RMS WHITE PAPER

LONGEVITY RISK:
SETTING THE LONG TERM MORTALITY IMPROVEMENT RATE

What Medical Science Tells Us About Future Longevity Risk

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1. EXECUTIVE SUMMARY

A significant source of uncertainty in determining annuity or pension liabilities is the projection of future mortality improvement. A common metric used in the U.K. to specify different projections is the 'Long Term Rate' (LTR) – part of a framework promulgated by the Continuous Mortality Investigation (CMI). The LTR is the ultimate rate of annual mortality improvement prevailing after 2030. In this report we focus on the mortality improvement of 80 year old males (a representative benchmark for improvement risk in defined benefit pensions).

The assumptions made about the LTR vary widely across different sectors of the industry and between different pension schemes. Commentators have suggested that the disparity in views of the LTR between sponsors, insurers and investors is hindering the growth of a larger market in longevity risk transfer and management.

For most of the 20th century, annual improvement rates (averaged over ten year periods) have oscillated within the range of -1% to 2% per year. However the past 20 years have seen mortality improvement rates increasing steadily, to a recent level of around 3% a year. The conventional view on LTR is that this level is unsustainable and mortality improvement rates will decline. Pension schemes consensus seems to be that the LTR will stabilize at or below 1.5%. Surveys suggest that 75% of pension schemes use a LTR of 1.5% or less.

A better conceptual model of mortality improvement might be that there is no stable 'LTR'. Instead, commensurate with historical experience, future mortality improvement can be expected in multiple phases driven by fundamental changes in social and economic conditions, together with major advances in medical science and public health care provision. Nevertheless, these can be equated to a view of LTR through the mortality improvement rate that is prevailing in twenty years' time.

This paper first examines the potential for trends in social conditions and medical progress to reduce annual improvement rates from 3% to below 1.5% within the next 20 years. A number of potential scenarios are explored:

Scenario 1: Current successes in reducing premature cardiovascular deaths will exhaust within this timeframe.

Scenario 2: Expected improvements in detecting and treating cancer cases will fail to materialize.

Scenario 3: Obesity levels accelerate.

We conclude that none of these scenarios alone provide a credible rationale for an LTR of 1.5%. In the absence of substantial evidence for declines in improvement it may be more natural to assume that recent trends will continue. We examine these implications:

Scenario 4: A 'Trend Neutral' assumption where recent momentum in lifestyle and medical advance is sustained. This results in an LTR around 2.0%.[1]

Scenario 5: Mortality improvements continue to accelerate, resulting in an LTR of around 4.5%.

The 2008/2009 economic crisis has reset some expectations for continuity of recent mortality trends. The U.K. NHS (NHS), which had seen annual funding increases averaging above 5% since 2002, will now have its budget frozen at a rate of zero growth until at least 2015. At the same time, changes in the economics of the pharmaceutical industry, exacerbated by economic austerity, are reducing investment in new medical research.

The potential impact of these changes on future mortality is explored in the following scenarios:

Scenario 6: Slower economic growth consistent with revised U.K. Bank of England median GDP forecasts results in an LTR of below 2.0%.

Scenario 7: Economic stagnation – U.K. GDP growth drops below 1% for more than a decade resulting in an LTR of 1.5%.

[1] Annual improvement rates in this scenario decline as the causes of death that are improving most rapidly become less prevalent.

The report goes on to set out a range of views of the future corresponding to various LTR values. Readers are encouraged to take their own view on what LTR is appropriate. This document aims to provide intuitive narrative and explanation to help contextualize this decision.

The current outlook for medical technology, health care infrastructure and social change ought to be pertinent factors in formulating a mortality projection. It may not be prudent to expect improvement rates in the 21st century to revert to levels seen in the late 19th and early to mid-20th century without considering how the world has changed in this time.

We hope this paper will demonstrate that "cause of improvement" modeling can help build consensus over what constitutes a realistic improvement projection.

2. MORTALITY IMPROVEMENT RATES AND LIABILITY

In order to estimate liability for a portfolio of annuitants, a projection of their future mortality rates is required. Although current mortality rates can typically be estimated directly from recent portfolio experience, extrapolating these rates appropriately forward in time is a considerable challenge.

Persistent downward trends in mortality have been observed over the past several decades but the extent to which these improvements will continue, accelerate or slow in the decades ahead is uncertain.

In addition to mortality improvement, interest rate and inflation risk also contribute significant uncertainty to pension liabilities. While affordable strategies have been developed for managing these risks, longevity risk remains as yet relatively more complicated to hedge and is a primary concern for pension trustees.

For clarity in this report we focus on the mortality improvement rate of an 80 year old male (the modal age of a typical in-payment defined benefit pension scheme) that prevails by the year 2032 in the England and Wales population. The twenty year outlook examined here is consistent with the duration periods of most importance to typical pension liabilities, derived from present values for discounted future payouts.

2.1. CMI Framework

The CMI, a research project of the U.K. Actuarial Profession, has pioneered a simple and widely adopted framework for constructing mortality rate forecasts.[2] The CMI framework can be used to explore the financial implications of various potential mortality improvement outcomes. The approach advocated by the CMI (as it relates to improvements over time in mortality at a fixed age):

- Measures the current temporal trend in general population mortality rates (e.g. male mortality in England and Wales is decreasing or increasing at a rate of 2-3% per annum depending on the age group).
- Analyzes the current rate of mortality improvement and how it might change in the future. For example, the mortality improvement rate in some areas has now reached 2-3% per annum. It is reasonable to consider that this cannot continue forever and that improvement rates may stabilize to a slower rate (e.g. 1.5%) in the future, possibly over the next 2 decades and remain there for the long term.

Figure 1 shows the recent historical data for an 80 year old male together with a range of projections using the CMI 2010 model for age-period effects only (i.e. birth cohort trends removed). The projections use the default settings of the model with a range of commonly-used long-term assumptions. These result in the assumption of a reversal of the current increasing trend of mortality improvement rates.

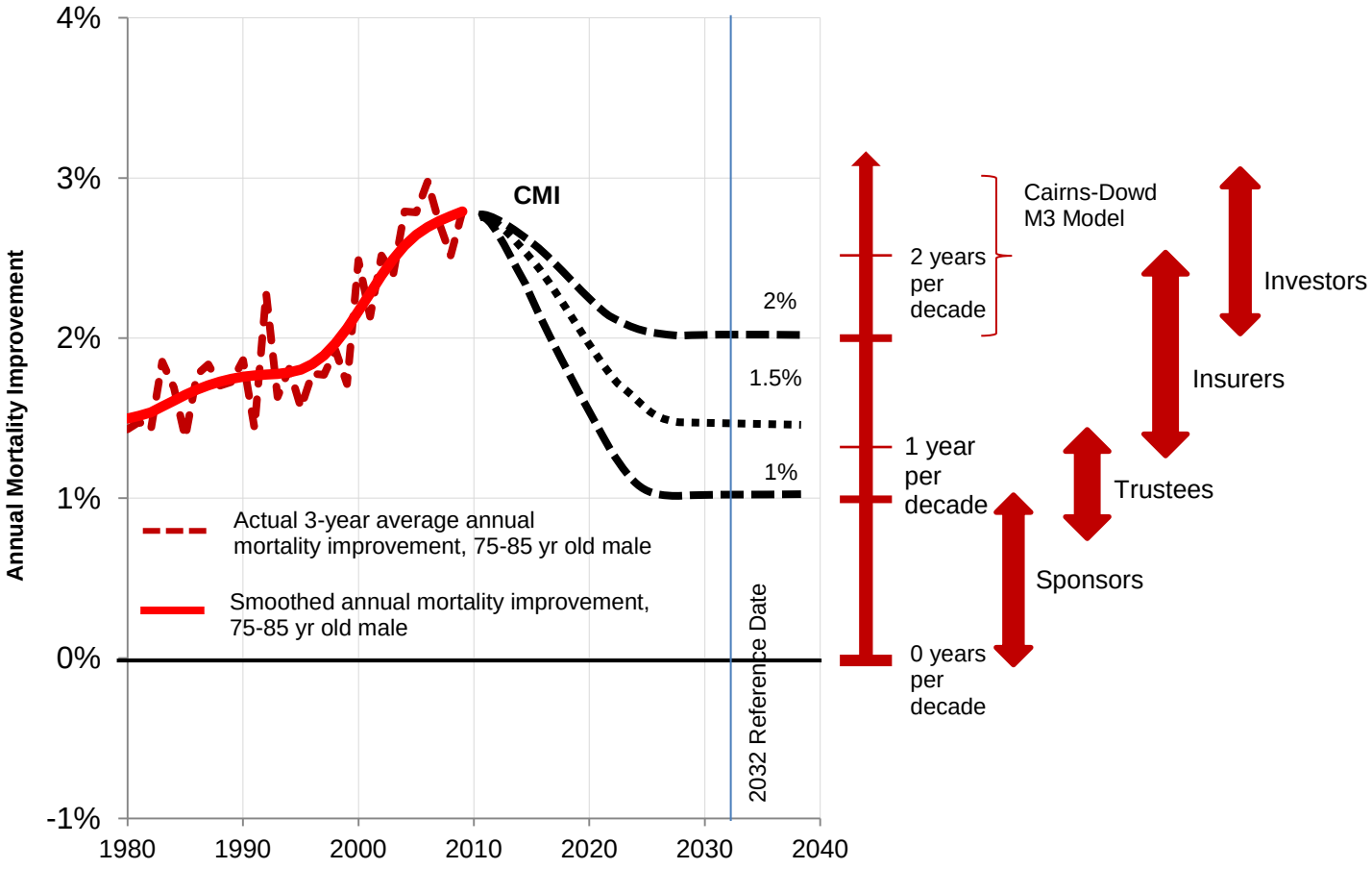
Mortality improvements vary by age, gender, and calendar year. Here we focus on a single measure: the mortality improvement for an 80 year-old male (representing a typical pension in payment) in 2032 (in 20 years' time), and we look only at the "age-period" mortality improvement, stripping out any cohort effect. Removing the cohort effect removes short-term fluctuations in improvements from one calendar year to the next. It also means that the rate at 2032 is equal to the CMI's LTR (LTR), which for an 80 year old is reached in the 40th year of projection in 2046, since the age-period component of the CMI model is assumed to reach the LTR within 20 years. Different assumptions about the shape of the decay will also have some differences in liability estimation, but the main focus of this study is in the key assumption of the magnitude of mortality improvement by 2032.

[2] CMI (2009) 'A prototype mortality projections model'

2.2. Current Views of LTR in the Market

The arrows to the right of figure 1 show the different perceived levels of pricing by different business interests in the market, derived from studies by pension actuaries working on de-risking strategies.[3] This disparity in perception of the likely future LTRs of mortality improvement between different sectors is cited as one of the key reasons for slow progress in the development of the longevity risk transfer market.

Figure 1: Projections of mortality improvement for an 80 year old male, assuming various long term rates of mortality improvement, without cohort effect.



