme" temperature. The approach is a standard time series one which assumes that there is a baseline value, which gives the contribution of all factors other than seasonal influenza (with ILI consultations as a proxy) and extreme temperature on number of deaths. This baseline is specified as the sum of two sinusoidal terms, one with period of one year and six months together will an allowance for the gradual trend in increasing numbers.

Figure 25 shows that the estimated number of influenza-related deaths in the period shown is essentially the difference between the observed values and the almost constant baseline estimates (or alternatively between values for a given year and that for winter 2013-14, when the number of flu-related deaths was estimated to be close to zero). The contributions of extreme temperature - confined to a small number of mainly non-winter months - and of the residual category are trivial compared with the deaths allocated to influenza. As expected, there is a close correspondence between Excess Winter Deaths (EWD and estimated flu-related deaths, as shown by the correlation matrix for the small number of years for which full values are available taken from Figure 5G of the 2018 PHE Report (PHE, 2018a, Table 9).

Figure 25 Deaths attributed to influenza



Source: PHE (2018a).

Since the only explanatory variable included in the FluMOMO model is an indicator of influenza activity (apart from the minor contribution from the extreme temperature indicator), all explained deaths will be associated with that variable, even though, for example, other studies that have also included variables such as temperature have found it to have a strong independent contribution even when indicators of influenza are also included (e.g. Hajat and Gasparrini, 2016). The number of flu-related deaths is defined simply as the model result, essentially the EWD figure less a fixed number of seasonal deaths. In this case, the model defines the outcome, rather than the usual situation where an *a priori* definition of the outcome variable defines the model. One point to note is that such estimates have no meaning at the individual level, but only the population level and are not comparable to estimates of cause-specific mortality that are based on individual-level assessments of cause or sometimes multiple causes.

Table 9 also shows very high correlations between flu-related deaths/EWD and flu vaccine effectiveness in period 2013-17 in England (although for reasons noted above, the model is constructed to maximise the number of deaths that will be attributed to flu, flu effectiveness is measured independently) strongly suggesting that they are closely related. However, it should be emphasised that only four full years of flu-related mortality estimates are available. There are some estimates from other sources for earlier years, for example, in Pebody et al (2017) but they are based not on ILI consultations, but laboratory sample tests for flu, so the estimates are not comparable.

For this period which covers that of the main interest for this study, EWD explains 93% of the variance in estimated flu deaths (or *vice versa*). Therefore, in practice, they can be used as proxies for each other (a simple approximation is that the baseline values account for about 15,000 additional deaths in winter as compared to other parts of the year with any deaths above this number allocated to influenza); alternatively, the difference between 2013/14 and other winter periods is very close to the number of modelled flu deaths.

Table 9. Correlation matrix of flu indicators, England 2013-17

	Excess winter deaths	FluMOMO deaths	Mean winter temperature.	Flu vaccine uptake 65+*	Flu vaccine uptake under 65 at risk*	Vaccine effectiveness*
Excess winter deaths	1	0.96	-0.86	-0.15	-0.03	-0.99
FluMOMO deaths	**0.96**	1	-0.9	-0.05	-0.11	-0.93
Mean winter temperature.	**-0.86**	**-0.9**	1	-0.36	-0.32	0.79
Flu vaccine uptake 65+	-0.15	-0.05	-0.36	1	0.79	0.27
Flu vaccine uptake under 65 at risk	-0.03	-0.11	-0.32	**0.79**	1	0.1
Vaccine effectiveness	**-0.99**	**-0.93**	**0.79**	0.27	0.1	1

Note: *UK values

Based on mortality from 15 European countries participating in the EuroMOMO network, around 217,000 additional premature deaths among people aged 65 occurred during the 2014/15 winter season in the European Union if similar excess mortality rates held across the EU (EuroMOMO, n.d.). The all-cause mortality model uses a different baseline from that shown in Figure 3, but the FluMOMO model produces a figure of about 180,000 additional flu-related deaths among those aged 65 and over in EU[67]. This figure may be compared with the global figure of approximately 500,000 deaths produced by Iuliano et al. (2018), even though older people in the EU accounted for just over 1% of the global population and flu levels in Europe were estimated to be lower than most other parts of the World. FluMOMO model flu-related mortality rates are also much greater than the estimate for the U.S. produced by the Centers for Disease Control of 45 thousand deaths among those aged 65 and over (51 thousand in total) in winter 2014-15, with an older population about half the size of that of the EU[68].