The CMI 2010 modeling approach has set a framework for the pension fund industry's view of where the best estimate level for mortality rate might be. Many people have made the assumption similar to that reported in the Pension Protection Fund 2007 report[4] of 1.5% for males and 1% for females as a benchmark rate, and other similar proposals.[5]

In a survey of pension fund trends in 2010[6], KPMG reported that of the pension fund clients who use the CMI 2010 model, at least 75% use a LTR of 1.5% or less, 47% use 1.25% or less and 34% use 1% as their baseline risk. In fact KPMG reported that in 2010, the first year of publication of the CMI 2010 model, that a large majority of their

3 Baxter (2011) 'The science of ageing'

4 Pension Protection Fund, Annual Report (Oct 2007)

5 Institute of Actuaries Sessional Meeting Feb 2007. Proposal made for an underpin of 1.25% p.a. for males, 0.75% p.a. for females.

6 KPMG's Pensions Accounting Survey May 2011

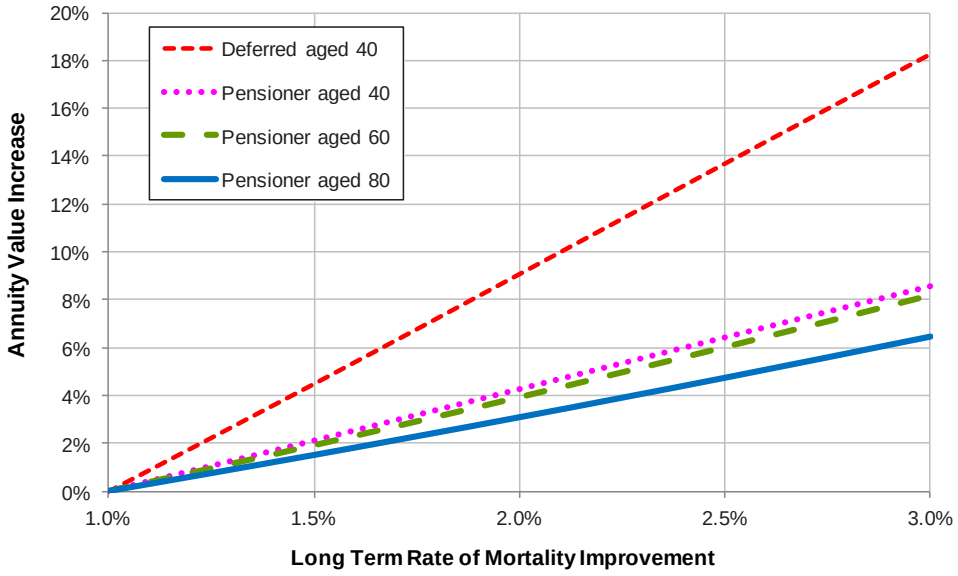
clients still use an earlier method of cohort projection, predominantly with an underpin of a LTR of 1% for both men and women.

2.3. Liability Implications of LTR Assumptions

Considering a higher LTR as the mortality projection assumption increases the expected liabilities for a pension fund, so the decision of which rate to use is important and could be potentially expensive in the setting of pension reserves.

Figure 2 shows how changing the LTR affects a single-life annuity for a range of pension plan members. Changing the LTR assumption from 1.0% to 2.0% causes an increase in annuity value of 3.1% for an 80 year old pensioner, 3.9% for a 60 year old pensioner, 4.3% for a 40 year old pensioner, and 9.1% for a 40 year old deferred member. The impact is greater for younger members with longer to live, and greater for deferred members than current pensioners.

Figure 2: The increase in single-life annuity values for pension plan members using different assumptions for the LTR of mortality improvement



The difficulty of estimating long term mortality improvement rates is recognized by the CMI Working Party, which refrained from recommending a default value, noting that "the choice of the LTR of Mortality Improvement is necessarily subjective and is the single most important parameter for Users to set for each projection".

2.4. CMI Historical Analysis

To assist with the overall assessment of the potential range for the LTR, a CMI Working Party examined the evidence for historical trends in mortality improvement, presented in CMI Working Paper 39[7], so that a view on suitable Long-Term Rates of Mortality Improvement may be usefully informed by an analysis of past trends in mortality improvement over a long period of time.

The CMI Working Party's analysis of an international average rate of mortality improvement used experience data from seven Northwest European countries having time-series data for a period spanning at least 150 years. This

[7] CMI Working Paper 39. 'A prototype mortality projections model', July 2009.

amount of data allowed for a comparative assessment of average annual rate of improvement for six quarter-century periods from 1854 to 2004. Results were segmented into decadal age ranges from 40 to 89.

The CMI Working Paper derives as a reference benchmark an average rate of U.K. mortality improvement over the whole of the 20th century of approximately 1% per annum. This historical long-term rate is a decisive element in framing current pension industry practice.

2.4.1. Recent period of high improvement

The CMI Working Party notes that, for most ages, rates of improvement for males have been far higher in the last quarter-century period than in any other. The average rate of change (for ages 40 to 89) has been 1.8% p.a. for the most recent quarter-century period. The equivalent average for the previous 125 years was only 0.6% p.a. The CMI Working Party acknowledges that the marked difference in mortality improvement rates for males from 1954-1979 to 1979-2004 is likely to reflect the effects of smoking in the earlier period, and the declining prevalence of smoking and general reductions in cardiovascular mortality, in the latter period. The smaller variation in female mortality improvement between these two 25 year periods reflects underlying gender differences in smoking prevalence and reductions in cardiovascular mortality.

2.4.2. CMI library of projections

LTRs of between 1% and 2% have been chosen for inclusion within the CMI library of projections, as the Committee felt these were likely to represent current industry assumptions regarding long term rates of mortality improvement.

2.5. Commentary on Industry Practice

Any projection is likely to combine historical experience with expectations of future differences. The issue is one of the relative weighting of different pieces of evidence. The industry survey of which LTRs are being used in practice suggests that the pre-1990 historical past is being given a very high weighting over the current mortality improvement level. This may be because there are limited models available to understand the causes of current improvements, and to explore more systematically how they will change in the future.

2.5.1. 'Reversion to mean' assumption

The concept implicitly being espoused by giving a high weighting to 20th century history is that mortality improvement might be like interest rates or other financial metrics and reflect economic cycles, which will be periodically higher or lower than average, but that will revert over time to a mean rate. This view considers the current period of high improvement as an aberration, and sees the early 20th century as some kind of 'natural' or default base level of mortality improvement to which populations will eventually revert.

At a philosophical level it could be argued that eventually in some utopian future, when all improvements have been exhausted, mortality improvement should revert to zero for the rest of time. Even this underlying assumption – that there might be some 'natural' upper limit to lifespan – is being called into question by modern medicine. But leaving that aside, the question is whether the causes of the current high mortality improvement levels are temporary and whether these will exhaust and revert to some default level.

We believe the concept of a default level may be the wrong paradigm to apply to an assumption about change in human lifespan. It is possible, and even likely, that the past few decades are better representatives of the future than rates of change in the early 20th century and earlier.

2.5.2. Concept of a mortality improvement waves

In the next sections we examine mortality improvement through history and explore the causes of fluctuations in mortality improvement rates over time. It is impossible to escape the conclusion that mortality is constantly changing. Historical data on mortality rates shows how mortality goes through periods of higher and lower levels of

decrease and also occasionally, increases, caused by different social conditions, medical advances, and resource availability. A better paradigm than there being a default level of mortality improvement is to expect there to be constant waves of mortality change ('vitages' in RMS terminology) arising from different causes. In this model of the world, the question for mortality projection becomes one of understanding how a current wave is likely to play out, how long it is likely to last, and then what kind of wave is likely to follow it.

It is not straightforward to reconcile this concept of successive waves of mortality change that might be expected in the future with a reference framework that expects mortality improvement to reach a plateau of constancy in the future. One key metric that we will use to reconcile this is the modeled best estimate value of mortality improvement in 2032 for our reference population of 80 year old men. Another method of reconciling the two different conceptual models is to compare the present value of liabilities resulting from the expected run-offs from both. For simplicity we tend to use the former – the mortality improvement rate at 2032.

In the CMI framework the value of mortality improvement attained at 2032 – the LTR – is expected to continue at that level for the rest of time. In the RMS modeling, the value of mortality improvement at 2032 will be in a trajectory that will continue to rise and fall again in years beyond that. The RMS modeling tries to assess timing uncertainty and probability distributions around the magnitude of impact of future successive waves of mortality change.

3. HISTORICAL PERSPECTIVE OF MORTALITY IMPROVEMENT

3.1. Measuring Mortality Improvement Rates

Mortality improvement rates are very volatile. Being the derivative of an observed mortality rate – i.e. the difference in the numbers of deaths per thousand people between one year and the next – this is sensitive to very small changes. Mortality rate itself is a difficult metric to measure accurately: the number of deaths increases with age, so can be measured with more reliability in large populations of older people. In the young, the populations are large but the number of deaths is small, so mortality rates are noisy. In the very old, the death rates are high but the numbers of living people are smaller, so again mortality rates are less reliable.

The most reliable age range tends to be from 65 to 90, hence our focus here on the 80 year old – around the current average life expectancy.

Subdividing populations and slicing them into narrow age bands reduces the reliability of the observations obtained. For this reason we take the average improvement of an age range from 75 to 85 to bracket the age of most interest.

To maximize statistical reliability, most analysts of improvement trends prefer to use national population statistics, rather than sub-sets that might better reflect the socioeconomic profiles of the pensioners in the schemes or annuity portfolios of interest. They apply the improvement rates observed in the general population to the base mortality rates measured in a scheme's experience data. This assumption maximizes the use of available data, provides good long term observational confidence, and is common practice so this study is similarly based on the national population statistics of England and Wales.[8]

Even for the most reliable aggregated population, the measurement of mortality improvement is very volatile year-on-year. Mortality rates fluctuate year by year – for example a harsh winter in one year may cause more deaths than average among 80 year olds, but the next year mortality rates are likely to be lower – so the mortality improvement, the difference in rates between the two years, will be high. Variations above and below average mortality rates drive large swings in their derivative: mortality improvement. Mortality improvement is autoregressive – i.e. a high mortality improvement for a short period of time is likely to be followed by a low or negative period of mortality improvement.

[8] Research work currently being undertaken at RMS may provide better assumptions to be used for the mortality improvement projections of defined benefit scheme pensioner populations and annuity portfolios, relative to those assumed for the general population

Annual mortality improvement rates in our chosen population have swung from +20% to -20% in the past. Since the 1980s, the year-on-year mortality improvement range has stayed within +10% to -10%. To observe structural or underlying trends in mortality improvement the mortality improvement rate has to be averaged over a longer time period. Averaging annual improvement over 5 years dampens the oscillations but still shows sizeable swings. Averaging annual improvement over 10 years provides sufficient stability to see long term trends.

It is worth noting that very long term averages are very low, and the longer the time period over which rates are taken, the lower the average annual rate. Table 1 shows the average annual mortality rate for our reference population over different lengths of the historical record.

The CMI study uses separate 25 year periods to consider average annual mortality improvement rates. In this paper it is the 10-year annual average mortality improvement metric that we discuss as the mortality improvement trend.

Table 1: Average annual improvement rates over different retrospectivetime periods

Time Period	Average Annual Improvement Rate
Over last 168 years (1841 to 2009)	0.34%
Over last 100 years (1909 to 2009)	0.71%
Over last 50 years (1959 to 2009)	1.35%
Over last 25 years (1984 to 2009)	2.22%
Over last 10 years (199 to 2009)	2.95%

The CMI decision to partition mortality improvement data into quarter-century bins has obvious practical statistical justification in respect of data aggregation, and provides a mortality model which is relatively straightforward to understand, use and modify. However, the choice of long duration partitions of the historical data reduces insights from actual underlying trends with shorter time period signatures. Also, significantly, it dampens – i.e. reduces – the average annual mortality improvement levels that are proposed.

The 10-year average mortality improvement through time (for the following 10 years) is plotted in figure 4. The damping effect of averaging mortality improvement over different numbers of years is shown in figure 5. This takes the historical record of 75-85 year old male mortality in England and Wales from 1841 to 2009 and plots the cumulative distribution of all of the mortality improvements observed each year (168 observations of change from one year to the next), relative to the cumulative distribution of them averaged over 5 years (164 5-year periods), 10 years (159 10-year periods) and 20 years (149 20-year periods). Note however that these overlapping time periods cannot be treated as independent observations.

The structural trend examined here is the 10-year annual average mortality improvement of 80 year old males.

3.2. Historical Perspective on Mortality Improvement

During history, mortality rates have declined at different rates during different periods. Figure 3 shows the historical mortality rates of 80 year old males in England and Wales over the past 170 years. Mortality is complex and changes in mortality arise from many different causes. Figure 4 shows the 10-year annual average of mortality improvement through history. There are distinct phases of social change that can be identified. Figures 3 and 4 are overlaid with an interpretation of the data as a series of broad trends that prevailed for certain periods. These are necessarily simplistic interpretations of complex social and medical advances but they indicate that mortality improvement trends change dynamically over time.

Figure 3: Historical mortality rates for 80-year old U.K. male 1841-2009, as broad phases of social change

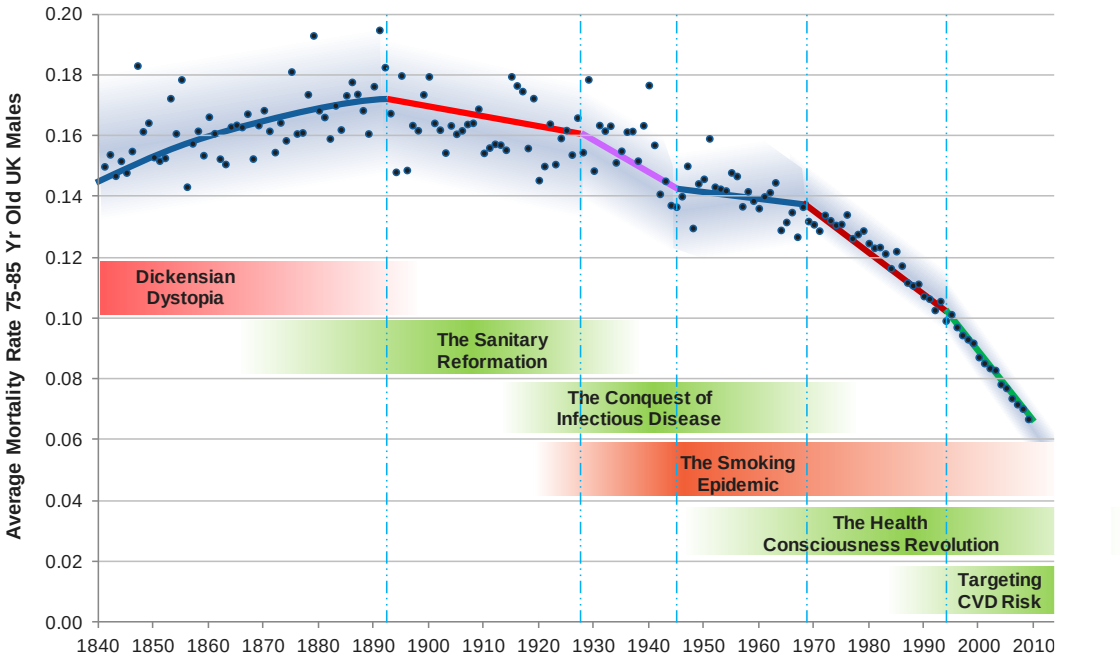
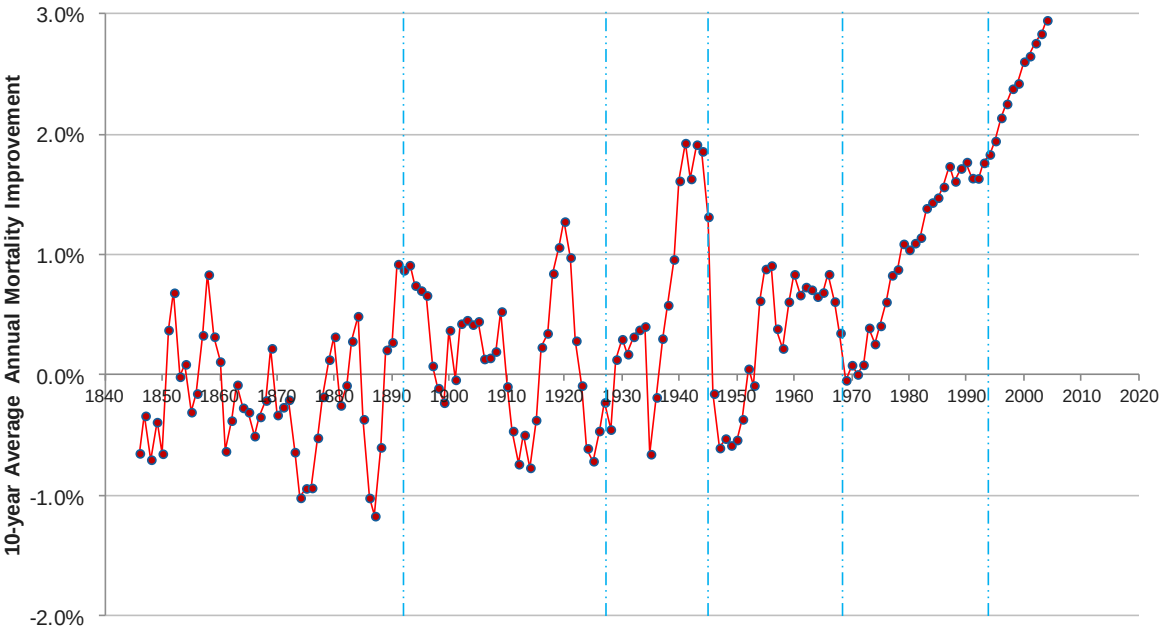


Figure 4: Mortality improvement rates for 75-85 year old U.K. males 1841-2009 (10-year average annual plotted at 5-year mid-point)



3.2.1. Historical phases of social change

These periods of social change related to mortality improvement, have significant overlaps and interactions, but can be summarized simplistically, and illustrated in figure 3, as:

- **Dickensian Dystopia** (mid-19th century to 1890s)

The period that followed the industrial revolution in Britain saw mass migration of more than half of the country's population from rural areas to live in cities with poor infrastructure and unsanitary conditions. Early cities had poor

air quality, rudimentary sanitation and constant threat of disease, particularly cholera. Mortality rates rose during this period, with negative rates of mortality improvement prevailing for most of this era.

- **The Sanitary Reformation** (1890s to 1940s)

The unsanitary conditions prevailing in cities were recognized as public health issues with the growing science of epidemiology. It was tackled through a period of great civic investment in urban infrastructure. Victorian engineers created sewerage systems, clean water supplies and hospitals. Disease and public health began to be studied scientifically. Death rates began to fall. Disease epidemics, including the Spanish Influenza pandemic, caused mortality shocks, but mortality improvement trends were generally positive.

- **The Conquest of Infectious Disease** (1920s to 1960s)

Medical science identified the causes and created treatments for common life-shortening diseases, including tuberculosis. Penicillin was first identified in 1928 and mass produced after 1945. Commercially available antibacterial antibiotics became available after the 1930s. Death rates from tuberculosis, a major killer in the early 20th Century were halved by 1930 and halved again by 1950 through health education and streptomycin treatments. Mortality reduction was particularly marked in those below the age of 45, and improvements were very high for infants and children. Mortality improvements for our reference group of 80 year old men were also high, reaching close to 2% towards the end of this period.

- **The Smoking Epidemic** (1940s to 1970s)

Health care became universally available with the creation of the National Health care Service in 1946, but coincided with post-war austerity. Smoking was not recognized as a health hazard and became a popular habit. Mortality rates drifted and suffered periods of deterioration. During this period, life expectancy improvements were split relatively evenly by age group.

- **The Health Consciousness Revolution** (1970s to present)

The science linking smoking to mortality was accomplished in 1956, but the public acceptance of this took another two decades. 1970 saw the peak of smoking-related deaths. Smoking rates halved during this period and health awareness grew. Lifestyle changes included diet, exercise, and prevention of accidents. Mortality rates started their rapid decline and the mortality improvement ended its oscillations and began a strong trend to 2% by the early 1990s.

- **Targeting CVD Risk** (1990s to present)

The effectiveness of statins in reducing CVD mortality of those with high cholesterol was proven in a controlled trial in 1994. Doctors began prescribing statins widely shortly afterwards. Routine screening for high blood pressure was introduced in the 1990s, with widescale prescription of antihypertensive drugs – more than 20% of the older U.K. population is now on blood pressure medication. Other medical advances in heart surgery and faster response times of paramedics greatly improved survival rates for heart attacks. Mortality improvement rates increased to their record recent high of 3%. In both of the last two periods, about two-thirds of life expectancy improvements resulted from mortality reductions for those over age 45[9].

3.2.2. Phases of mortality improvement

These distinct phases can be identified in the historical mortality record. Shifts from one regime of mortality improvement to another happen as scientific advance, economic conditions, and social acceptance combine to create new conditions.

Over time, the primary drivers of mortality improvement have changed. So too have the most prevalent causes of death. As a consequence of this it should be expected that in general:

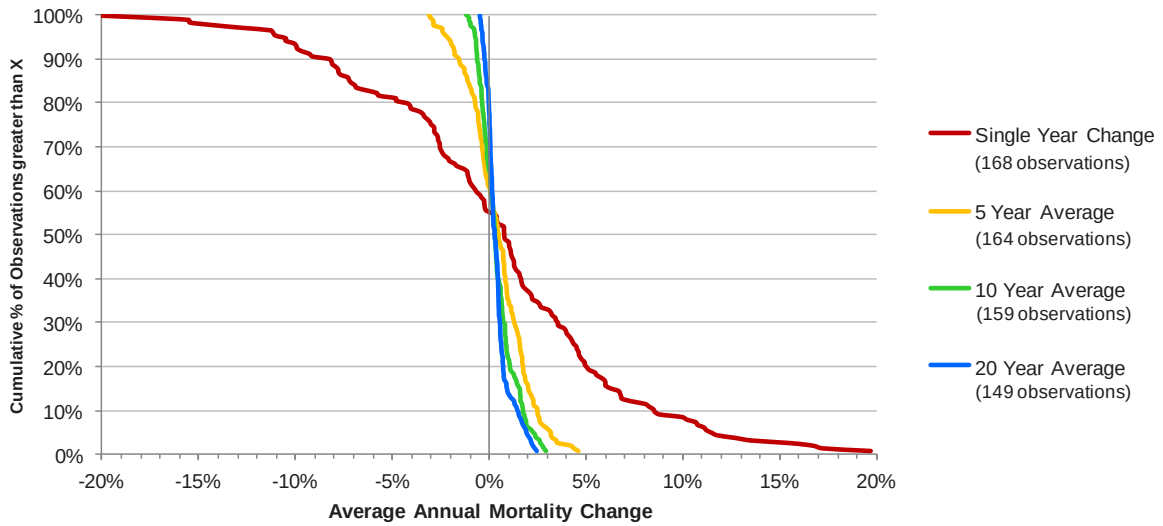
- Each phase is associated with a particular average improvement trend.