There is considerable scope for variation in estimates of flu-related deaths; indeed, the definition of flu-related deaths is unclear and is often defined by the model. The basis of deaths associated with influenza is very different from conventional cause of death analyses. The latter are based on an assessment of the cause of each individual death, sometimes including tests or otherwise as determined by, for example, a physician's experience of the decedent. The UK published flu-related deaths figures do not relate to individuals but are essentially residuals in a model that subtracts the total number of deaths from the assumption that there is an almost constant pattern both within and across years in all mortality apart from flu-related mortality, which is assumed to be responsible for virtually all variation.[69]

Given the uncertainties involved, it might appear surprising that the EuroMOMO model produced estimates of high precision – see, for example, the estimated values for adults 15-64 in 2017/18 in Table 10.

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[67] For more, see: http://www.euromomo.eu/methods/pdf/winter_season_summary_2015_16.pdf
[68] For more, see: https://www.cdc.gov/flu/about/burden/index.html
[69] Note that even if it was demonstrated that there were deaths associated with influenza, the impact may be less than the estimated numbers appear to show. If this effect were to advance a death that would have otherwise occurred later in the year, then there would be no difference in number of annual deaths and only a very small effect on population denominator (indeed none at all in the death would have occurred before mid-year since the denominator is the mid-year population).

Table 10 Number of deaths associated with influenza observed through the FluMOMO algorithm with confidence intervals, England, 2013 to 2014 season to 2017 to 2018 (up to week 15)

	All ages	0-4 years	5-14 years	15-64 years	65+ years
2013/14	3,107 (2,706 to 3,526)	55 (41 to 70)	11 (5 to 18)	438 (366 to 515)	400 (224 to 607)
2014/15	34,300 (33,362 to 35,247)	128 (110 to 147)	14 (14 to 14)	2,013 (1,888 to 2,139)	27,014 (26,184 to 27,853)
2015/16	14,357 (13,588 to 15,141)	112 (92 to 133)	10 (4 to 19)	2,221 (2,073 to 2,372)	9,618 (8,993 to 10,256)
2016/17	17,592 (16,825 to 18,370)	64 (50 to 80)	15 (8 to 23)	1,069 (966 to 1,176)	13,486 (12,820 to 14,164)
2017/18*	15,969 (15,125 to 16,828)	6 (6 to 6)	1 (1 to 1)	1,112 (1,112 to 1,112)	15,004 (14,215 to 15,807)

Source: Number of deaths associated with influenza observed through the FluMOMO algorithm with confidence intervals, England, 2013 to 2014 season to 2017 to 2018 (up to week 15)

However, such estimates must be treated with caution. There are two sources of error in models, parameter uncertainty, which is determined by the accuracy with which the model parameters are estimated. Simple models using very large sample sizes can estimate a small number of parameters accurately and these are the precision estimates usually quoted. However, there is also model uncertainty – the fact that the estimates may be incorrect because the model is inappropriate and/or incomplete. The wide range of alternative estimates of flu-related deaths from different studies emphasises that model uncertainty is substantial and that estimates that do not allow for this should be treated with caution (Cairns, 2000).

The almost entire allocation of variation in winter deaths to influenza is in contrast to other studies which have emphasised other factors, in particular, that temperature has a substantial impact. There is a large correlation between EWD and annual mean temperature in Table 9, and other studies have identified fuel poverty and temperature as a major factor in excess winter deaths (Hills, 2012; Hajat and Gasparrini, 2016). While comparable estimates of flu-related deaths are not available for earlier periods, it seems plausible that these will also be closely related to EWD. If this is not the case, then since flu could only have a contribution to stalling if the number of additional deaths in the period since 2011 was substantially greater than the number in the preceding period, lack of evidence would preclude any useful conclusions being drawn.