[9] Cutler & Meara (2001) National Bureau of Economic Research Working Paper No. 8556

- Each phase has its own characteristic level of volatility.
- There is diversification between phases.

In estimating the distribution of future mortality rates it could be expected that these characteristics would also apply to future phases of improvement.

Figure 5: Distribution of average annual mortality improvement rates for 75-85 year old U.K. males, observed over sustained periods, 1841-2009



4. UNDERSTANDING RECENT MORTALITY IMPROVEMENT

The LTR projection focuses on the next 20 years, and the key metric of interest is the mortality improvement rate at 2032. To project forward 20 years, it is sensible to look backwards 20 years, and to consider the trajectory of mortality improvement observed in that time and to understand what has occurred. In this section we consider available data from 1990 to 2010.

4.1. Current Cycle of Mortality Improvement

From the long term study presented in the previous section, it is clear that the current period is one of very high and consistently increasing levels of mortality improvement. This period has not been entirely unprecedented in the magnitude of mortality improvement that has been seen in the long term historical record: the record for peak levels of mortality improvement was for young people (under 30 year olds) in the 1940s, during the period we term 'The Conquest of Infectious Disease' when the 10-year annual average mortality improvement rate exceeded 10%. However what is notable about the recent period is the fact that benefits have been strong for the aged population, and particularly pensioners incurring annuity liabilities, but also the duration of the uni-directional trend in improvement. Ten-year average mortality improvement has been increasing since the 1970s – almost 40 years so far for this cycle. Most other cycles of mortality improvement in the record (see figure 4) have inflected within one or two decades.

4.2. Changes in Causes of Death

Mortality is complex. People die from a multitude of different causes, and the factors and treatments that influence the likelihood of dying from these causes have complex interactions. The causes of mortality change are difficult to tease out precisely from medical data, but relationships between changing risk factors, medical treatments, and mortality are well understood in the field of epidemiology and public health.

Figure 6 shows the change in mortality rate and causes of death for 75-84 year old males over the past two decades. The mortality rate has dropped from 93 to 57 deaths per 1000, a reduction to just above 60% of its rate in 1990, and an average mortality improvement rate of ~2.5% annually over that 20 year period.

Figure 6: Mortality rates for U.K. men aged 75-84, by cause of death, comparing 1990 with 2010

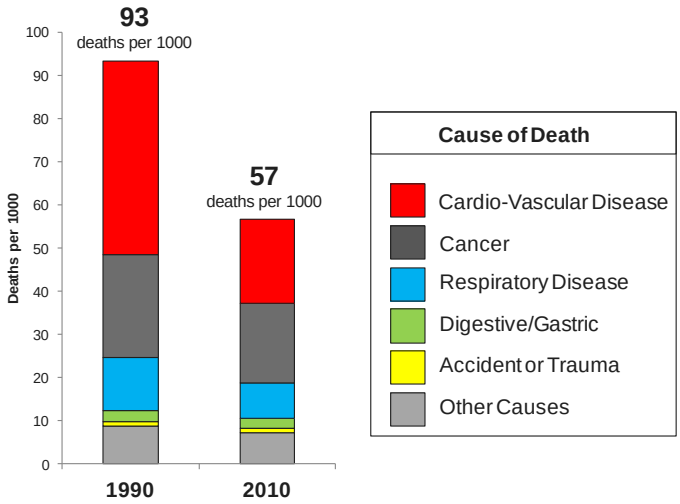


Figure 6 shows that there was a reduction in mortality in nearly all major cause of death groups between 1990 and 2010. The largest reduction has been in cardiovascular disease (CVD) – deaths owing to circulatory problems such as heart attacks and strokes. Premature mortality from CVD, more than halved in this age group over the period, averaging an annual improvement rate of more than 4%. During this period CVD mortality improved at about triple the rate of reductions in mortality from all other causes.

Mortality improvement over the past two decades has been dominated by CVD which accounted for approximately two thirds of the gains observed.

Table 2: Cause of death mortality improvement and reduction 1990-2010 in 75-84 year old U.K. males

Cause of Death Group	Average Annual Mortality Improvement (1990-2010)	Cause Specific Mortality Reduction (1990-2010)	Proportion of Total Mortality Reduction (1990-2010)
CVD	4.1%	57%	69%
Cancer	1.2%	22%	14%
All other causes	1.4%	24%	17%

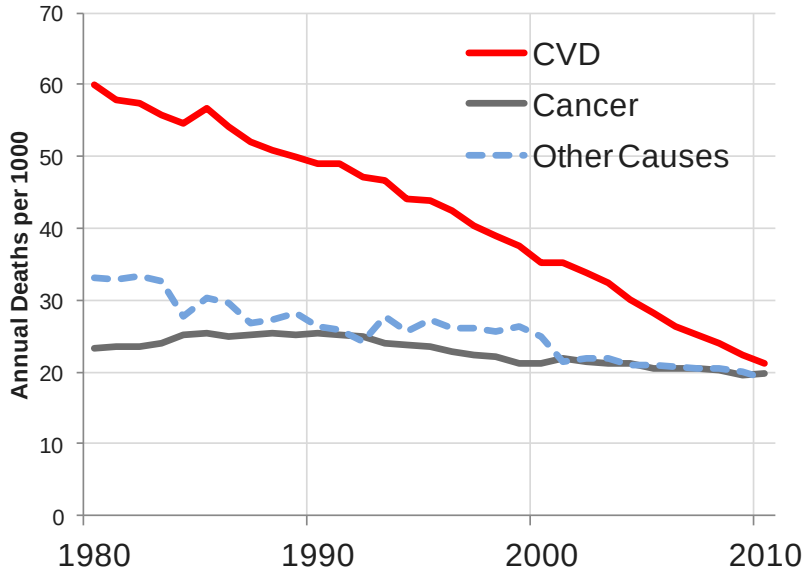
4.3. Reducing Premature Mortality from Cardiovascular Disease

CVD, mainly heart attacks and strokes, has been a leading cause of death in the over-60s for the past 50 years. CVD generally involves atherosclerosis – gradual thickening of the walls of the arteries as a result of accumulation of fatty materials. This ultimately leads to a rupture of the artery, most critically in the blood supply to the heart, causing a heart attack, or in the brain, causing a stroke. Men are at much greater risk of heart disease than pre-menopausal women, but in older women risks are similar.

CVD was a relatively rare cause of death in the 19th century but became a leading cause of death for industrial societies in the 20th century. The ascendance of CVD as a major cause of death has been attributed to increasing economic affluence, reduction in manual labor and physical exercise, abundance of cheap calorific food, proliferation of tobacco use, and greater numbers of people attaining older ages.

The reduction of CVD mortality has come about partly because of changing lifestyles and reduction of the risk factors that cause atherosclerosis, and partly from medical interventions, better treatments and detection, and improved survival from CVD events. One of the factors helping reduce CVD is that there is a single medical process involved – other major causes of death, such as cancers or respiratory disease, are much more complex and involve many different medical processes.

Figure 7: Mortality trends for all cancer and all CVD: males 75-84 years of age, England and Wales (Cohort effects removed)



4.3.1. Lifestyle risk factor reduction for CVD

Smoking is one of the major lifestyle risk factors for CVD. Smokers are almost twice as likely to have a heart attack when compared to people who have never smoked. Smoking accelerates the atherosclerosis process, the carbon monoxide in cigarette smoke reduces oxygen levels in the blood, and nicotine raises blood pressure. Over the past 20 years the rates of CVD mortality have declined due to the reduction in smoking rates. Despite the health penalties of smoking been well understood since the 1950s, with epidemiological studies finally proving the causal links between smoking and cancer and CVD, the wider social rejection of smoking has taken a lot longer. Health warnings on cigarette packets, bans on TV advertising, strong educational emphasis, and, most importantly, peer pressure in leading social groups have helped change smoking prevalence. In the mid-1970s, more than half of all men smoked. Smoking has steadily declined (with a minor resurgence in the 1990s) to around a quarter of men smoking by 2008. The impact of this reduction on CVD mortality has been marked. This was strikingly illustrated by the smoking bans in public places introduced in different countries which resulted in marked reductions in CVD admissions to hospitals in the months following the ban:

- Italy (2005) – 11% reduction
- Scotland (2006) –17% reduction
- France (2007) –15% reduction
- England (2007) – 2.4% reduction

Other lifestyle changes include the growing popularity of physical exercise. In the U.K. membership of a health club has increased from 4% of the population in 1998 to 14% by 2006. Diet has become an increasing focus of lifestyle

changes to “look after your heart”. Major educational campaigns have drawn attention to dietary content in relation to cholesterol – a key risk factor for atherosclerosis. People have switch from using dairy products and other types of full fat food products to low fat substitutes. An increasing emphasis is being placed on public awareness, individual responsibility for health and increasing information and education about risk factors.

It is worth noting that risk factors interact and amplify each other – for example high cholesterol, hypertension and cigarette smoking compound to increase CVD risk by a factor of seven. Reducing any one of the factors can have powerful interaction to amplify its beneficial effects with other risk factors, and individuals who reduce one risk factor tend to reduce several.

4.3.2. Medical interventions in reducing CVD mortality

In addition to lifestyle changes, there has also been a major impact on premature CVD mortality from medical interventions. These fall into three broad areas – prevention, response, and post-event treatment.

Prevention of CVD events arises from doctors providing drugs and treatments that reduce the risk of a future CVD event. Quite apart from doctors providing advice to high risk patients about lifestyle choices that reduce risk factors, foremost in the campaign to reduce CVD deaths has been the prescription of antihypertensive treatments (to reduce high blood pressure) and statins, to reduce high cholesterol. Antihypertensive drugs were first developed in the late 1940s, but became widely available from the 1980s onwards. By 1995, around 17% of the US adult population was taking antihypertensive medication, rising to 24% by 2010. In the U.K. routine screening for hypertension by taking the blood pressure of patients became commonplace from the 1990s onwards: hypertension treatment now accounts for some 12% of doctor activity, and around £1 billion ($1.5 billion) in drug expenditure. The prescription of low-cost statins to treat high cholesterol become common from the late 1990s onwards, following the demonstrated effectiveness of a 30% relative reduction in the risk of death with simvastatin treatment in a clinical trial published in 1994. In the U.K. by 2008, approximately a third of the adult population over 45 was now taking prescription statins, seven times as many as in 1998. This is partly attributable to decreasing costs of statin drugs. By 2003 Pfizer’s Lipitor had become the best-selling pharmaceutical in history, but as it and other big name drugs came off patent from 2004 onwards, generic statin drugs boosted the uptake.