The apparent close association between EWD and influenza has meant that competing explanations have received little attention in recent years. The policy responses to, for example, fuel poverty would need to be more expensive, political-charged (since closely-related to socio-economic disadvantage) and wide-ranging than to influenza. However, before leaving this area, the implicit assumption underpinning much of the discussion about the role of EWD on the slowdown in mortality improvement will be examined.

Estimation of time trends

The discussion of the role of flu on recent trends has largely ignored earlier years – while attention may be drawn to "bad" years such as 2015 and 2012, where EWD is higher than surrounding years, there were also years with low values, indeed winter 2013-14 was the lowest ever recorded as noted above. EWD can be important for trends after 2011 only if it can be shown that the effect is sufficiently larger than in earlier periods. Table 11 shows decadal averages of the two indicators of EWD over time. The mean values in period 2011-16 are slightly lower than in 2001-10 for both the Excess Winter Mortality Index and for excess winter deaths. Inclusion of the latest two years gives values that are somewhat greater than the first decade of the 21st century, but substantially lower than in earlier periods[70]. In fact, the early 2000s stand out as the anomaly, with much lower variability than in earlier or later periods. Circulation of particular strains may have had some influence – A(H3N2) is known to have substantial effects on mortality especially for older people. However, the number of additional excess deaths in the recent period as compared with the preceding periods is clearly insufficient to make a substantial contribution to the trends shown in Figure 22.

Table 11 Excess Winter Mortality index and Excess Winter Deaths, United Kingdom 1963-2018

	Excess winter Mortality index (%)		Excess winter deaths (thousands)	
Period	Mean	Standard deviation	Mean	Standard deviation
1961-70	32.3	8.4	61,649	16,096
1971-80	22.1	5.1	45,496	10,367
1981-90	20.6	5.6	42,045	11,404
1991-2000	19.7	6.3	38,948	11,710
2001-10	15.7	3.5	28,999	5,743
2011-16	15.3	5.4	27,907	10,022
2011-18	16.9	5.6	31,348	10,856

In addition, the trend of Figure 6 shows a clear incremental deviation from the trend in the earlier period since 2011, therefore the mechanism involved has to be one that would lead to a reduction in improvement of about 30 per 100,000 for males in the first year as compared with the previous trend[71], then a reduction of about 60 per 100,000 in the second year and by around 150 per 100,000

[70] Since most of the discussion has centred on comparison of periods 2006-10 and 2011-16 periods; we note that 2006-10 values (not shown) were higher than those for 2011-16 on both measures. These data are based on date of registration rather than occurrence since occurrence data are not available for UK. England and Wales data based on occurrences provide similar conclusions.
[71] The difference in the slopes in Figure 23 – the corresponding figure for females is about 20 per 100,000, but similar comments apply to women as to men

after 5 years (or a difference of about 14% by 2016).[72] If EWD were to have a substantial role in explaining the slowdown in mortality improvement, the differentials between winter and non-winter months would need to very large and there is no evidence for this happening. In addition, the fact that influenza epidemics occur intermittently, and the lethality of strain and vaccine effectiveness vary, the pattern of regular divergence in underlying trends from earlier patterns shown in Figure 23 would seem to require a mechanism that is continuing and predictable rather than occasional and random.

Conclusions

Sound policy decisions require good information, with a correlation of –0.99 between flu vaccine effectiveness and excess winter deaths, and if excess winter deaths were to be a major component of the stalling of mortality improvement, there would be a strong case for concentrating on this area. While, we do not find a strong case for a substantial contribution of influenza to the downturn in mortality improvement between the periods just before 2011 to those just after 2011, this does not detract from the need to Improving flu vaccine effectiveness and coverage and to. maintain and improve the current system of surveillance for influenza and other chronic diseases. The Chief Medical Officer, Professor Dame Sally Davies said[73]:

> “Getting the flu vaccine is the single best way to protect yourself against this potentially fatal illness … a newly available vaccine that is more effective will be offered to over-65s. This could prevent hundreds of deaths”.