When an individual experiences a CVD event, such as a heart attack or stroke, the medical treatment they receive reduces their chances of dying either immediately or later. The past two decades has seen major advances in immediate response, and in post-event treatment. The speed with which an individual receives medical attention after a heart attack or a stroke is critical to their survival. During the past 20 years medical response times have reduced significantly, to a current target time for ambulance arrival times of 8 minutes. Achieving this has resulted from better organization of emergency services, prioritization of life-threatening incidents, use of fast-response paramedics, and improved information technology. Improved survival rates from all kinds of life-threatening incidents is also attributed to the general public calling emergency services faster using their cell phones, which have become ubiquitous over the past 20 years (from 15% of the population in 1990 to 80% by 2010).

Post-event treatment of CVD patients has also improved significantly, with a growing armory of surgical techniques and drugs to reduce the likelihood of a deadly recurrence of the event. Heart surgery has become much safer and more commonplace, a wide range of new surgical appliances have been developed, such as stents, angioplasties, bypass surgery, and revascularization. New classes of drugs introduced in the past 20 years enable blood thinning, clot dissolving (thrombolysis), and resistance to platelet formation. Recurrence of heart problems can be regulated using implant technology such as pacemakers, which have become increasingly used as they have reduced in size and cost, improved in reliability and ease of surgical implantation. Mortality rates for hospitalized heart attack victims within the first month have been cut from 20% in 1995 to 10% today, and mortality within a year from 45% to 24%.

4.4. The Causes of Cancer Reduction

In contrast to the large drop in mortality from heart disease, the decline in cancer mortality rates has been less dramatic. Unlike CVD, which is a single medical process, cancer is a multitude of diseases with complex etiology. Despite concerted attempts to find cures, progress on reducing premature mortality from cancer has been slow.

Age-standardized cancer mortality rates changed little in the latter half of the 20th century. There were actually slight increases starting in the 1950s, followed by roughly equivalent declines in the 1990s resulting in barely any net change between 1950 and 1999.[10]

Figure 7 shows cancer mortality for older males increased up to the 1990s and then started a gradual decline. Similar results are seen in people at other ages.

Reductions in cancer mortality have become more evident in recent years. In the past decade, age-adjusted cancer mortality fell by 10-15 percent in the U.K.; with improvements in all of the most common types of cancer death (including lung cancer and prostate cancer in males, breast cancer and cervical cancer in females, and stomach cancer in both genders). Reasons for these declines include increased deployment and improved quality of screening, and advances in medical treatments and surgical techniques.

4.4.1. Lifestyle risk factors reducing cancer

Some of the lifestyle risk factors that have been influential in reducing CVD also affect cancer – notably smoking. Smoking is a major risk factor for lung cancer, mouth and throat cancers, and increases the risk of over a dozen other cancers. As smoking rates have declined, smoking-related cancer incidence has followed.

The etiological relationship between tobacco exposure and several types of cancer, most notably lung cancer, is well established in the literature. In the U.S. anti-tobacco public health campaigns began in the 1960s, following the Surgeon General's 1964 report on the harms of smoking. Increased awareness of the adverse health effects of tobacco consumption has since been a primary catalyst for declines in smoking rates and tobacco-related cancers. Studies show that lung cancer incidence and mortality reduction has followed the reduction in smoking rates with a time lag of approximately 20 years.[11]

Smoking surveys show that 65% of men in Britain were cigarette smokers in 1948. By 1970, the percentage had fallen to 55%. Lung cancer mortality started to decrease in males around the mid-1970s. As in the U.S., U.K. lung cancer mortality, which was increasing over time, is now decreasing and those variations were foreshadowed by trends in past smoking behavior.[12]

4.4.2. Earlier detection of cancer

More widespread screening has led to earlier detection of cancers, which in turn has improved cancer survival rates. PSA (prostate-specific antigen) screening for prostate cancer and mammography for breast cancer are prime examples of common tests that have led to greater detection at earlier cancer stages (i.e., nonclinical cases) and subsequently increases in case-specific survival, because treatment could be initiated before cancer metastasis or progression to more advanced stages.

4.4.3. Medical advances in reducing cancer mortality

Medical advances, such as better surgical techniques (e.g., minimizing amounts of normal tissue removed during surgery for cancer) and more effective pharmaceuticals and therapies (e.g., radiation and chemotherapy, combined with surgery), have also increased cancer survival rates. Before the end of the 20th century, exploratory surgery was needed in order to confirm a cancer diagnosis. Since the 1970s, medical advances have replaced these with

[10] Department of Health (2001) *Cancer trends in England and Wales 1950-1999*

[11] Cutler (2008); *Are We Finally Winning the War on Cancer?*

[12] Cancer Research UK (2012); *Brief history of tobacco consumption in Britain*

less invasive scans. Progress in ultrasounds, CT, MRI, and PET scanning now allows for more effective screening and accurate diagnoses; surgeries to operate on tumors can now be guided by these types of scans or by cameras and scopes. All of these advances have subsequently led to improved survival rates.[13]

4.5. Reduction in Other Causes of Death

Reductions have been seen across nearly all types of causes of death. Accidents and trauma deaths have been reduced with safer road travel and better trauma care. A significant minority cause of death, particularly for the 80 year olds and older, is respiratory disease. This has reduced, but mainly as a result of reducing smoking levels in the population. Medical treatments for respiratory damage are very limited – damaged lung tissue cannot today be repaired and treatments that are available mainly ease the symptoms.

4.6. Attributing Causes of Recent Mortality Improvement

Causes of mortality improvement are complex and interrelate across multiple causes of death. 'Cause of Death' models in the actuarial literature have notoriously suffered from trying to represent these complexities and inter-relationships in multivariate modeling. RMS analysis makes the process more tractable and amenable to projection modeling by considering 'Cause of Improvement' rather than by cause of death.

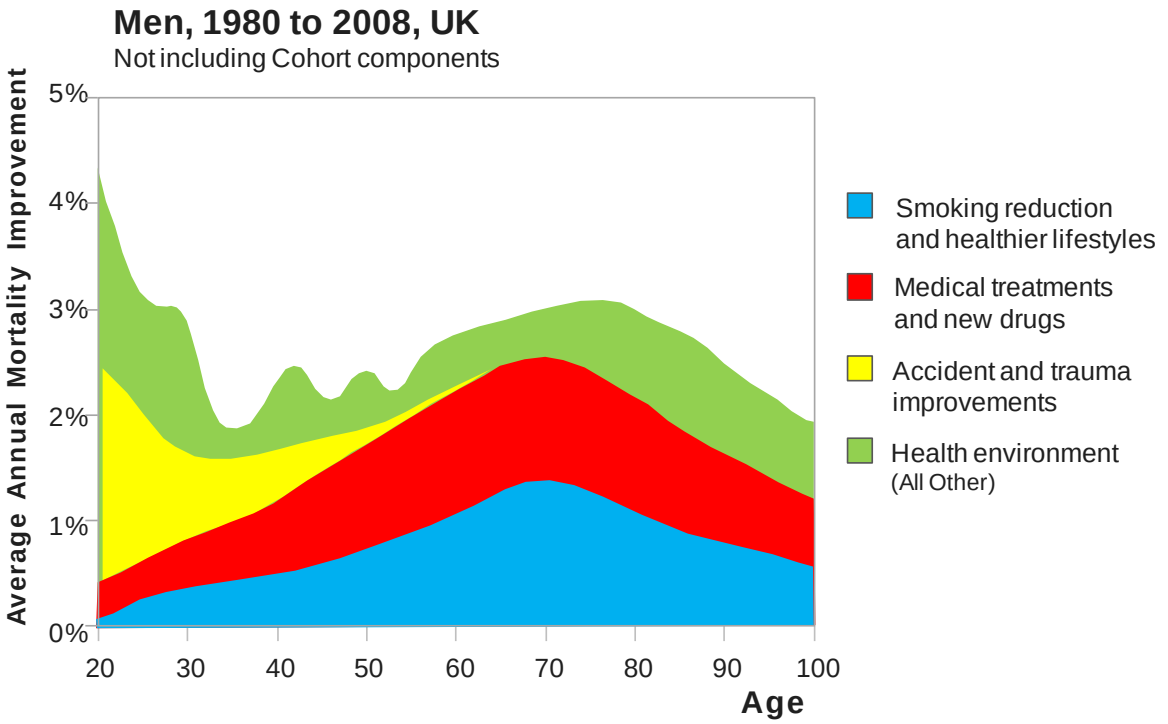
We consider three broad categories of causes of improvements that can be seen as resulting from different mechanisms in our society. RMS terms these 'vitagion' categories. These different mechanisms can be treated separately in the modeling to understand how they might influence future changes in mortality improvement:

- **Lifestyle trends**: Personal choices and social practices, with changing attitudes towards fitness and personal health, including trends such as smoking prevalence and obesity rates. Change occurs through sociological mechanisms, education, and individual decision-making.
- **Medical intervention**: Treatments, diagnosis, and drug prescription to reduce the incidence of major causes of premature death. The process of medical advance is driven by new drug discovery, development of new surgical and treatment procedures, and the economics of the health care and bio-technical industry. Treatments are made available through health care systems.
- **Health environment**: Other external factors that influence mortality, including the physical environment such as climate, housing, travel infrastructure, sanitation, law enforcement, and welfare services. Changes in the health environment occur through political and organizational processes, broad infrastructure investments and longer–term social processes of change.

Understanding how much of the recent mortality improvement trend has been driven by these three different causes of Lifestyle, Medical Intervention and Health Environment is important to assess the future trajectories and constraints on mortality improvement rates over the next 20 years. Attributions have been made from detailed epidemiological studies that can guide our analytical approaches. This is summarized in figure 8.

[13] American Cancer Society (2011); *The History of Cancer*

Figure 8: Attribution of mortality improvement during the past 20 years, across different ages, by cause of improvement



4.6.1. Attribution of improvements by cause

Quantitative analysis by two separate sources[14,15] of the drivers of CVD decline between 1981 and 2000 has identified that around 60% of CVD mortality gains were due to improvements in lifestyle-related CVD risk factors, with about 40% of CVD mortality improvement attributable to medical intervention.

For cancer, an analysis by a health economist estimates that around 55% of the improvements since the early 1990s in the U.S. is due to medical interventions including treatment and screening, with 23% relating to lifestyle factors.[16]

Almost all of the mortality improvements in respiratory disease can be attributed to lifestyle (reductions in smoking) as medical treatment has been only palliative. Around 10% of mortality improvement is attributed to other causes of death for medical intervention.

There is a volume of research published about accidents which shows that accident and trauma-related mortality improvements are predominantly attributable to health environment causes such as health and safety legislation, traffic control, and socioeconomic conditions. The influence of Health Environment diminishes with increasing age. There is an age dependent shift towards Health Environment at younger ages and towards Lifestyle at older ages.

Overall, for the past 20 years of mortality improvements seen in the U.K. population of 80 year old males, we attribute 50% to Lifestyle changes, 40% to Medical Intervention, and 10% to Health Environment changes.

4.7. What Might Happen in the Next 20 Years?

The causes of the recent wave of high mortality improvements over the past 20 years have been identified. We can see that there has been a 'perfect storm' of coinciding conditions, where healthy lifestyle changes have been

14 Unal and Capewell (2004), using the IMPACT model

15 Lichtenberg (2005)

16 Cutler (2008)

adopted by increasing numbers of the population, at the same time that new preventative drugs have been made widely available to reduce risk factors, and medical treatments have advanced in their effectiveness.

To make projections for the next 20 years we need to consider how the rates of change for these components of the mortality improvement may alter in the future. Are they likely to be sustained, and if so for how long, might they slow, and if so, when, or might they actually increase? We need to explore whether there is evidence to suggest that the same pace of change can be maintained, what the limits and durations of the current wave of improvement are likely to be, and what assumptions would be prudent to make for estimation of future longevity liabilities.

In the next sections we consider a number of potential scenarios for how future mortality improvement might progress. Firstly we look at three scenarios for extreme trend reversal. We explore potential scenarios that could cause mortality improvement rates to abruptly slow from the current rate of mortality improvement to one that is less than half of todays by 2032.

Secondly we examine scenarios where current trends either stay the same or actually increase.

Thirdly we review how different economic outlooks might influence these various scenarios and what mortality improvement projections would result from different underlying assumptions about future economic prosperity.

Finally we consider which sets of assumptions would be most appropriate for different conditions.

5. POTENTIAL CAUSES OF EXTREME TREND REVERSAL

This section considers some possible hypotheses as to how a trend reversal might occur. Specifically we consider scenarios that would reduce the rate of mortality improvement from a run rate of 2.5% annual improvement over the past two decades to arrive at an LTR of between 1.0% and 1.5% by 2032. All scenarios in this paper are developed using population-based mortality data from England and Wales published by the Office of National Statistics, with cohort effects removed.

These hypotheses consist of:

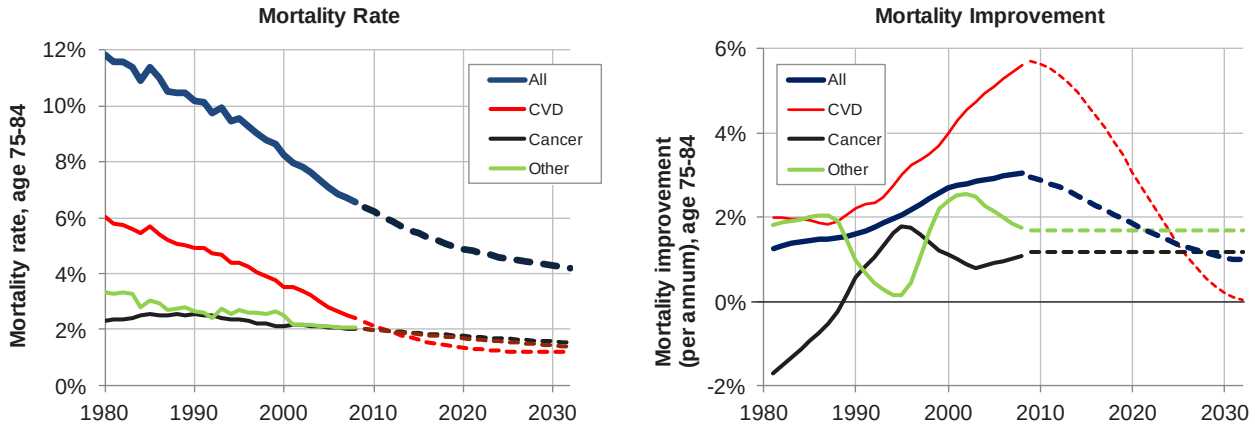
- Scenario 1: Rapid exhaustion of reducing premature cardiovascular deaths
- Scenario 2: Failure to reduce cancer mortality
- Scenario 3: Mortality deterioration due to the obesity epidemic

5.1. Scenario 1: Rapid Exhaustion of Reducing Premature Cardiovascular Deaths

Mortality reduction over the last two decades has been driven by a strong decline in deaths from CVD. One commonly cited hypothesis is that improvements from reducing premature CVD deaths will eventually exhaust through diminishing returns as CVD mortality approaches minimal levels. This scenario explores whether this might occur in the near future, and whether CVD mortality improvement rates might decline fast enough to bring the total mortality improvement rate down to below 1.5% by 2032, to reach the LTR values commonly assumed by many in the pensions industry.

Table 2 and Figure 6 shows that mortality from CVD has been falling at an average annual rate of over 4% each year from 1990 to 2010, from 45 deaths per 1000 to 20 deaths per 1000. The 20 deaths per 1000 of CVD mortality that remains is only a half of that seen in 1990, so clearly the absolute levels of CVD mortality that can be eroded are finite. However the question being considered is not the absolute level of reduction, it is the mortality improvement rate – the amount of reduction each year of the previous year's mortality. A continuing reduction of CVD mortality by 4% a year will reduce CVD mortality from its current rate (expected to be about 18 per 1000 in 2012) to just below half of its current rate (8 per 1000) by 2032. The 1990-2010 reduction saw CVD rates fall by 25 deaths per thousand. If CVD can be reduced by a further 10 deaths per thousand over the next 20 years, the same mortality improvement rate trajectory will be maintained.

Figure 9: Scenario 1: Rapid exhaustion of the rate of reducing premature cardiovascular deaths



From studies of the type of CVD deaths and the medical processes involved, we believe that at least 90% of current CVD premature mortality could potentially still be prevented: 75% could be achieved with current medical treatments, combined with further lifestyle improvements, and an additional 15% of reduction could be achieved if it became possible to repair damaged heart tissue, perhaps using regenerative medicine techniques in the future.

As CVD mortality reduction reaches these limits we would expect it to slow, and we explore this in future scenarios, however the current rate of improvement would not take the CVD mortality rate close to these bounding limits by 2032.

There is little evidence to date to suggest that CVD mortality improvement could dramatically slow. However, it could potentially occur if most of the types of CVD deaths that can be prevented have already been prevented and the remaining deaths are somehow a lot more difficult to reduce. There are some CVD deaths than are probably unpreventable under current conditions – sudden severe heart attacks account for around 5% of current CVD deaths and these would not respond to treatments. It could be assumed that modern treatments for CVD sufferers would not improve any further and that no additional people could benefit from it. It could be assumed that those currently taking antihypertensives and statins are all of the people who could ever benefit and that no further benefits can be obtained from improving or extending preventative medicines. It could also be assumed that lifestyle changes could suddenly stop spreading through the population, and that the numbers of people who currently smoke and have poor diets will stabilize at close to their current levels.

In scenario 1 we assume all of these. We assume that CVD mortality improvement slows to zero over 20 years, while mortality improvement due to cancer and other causes of death maintain their current rates of progress. Under this scenario, the overall mortality improvement declines to around 1% by 2032. Figure 9 shows a simulation of the rapid exhaustion of mortality improvement due to CVD.

5.1.1. Commentary on scenario 1 – CVD exhaustion

In the view of RMS this extreme reversal in CVD improvement required to bring overall mortality improvement down to 1% is an unlikely outcome. There is still significant potential for further improvements in reducing CVD mortality. Around 25% of the population still smoke (although only 8% of 80 year old men), and the generations behind them have lower smoking rates, so next years' 80 year olds will have lower smoking rates than this year's, and so on into the future – note that future reductions of smoking levels don't require today's smokers to quit. Similarly the 60 year olds today who will become the 80 year olds of 2032 tend to be making healthier lifestyle decisions and more of them are improving their exercise regimes and diets. Preventative medications such as antihypertensives and statins have considerable potential for increased effectiveness – studies of compliance show that only a low percentage of people take their drugs as often as they are supposed to, and it is likely that those currently prescribed are self-referring so there may be many high risk individuals that could benefit if more rigorous screening were applied. It is

also possible that universal preventative medication could become a standard procedure: health care specialists are advocating putting everyone over 50 on statins, or providing a universal 'polypill'. The polypill is formulated as a combination of statins, blood pressure lowering drugs, folic acid and aspirin, and is estimated to reduce ischemic heart disease and stroke events by 88% and 80%, respectively, if taken preventatively by all those aged over 55 and those with existing heart disease.[17]

5.2. Scenario 2: Failure to Reduce Cancer Mortality

Besides CVD, cancer is the other major cause of death, and as CVD mortality reduces it assumes more importance. For people over the age of 65 in U.K., cancer has now become the greatest cause of death. The contribution to mortality improvement from reducing cancer mortality will become an increasingly important part of the mortality improvement calculus.

5.2.1. Increasing cancer focus for health care

Cancer is assuming greater priority for health care expenditure and is a major focus of performance improvement for the U.K. NHS. The pharmaceutical industry is investing heavily in new types of drugs to treat cancer. Of the 3,000 new drugs currently undergoing clinical trials, nearly a third are treatments for different types of cancer.[18] Current medical advances that are in progress for reducing premature cancer mortality include new mass-screening methods of detecting cancers earlier, genetic profiling of cancer mechanisms, a new generation of monoclonal antibody drugs, and investments planned for new NHS cancer treatment centers to be built across U.K.

5.2.2. The elusive cancer victory

However, cancer is a very different disease to CVD, and has proven difficult to reduce cancer-related mortality. In fact cancer is not a single disease, but a variety of different diseases, and cellular processes can adapt to evade treatment. Finding 'a cure for cancer' has been elusive. The history of medical progress in combating cancer is one of constant failure to match expectations. In 1972 President Nixon declared 'war on cancer' and expressed an optimism that it would be won by 1976. In 1977 the American Cancer Society expressed high confidence that breast cancer would be controlled "within a few decades". However after decades of investment by the biotech industry in medical research, drug treatment is not yet as effective as hoped. New pharmaceuticals over the past decade provide on average only 10 months of remission, although some individual cases have achieved spectacular remission. Tumors tend to develop resistance and change their genetic processes. Drugs are toxic and are currently very expensive. A number of the new generation of cancer drugs have not achieved the cost-effectiveness thresholds required for adoption by the U.K. NHS.

5.2.3. Could cancer prevalence increase in the population?

Other lifestyle or health environment conditions could potentially cause cancer prevalence to increase. There are occasional scare stories that suggest that some new aspect of modern life could potentially unleash a new wave of cancers in the population – mobile phones; overhead power cables; deodorants; microwave ovens; plastic containers and wrap; red meat; night work shifts. However, detailed studies have so far failed to identify any statistically valid evidence that population cancer mortality might increase.

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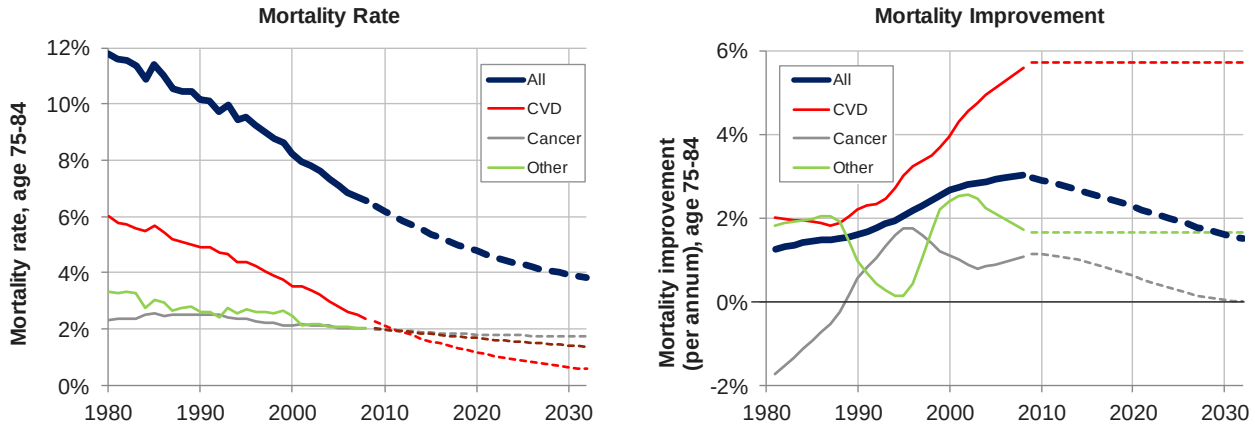
[17] Wald and Law (2003) 'A strategy to reduce CVD by more than 80%'

[18] RMS maintains a database of 3,028 New Chemical Entities (NCE) & New Molecular Entities (NME) currently in clinical trials with Federal Drug Administration, of which 878 are undergoing trials for treating some form of cancer.