[72] This approach implicitly assumes that the previous period provides a benchmark against which to assess current trends and in this case to find them wanting. If the previous period was particularly good due to one-off factors, the apparent deterioration could be over-emphasised, but clearly current rates of mortality improvement are very low in comparison with those not only of the early 2000s, but of earlier decades as well.

[73] See: https://www.gov.uk/government/news/new-flu-vaccine-available-this-winter-for-those-aged-65-and-over

Appendix II - Survey among European Statistical Offices about the knowledge of the mortality crisis of 2015 (September 2018)

Introduction

The “mortality crisis” of the year 2015, in particular the increase of the observed number of deaths compared to the expected values and the decrease in life expectancy at birth, has attracted attention in the scientific literature and in the non-scientific press. Albeit the crisis occurred in many populations, most of the existing knowledge refers to a small number of countries, and wider international overviews are comparatively rare (see Section I of this report).

To gain further insights into the possible causes of the unexpected decrease in life expectancy, we carried out an investigation among the European Statistical Offices about their interpretation of recent mortality trends in September/October 2018. Another purpose of the survey was to examine the general awareness of the statistical offices of the existence of the 2015 mortality crisis. This Appendix to our report describes the process of collecting the information and summarizes the main results from this investigation.

Step 1: Background information on life expectancy in European countries in 2014-2016

Our reference data was information about life expectancy at birth by year and sex published by Eurostat for all states which are member or candidate countries of EU or EFTA countries (Iceland, Liechtenstein, Norway and Switzerland[74]). Table 12 summarises this data for the years 2014-2016. Out of the 38 countries included in this table, six (Bulgaria, Estonia, Latvia, Romania, Norway and Turkey, highlighted in grey in the table) did not show a decrease in life expectancy at birth between 2014 and 2015. For some of the other countries, the decline occurred only among women (Denmark, Ireland, Luxembourg, Liechtenstein, Montenegro, North Macedonia) or among women and the total population, but not among men (Lithuania, Hungary, Sweden, Serbia). Some countries experienced a decrease in life expectancy one year later between 2015 and 2016 (Finland, for men and for the total population, Turkey, only for the total population) or one year earlier between 2013 and 2014 (Latvia, data not shown).

Step 2: Getting in touch with the National Statistical Offices

We selected the countries of Table 12 in which life expectancy at birth declined at some point during the period 2014-2017. A total of 32 countries was included in the survey of the national statistical offices about the mortality crisis of 2015. We prepared a standard text which was sent to the contact points of the statistical offices via email or via a contact form provided on the respective website (see Box 1). After a short introduction to the topic of the mortality crisis in 2015, three specific questions were asked:

1. Do you have any explanation for the decrease in life expectancy in your country?
2. Do you know anyone who is studying the increase in mortality in your country?

[74] See also: https://www.efta.int/

3. Do you know any publication(s) (in whatever language) about the decrease in life expectancy in your country, and if so, could you please give us corresponding references or web links?

The contact information of the national statistical offices was taken from https://ec.europa.eu/eurostat/web/links and the contact process was realized in September 2018.

Step 3: Collection of answers

The answers of the statistical offices are summarised in Table 14. We did not receive any answer from Luxembourg, Malta, and Iceland. The United Kingdom forwarded the email to a specialised unit. The quality of the answers depended strongly on the legal and scientific status of the statistical offices. Some of them are also concerned with research issues, whereas others are only collecting data. Some of the statistical offices answered explicitly that they do not perform any kind of elaboration on the data they collect (Spain, Cyprus, Albania).

A total of 17 statistical offices provided us an explicit answer about possible causes for the decrease in life expectancy. From the inspection of the answers provided, it is evident that not all statistical offices were aware of the 2015 mortality crisis at the European level. Moreover, some countries (Denmark, Croatia, Slovenia and Liechtenstein) explicitly declared that they have no explanation for the decrease in life expectancy in 2015 and redirected us to more specialized research units.

Following previous work (from ISTAT, Italy) we divided the explanations in three broad groups: explanations related to meteorological issues, to non-meteorological issues and to the composition of the population at risk of dying.

1) Meteorological issues: Some offices gave as a possible explanation the existence of a very hard winter in 2015 (France, Italy and the Netherlands), in some cases together with heat waves in the summer of 2015 (Czech Republic, Italy, Hungary, Austria, Switzerland and Serbia).
2) Non-meteorological issues: The influenza epidemic was suggested as a possible cause by approximately half of the countries (Denmark, Italy, Hungary, the Netherlands, Austria, Sweden, Switzerland and Serbia). According to the offices of the Czech Republic and Hungary, the increase in the number of deaths from respiratory and circulatory diseases was attributable directly to the influenza epidemic. When the age pattern in mortality was mentioned, it was referring to a mortality increase in the old ages in general (Italy, Austria, Sweden, Switzerland), or to older women in particular (Hungary and Slovakia). A small mortality crisis among young people (age 18-35) was mentioned by Sweden, probably due to the abuse of drugs and alcohol. The end of the decreasing trend in smoking prevalence was also mentioned as a concomitant factor by Sweden.
3) Composition of the population at risk of dying: The only country that suggested a possible cohort effect is Italy. The explanation would be that, due to the natality crisis during the first world war and the subsequent recuperation of births, the number of people at ages 95+ in

> the year 2015 increased, therefore causing an increasing number of deaths in the highest age group. However, this was only one of the possible causes suggested by Italy. A number of countries (Czech Republic, Germany, France, Italy, Hungary and Serbia) gave as explanation the existence of a "compensation of deaths between adjacent years", or also of the "harvesting effect", after the observation that there is no decline in life expectancy if it is computed as average of 3 years (what is actually done routinely in Germany and Portugal). Actually, most countries of this group recognized that 2014 was a particularly favourable year for surviving, with a lower number of deaths than expected.

Among other possible answers provided it is to be noted that some countries excluded that the mortality crisis is the result of data artefacts (Germany and Austria, the latter referring to their statistical system). Several countries underlined that they see it as a temporary phenomenon (Portugal, Slovenia, Sweden, Liechtenstein and Serbia), and only the Netherlands referred to the economic crisis and new end-of-life regulations as a possible contributing cause.

Concluding remarks

The statistical offices of European countries suggested several possible factors that might have caused the mortality crisis, rather than one single explanation. Some statistical offices were neither aware of the mortality crisis itself, nor of its wide geographical appearance. Among the explanations provided, the most common ones were related to the weather conditions (winter peaks and heat waves), the aggressiveness of the influenza epidemics, and the changes in the composition of the population at risk, with a compensation of deaths from a very favourable year 2014 to a quite unfavourable year 2015.

Table 12 - Life expectancy at birth in 2014, 2015, 2016 by sex (total, men and women) and country