Figure 10: Scenario 2: Failure to reduce cancer mortality



5.2.4. A scenario for failure to reduce cancer mortality

It could be argued that we should expect a significant reduction in mortality improvement levels as an inevitable consequence of the transition from CVD-led improvement to cancer-led mortality reduction. A pessimistic view of cancer treatment potential would be that medical science will continue to make only slow or non-existent progress over the next 20 years. Some of the reduction in cancer mortality observed over the past 20 years has been achieved by the population reducing their own cancer risks, for example by reducing smoking rates.

In scenario 2, we assume that cancer-reducing lifestyle changes stall, and that there are only minimal future medical advances in detecting and reducing premature cancer mortality. Scenario 2 – failure to reduce cancer mortality – is modeled in Figure 10. We assume that cancer mortality improvement slows to zero over the next 20 years, while mortality improvement due to all other causes remains at current levels. Under this scenario, the overall mortality improvement falls, but only gradually and does not go below 1.5% by 2032.

5.2.5. Commentary on scenario 2 – cancer failure

Even the complete cessation of cancer progress over the next 20 years is insufficient, on its own, to drive the kind of extreme trend reversals anticipated in market expectations of a 1.0 to 1.5% LTR.

If all other mortality improvement causes continue along their current trends and the only variable to be altered is the mortality improvement arising from reducing cancer mortality then reducing the overall mortality improvement below 1.5% by 2032 would require the cancer mortality rate to remain at around 2% or even increase.

RMS believes that a scenario of very poor cancer mortality progress over the next 20 years is highly unlikely. Significant improvements in U.K. would be possible simply by adopting screening and detection processes on a par with other peer countries. Current U.K. cancer survival rates are inferior to those in comparable countries such as Australia, Canada, Norway and Sweden.[19] Denmark is the only country that has worse survival rates than the U.K. Considerable mortality improvement would result from bringing U.K. health care metrics on cancer up to the average of the European Union. This requires improved educational levels about cancer in the general population, so that self-referral and early-detection rates can be improved, and also requires resources and institutional focus. The transition from CVD-led mortality improvement to cancer-led improvement is a gradual process, and it would be difficult to justify low mortality improvement rate assumptions by 2032 on the basis of cancer treatment pessimism.

[19] International Cancer Benchmarking Partnership (2008) The Lancet: Cancer survival in Australia, Canada, Denmark, Norway, Sweden, and the UK, 1995–2007.

5.3. Scenario 3: Mortality Improvement Curtailed by Obesity Epidemic

Obesity rates have steadily increased in the U.K. over the past several decades. Obesity is defined as a body mass index (BMI) of over 30.[20] BMI distributions for the population as a whole are shifting, with more people crossing the thresholds of obesity. Almost a quarter of adults in England were classified as obese in 2009, up from 5% in the mid-1980s. A substantial body of research has linked obesity to rising health care costs and a significantly increased risk of death, primarily due to heightened risk of CVD, hence public health analysts labeling this demographic shift as 'the obesity epidemic'. It is known that increasing obesity rates have a negative effect on mortality improvement, and in the United States (U.S.) this has been cited as a potential cause of a reversion to a lower long term mortality improvement rate.[21]

Obesity levels are higher in U.S. – about a third of U.S. adults are now obese[22] – and this increase began earlier. The U.K. has obesity levels similar to those of the U.S. in the mid-1980s and is rising at a similar rate to that seen by the U.S. at that time. Increasing levels of obesity are in fact being seen across the developed world, at different levels and paces, but nowhere has obesity been 'solved' or trends of increasing obesity in the total population been reversed. The issue of increasing obesity in pensioner populations and insured portfolios is an important element of mortality study.[23] Obesity rates tend to be higher in lower socioeconomic groups, and obesity rates increase with age, to a peak in 65-74 year olds, after which obesity rates diminish significantly. Obesity rates in 80 year old men are currently just over 20%.

5.3.1. The obesity burden on mortality improvement

Obesity imposes a negative 'burden' on mortality improvements. Our analysis suggests (figure 13) that for at least the past 15 years, increasing levels of obesity have applied a burden of around 0.1 percentage point on the average annual improvement – i.e. without the obesity epidemic, the mortality improvement of 80 year old men would be 3.05% instead of 2.95%.

The burden is imposed by the *rate of increase* of obesity levels in the population.

For obesity to reduce the LTR to below 1.5%, it would need to impose a burden of more than 0.7% after accounting for changes in cause of death prevalence. In this scenario, we explore what levels of obesity increases are commensurate with this level of burden.

5.3.2. Obesity and mortality

Individuals who are obese have a significantly increased risk of death from all causes, compared with healthy weight individuals. Studies show that the increased risk varies by cause of death, and most of this increased risk is due to cardiovascular causes. Body Mass Index (BMI) is a strong predictor of mortality among adults. Overall, moderate obesity (BMI 30-35) reduces life expectancy by an average of three years, while morbid obesity (BMI 40-50) reduces life expectancy by eight to ten years".[24] Figure 11 shows the relationship of BMI and increased mortality hazard for non-smoking individuals in varying age groups.[25]

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20 Body mass index is defined as weight in kg/(height in m)^2

21 Olshansky et al., (2005).

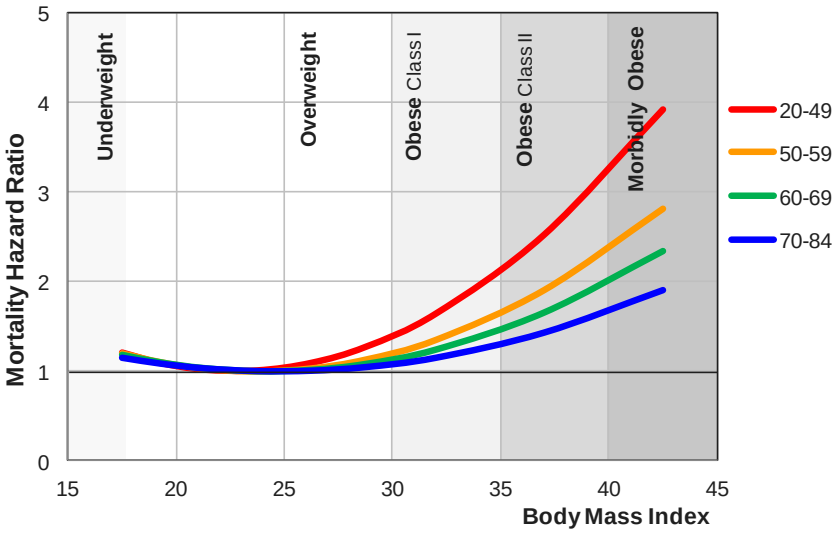
22 NIDDK Statistics on obesity prevalence

23 RMS has a joint research project into the likely impacts of obesity on mortality in pensioner populations with the Obesity Learning Centre, part of the U.K's National Heart Forum.

24 National Obesity Observatory. Obesity and Life Expectancy 2010

25 Berrington de Gonzales et al. (2010)

Figure 11: Obesity mortality hazard: the increase in mortality, relative to a normal body weight, for different levels of BMI at different ages



The "J-shaped" or "U-shaped" relationship illustrated in figure 11 between the all-cause mortality ratio and BMI has been noted in several studies.[26] One consequence of this is that increasing obesity translates into a rapidly increasing mortality hazard. The hazard ratios for elderly populations tend to decrease at least in part because of increased propensity for non-obesity related causes of death. A more subtle observation is that the nadirs of the hazard ratio curves tend to shift to the right. One potential explanation is that body weight has a protective influence on surgical outcomes and respiratory disease. Increasing obesity rates consequently have a diminished impact on mortality outcomes of elderly populations, and in particular, pension portfolios.

5.3.3. Potential obesity trajectories

Figure 12 shows the timelines of obesity levels of 80 year old males (BMI<30), and figure 13 shows the burden these trends impose on mortality improvement. A number of potential future trajectories are illustrated:

a) Expected Obesity Trajectory – obesity peaks at 35% in the mid 2030's and then gradually decreases

b) Continued Obesity Trend – an unabated continuation of the recent rate of increase in obesity for the foreseeable future. About 40% of 80 year old men are obese by 2032 in this projection.

c) Accelerated Obesity Epidemic – an accelerated trend that imposes a burden on mortality improvement of 0.8%. Over 60% of 80 year old men would be obese by 2032.

The 'Expected' obesity trajectory assumes that the obesity epidemic will slow, stabilize and then potentially decrease, as the generations behind this one reject obesity as a lifestyle. Eventually the rate of increase must slow – it obviously cannot exceed 100% – but it is likely that stabilization could occur much sooner. This 'expected' projection is broadly similar to the projection of the U.K. Government Office for Science Foresight report[27] which expects obesity levels of 52% (90% confidence interval of 48-55%) for males aged 21-60 by 2034.

[26] Kivimaki (2008) & Berrington de Gonzales (2010) & Orpana (2010)

[27] Foresight Report: *Tackling Obesities: Future Choices* (2007)