	Total			*Men*			*Women*		
Country	*2014*	*2015*	*2016*	*2014*	*2015*	*2016*	*2014*	*2015*	*2016*
EU (27 countries)	*80.9*	*80.6*	*81.0*	*78.1*	*77.9*	*78.2*	*83.6*	*83.3*	*83.6*
EU (before entry of Croatia)	*80.9*	*80.6*	*81.0*	*78.1*	*77.9*	*78.2*	*83.7*	*83.3*	*83.7*
EU (19 countries)	*82.0*	*81.6*	*82.0*	*79.2*	*78.9*	*79.3*	*84.7*	*84.2*	*84.6*
EU (18 countries)	*82.1*	*81.7*	*82.1*	*79.3*	*79.0*	*79.4*	*84.7*	*84.2*	*84.6*
Belgium	81.4	81.1	81.5	78.8	78.7	79.0	83.9	83.4	84.0
Bulgaria	74.5	74.7	74.9	71.1	71.2	71.3	78.0	78.2	78.5
Czech Republic	78.9	78.7	79.1	75.8	75.7	76.1	82.0	81.6	82.1
Denmark	80.7	80.8	80.9	78.7	78.8	79.0	82.8	82.7	82.8
Germany	81.2	80.7	81.0	78.7	78.3	78.6	83.6	83.1	83.5
Estonia	77.4	78.0	78.0	72.4	73.2	73.3	81.9	82.2	82.2
Ireland	81.4	81.5	81.8	79.3	79.6	79.9	83.5	83.4	83.6
Greece	81.5	81.1	81.5	78.8	78.5	78.9	84.1	83.7	84.0
Spain	83.3	83.0	83.5	80.4	80.1	80.5	86.2	85.7	86.3
France	82.8	82.4	82.7	79.5	79.2	79.5	86.0	85.6	85.7
Croatia	77.9	77.5	78.2	74.7	74.4	75.0	81.0	80.5	81.3
Italy	83.2	82.7	83.4	80.7	80.3	81.0	85.6	84.9	85.6
Cyprus	82.3	81.8	82.7	80.3	79.9	80.5	84.3	83.7	84.9
Latvia	74.5	74.8	74.9	69.1	69.7	69.8	79.4	79.5	79.6
Lithuania	74.7	74.6	74.9	69.2	69.2	69.5	80.1	79.7	80.1
Luxembourg	82.3	82.4	82.7	79.4	80.0	80.1	85.2	84.7	85.4
Hungary	76.0	75.7	76.2	72.3	72.3	72.6	79.4	79.0	79.7
Malta	82.1	82.0	82.6	79.9	79.8	80.6	84.3	84.1	84.4

	Total			*Men*			*Women*		
Country	*2014*	*2015*	*2016*	*2014*	*2015*	*2016*	*2014*	*2015*	*2016*
Netherlands	81.8	81.6	81.7	80.0	79.9	80.0	83.5	83.2	83.2
Austria	81.6	81.3	81.8	79.1	78.8	79.3	84.0	83.7	84.1
Poland	77.8	77.5	78.0	73.7	73.5	73.9	81.7	81.6	82.0
Portugal	81.3	81.3	81.3	78.0	78.1	78.1	84.4	84.3	84.3
Rumania	75.0	75.0	75.3	71.3	71.5	71.7	78.7	78.7	79.1
Slovenia	81.2	80.9	81.2	78.2	77.8	78.2	84.1	83.9	84.3
Slovakia	77.0	76.7	77.3	73.3	73.1	73.8	80.5	80.2	80.7
Finland	81.3	81.6	81.5	78.4	78.7	78.6	84.1	84.4	84.4
Sweden	82.3	82.2	82.4	80.4	80.4	80.6	84.2	84.1	84.1
United Kingdom	81.4	81.0	81.2	79.5	79.2	79.4	83.2	82.8	83.0
European Economic Area (EEA) (EU28 und IS, LI, NO)	*80.9*	*80.6*	*81.0*	*78.1*	*77.9*	*78.2*	*83.6*	*83.3*	*83.7*
European Economic Area (EEA) (EU27 und IS, LI, NO)	*80.9*	*80.6*	*81.0*	*78.1*	*77.9*	*78.3*	*83.7*	*83.3*	*83.7*
European Free Trade Association (EFTA)	*82.9*	*82.8*	*83.2*	*80.8*	*80.7*	*81.3*	*85.0*	*84.8*	*85.0*
Iceland	82.9	82.5	82.2	81.3	81.2	80.4	84.5	83.8	84.1
Liechtenstein	82.1	82.7	82.3	81.0	80.9	80.6	83.2	84.5	84.0
Norway	82.2	82.4	82.5	80.1	80.5	80.7	84.2	84.2	84.2
Switzerland	83.3	83.0	83.7	81.1	80.8	81.7	85.4	85.1	85.6
Montenegro	76.5	76.5	76.5	74.1	74.4	74.1	78.9	78.6	78.9
North Macedonia	75.5	75.5	75.4	73.5	73.5	73.4	77.5	77.4	77.5
Albania	78.2	77.9	78.5	76.3	76.2	77.0	80.2	79.7	80.1
Serbia	75.4	75.3	75.7	72.8	72.8	73.2	78.0	77.9	78.3
Turkey	78.1	78.2	78.1	75.4	75.4	75.4	80.9	81.0	81.0
Georgia	74.1	73.0	72.7	69.9	68.7	68.3	78.2	77.4	77.2

Source: Eurostat, downloaded 30.03.2018

Table 14 – Summary of answers provided by the National Statistical Offices about the possible causes of the mortality crisis of 2015

	Belgium	Bulgaria	Czech Republic	Denmark	Germany	Estonia	Ireland	Greece	Spain	France	Croatia	Italy	Cyprus	Latvia	Lithuania	Luxembourg	Hungary	Malta	Netherlands	Austria	Poland	Portugal	Rumania	Slovenia	Slovakia	Finland	Sweden	United Kingdom	Iceland	Liechtenstein	Norway	Switzerland	Montenegro	North Macedonia	Albania
Not contacted		X				X								X									X			X					X				
No answer																X		X										X	X				X		
Unavailability of recent data							X																												
No research on collected data								X	X				X																						X
Life tables calculated on a three-year-basis					X																	X													
Generic info provided										X			X		X						X													X	

LIST OF EXPLANATIONS CITED

	Belgium	Bulgaria	Czech Republic	Denmark	Germany	Estonia	Ireland	Greece	Spain	France	Croatia	Italy	Cyprus	Latvia	Lithuania	Luxembourg	Hungary	Malta	Netherlands	Austria	Poland	Portugal	Rumania	Slovenia	Slovakia	Finland	Sweden	United Kingdom	Iceland	Liechtenstein	Norway	Switzerland	Montenegro	North Macedonia	Albania
None				X							X													X						X					
	METEOROLOGICAL CONDITIONS																																		
Combination of winter peak and summer heat waves			X**									X					X			X												X			
Winter peak in 2015										X		X							X																
	NON-METEOROLOGICAL CONDITIONS																																		
Influenza epidemic				X*								X					X		X	X							X					X			
	Increase in mortality specific to age groups																																		
Young																											X								
Young men															X***																				
Old												X								X							X					X			
Old women																	X								X										
Specific diseases (respiratory diseases)			X														X																		
	POOL AT RISK OF DYING																																		
Cohort issues												X																							
Population ageing	X																																		
Compensation of deaths between			X		X					X		X					X																		

adjacent years or harvesting effect																																			
2014 named as a favourable year			X							X		X					X																		
	OTHER																																		
Excluding data artefacts or data quality problems					X															X															
Economic situation																			X																
Volatility of data /temporary phenomenon																						X			X		X			X					
Regional pattern																						X													

Box 1: Letter sent to the National Statistical

Dear […],

I am contacting you on behalf of Dr. Marc Luy, head of the research group on Health and Longevity at the Vienna Institute of Demography of the Austrian Academy of Sciences.

Our research is focusing on trends and determinants of mortality and life expectancy. There has been a surprising trend change around the year 2015 when almost every European population experienced a decrease in life expectancy. In some countries, this decline is evident only for men or only for women, but in most cases it is a general phenomenon. Until today, no fully satisfactory explanation has been found for this increase in mortality.

We would like to understand the causes for this changing trend in life expectancy and we would be extremely grateful for your support. Therefore, we would like to ask you to forward this email to the responsible department or colleague of your institute. It would be really a great help for us to learn to what extent this decrease in life expectancy has been debated in your country and, above all, whether your institute or anyone else has provided an explanation for this phenomenon or a hypothesis to explain it. In particular, we would have the following three questions:

1. Do you have any explanation for the decrease in life expectancy in your country?
2. Do you know anyone who is studying the increase in mortality in your country?
3. Do you know any publication(s) (in whatever language) about the decrease in life expectancy in your country, and if so, could you please give us corresponding references or web links?

We are aware that your time must be very limited for dealing with such inquiries. Any information you can send us – even a short reply – would be extremely helpful for our research.

Please feel free to get in touch with us for any kind of clarification or for any question you might have. Our contact details can be found below.

We are looking forward to hearing from you and we thank you very much for your support.
With kind regards,

[…]