Figure 12: Future projections for obesity prevalence in 80 year old males

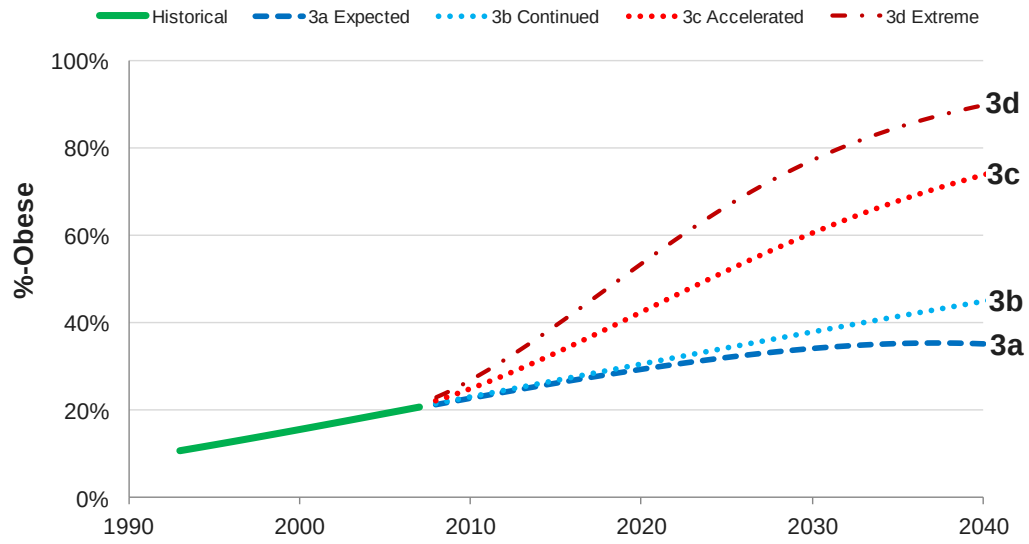
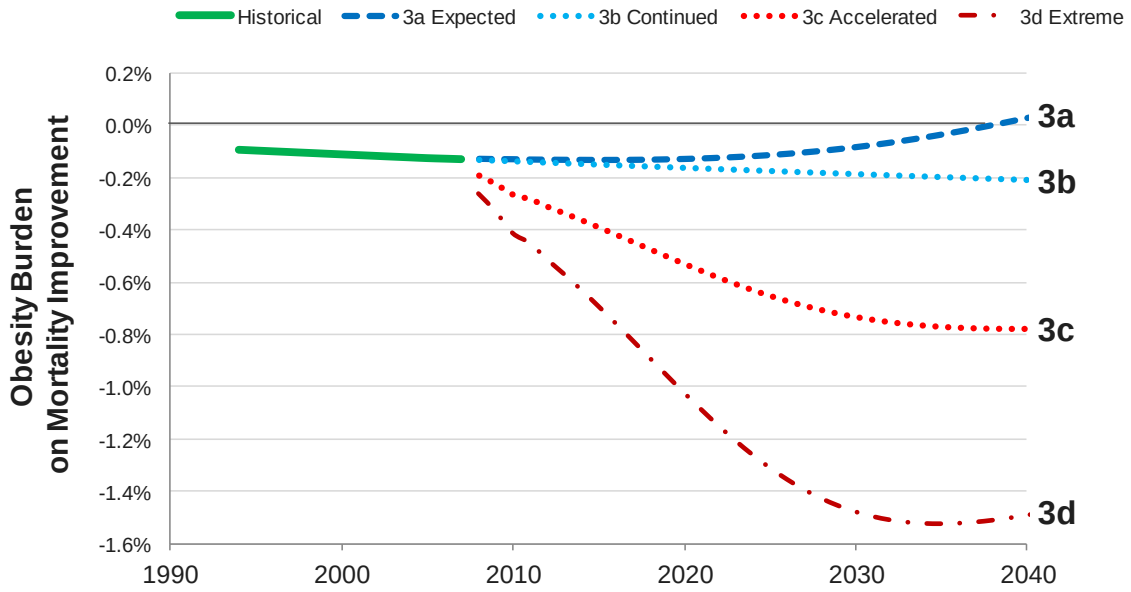


Figure 13: Impact of obesity projections on annual mortality improvement expectations



The RMS projections differ from the Foresight report in having obesity levels on a declining trajectory after 2034, something the Foresight report warns can only be achieved with concerted political will and social endorsement. The difference in post-2034 projections is not significant for this exercise as it is beyond the 20 year timeframe.

However, conceptually we assume that it is likely that the obesity epidemic will follow the paradigm of the smoking epidemic: a wave of uptake, toleration and rejection over several decades and eventually reduced not by individuals changing their own habits, but by fewer individuals in subsequent generations holding to that lifestyle choice. The issue is "when and at what level might this epidemic peak?" Younger people and those of higher socioeconomic status may reject obesity in their peer group earlier. There is little evidence yet to suggest when we might expect

obesity to peak, but there are suggestions that obesity rates may be starting to level off in the U.S.[28] In the 'Expected' projection, we forecast a further near-doubling of obesity before it peaks in 2034 (25 years after the 2009 data). The reducing rate of obesity increase in this projection decreases the burden on mortality improvement. By 2040 it is actually *adding* a small amount to the annual rate of mortality improvement.

The Accelerated Obesity Epidemic scenario of 3c required to impose a burden of 0.8% requires the obesity epidemic to accelerate very significantly – over half of all 80 year old men would be obese within 12 years.

Commentary on Scenario 3 - Obesity

The increase of obesity is imposing a mortality improvement burden today of around 0.1 percentage point. It is plausible to assume that this burden could increase and could further dampen the mortality improvement rates into the future. However, the analysis shows that the burden results from the rate of increase of obesity in the population.

The obesity-related burden on mortality improvement can be increased by accelerating the rate at which the population becomes obese, but sustaining this faster rate of obesity increase over a lengthy period of time, such as the 20 year window of our LTR, results in unlikely future levels of obese 80 year olds. For obesity to impose a burden of 0.8 percentage point results in 60% of 80 year old men being obese by 2032. For this projection to occur, the average 80 year old man would need to be more than 13 kgs (2.1 stone; or 30 lbs) heavier in 2032. This projection is behaviorally and biologically extreme.

As obesity levels rise, it is likely that more severe counter-actions will be taken to combat it. Medical treatments may be applied to reduce the mortality hazard of obesity. These counter-actions will reinforce the positive trends for mortality improvement.

Overall, it seems unlikely that obesity can drive a reversal of mortality trends to account for an extreme trend reversal that would bring annual mortality improvement rates down to 1.5% or less by 2032.

5.4. Summary of Scenarios for Extreme Trend Reversal

In this section we have examined three potential candidate causes of an extreme trend reversal:

- Rapid exhaustion of reducing premature cardiovascular deaths
- Failure to reduce cancer mortality
- The obesity epidemic

None of the above provides a plausible analytical mechanism of sufficient magnitude to assume that mortality improvement rates will reduce from their current levels to below 1.5% a year by 2032.

It is possible that all three mechanisms, occurring together at slightly less extreme levels of implausibility, could combine to bring about a LTR of below 1.5%. One potential correlate that could plausibly cause all three of these mechanisms to occur is the general economic environment: during periods of economic austerity it would be reasonable to assume that funding for medical health care treatment will be constrained, and that poorer lifestyles will result. We examine this in the final section of this paper.

Before that, we consider the other side of the coin: the potential for the recent trends of high mortality improvement to continue or even increase, and the implications these would have for the dimension of the LTR.

6. POTENTIAL TREND CONTINUATION OR INCREASE

The 10-year average rate of annual improvement has been increasing steadily for the past two decades and has now reached approximately 3% for 80 year old males. In the previous section we examined the possibility that rate

[28] Flegal et al (2012)

of annual improvement might undergo an extreme trend reversal and drop to half or a third of its current rate within the next two decades. In this section we consider the implications of the mortality improvement trend continuing at a similar high level, and also the plausibility of a further acceleration to even higher levels of mortality improvement by 2032.

6.1. Scenario 4: 'Trend Neutral' Assumptions

There is little evidence in the data to suggest that the increasing trend of mortality improvement has exhausted or is about to turn dramatically. A more prudent approach would be to assume that this rate of improvement will continue at something similar to this magnitude.

6.1.1. Continuing lifestyle improvements

The potential outlook for further improvements to be made in reducing premature CVD are described below. Smoking rates are likely to decline further – public support is high for decreasing smoking levels further, and measures under debate include banning retail displays of cigarettes, banning smoking in private cars, removing branding from cigarette packaging, and increasingly aggressive public health interventions. Smoking rates are already low for 80 year old men, so the benefits that will accrue from further smoking reduction will be relatively modest, but they should be expected. Reductions of CVD mortality will also accrue from general improvements in lifestyle practices that are verifiably healthier in each year's 80 year olds, with increasing levels of exercise and diet choices. There seems no obvious sign of lifestyle reversals or new risk factor practices that might change these patterns. Increasing alcohol consumption in middle age is one potential concern, but this is not currently a mortality hazard of sufficient scale to change a 20 year outlook. The changes in lifestyle that have been occurring over the past generation are still in process, many can still benefit from this, and there is no obvious reason to expect this not to continue at some speed or another.

6.1.2. CVD mortality erosion from medical intervention

CVD mortality can reasonably be expected to continue to benefit from strong medical intervention. The health service has developed an understanding of how to achieve these benefits and is focused, resourced and incentivized to bring CVD mortality down further. Continuing to reduce CVD mortality by 4% a year will entail improving the targeting of people at risk and improving the efficacy of preventative treatments for those given prescriptions. General Practitioners are being encouraged to extend CVD risk assessment to more of their patients using blood tests, exercise stress tests and other techniques. Further improvements in extending the life expectancy of people who have suffered a CVD event can be expected with new generations of pharmaceutical treatments and surgical techniques currently in development.

6.1.3. Cancer advances

Cancer mortality can be expected to continue to erode, and as outlined above, the investment levels in medical research and focus of health care professionals holds out the promise of more rapid progress in reducing cancer deaths than has been seen to date. Cancer mortality is difficult to erode but it would be rational to expect at least the recent levels of progress to continue. The benefits that have been seen in CVD mortality improvement from people giving up smoking could also be expected to continue to drive mortality erosion from cancer, particularly lung cancer, for many more years to come. When someone quits smoking, their risk of CVD reduces significantly within three months but their risk of lung cancer reduces much more gradually. It takes a number of years after quitting for the risk of cancer to start to decline. This benefit increases the longer a person remains smoke free[29]. So the benefits already seen in reduced CVD from reducing smoking levels in the population over the past 20 years could be expected to be reflected in reduced cancer prevalence over the next 20 years. We considered, above in section 5.2.3, the possibility of a potential increase in cancer prevalence from some new lifestyle habit, but showed that

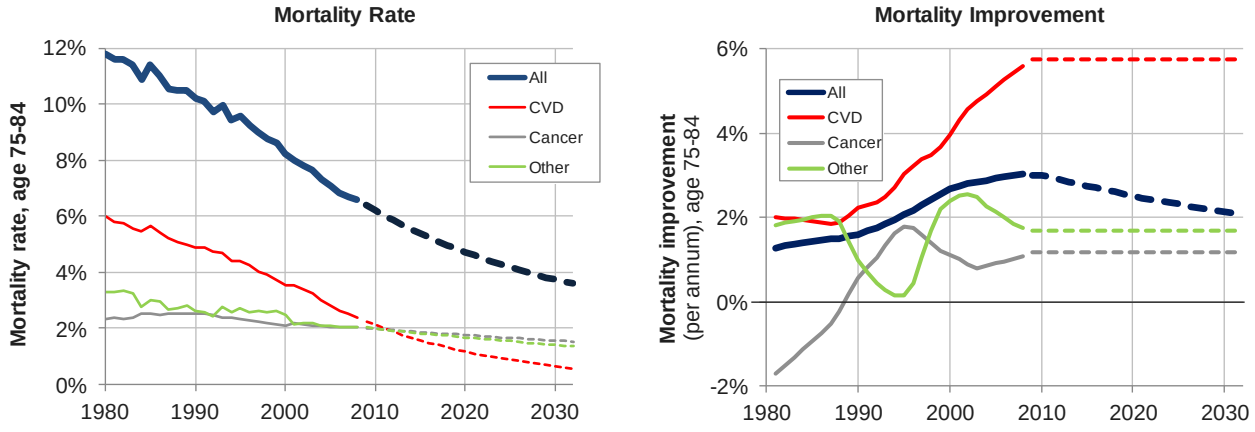
[29] U.S. Department of Health and Human Services. *The Health Consequences of Smoking: A Report of the Surgeon General*.

there is no evidence to suggest that this should be a concern or a legitimate factor in mortality improvement estimation.

6.1.4. New medical advances: regenerative medicine

It would be sensible to factor in to future estimates of mortality improvements any new medical advances that could potentially make an additional contribution to the reduction of mortality. The most promising technologies are regenerative medicine: new techniques to repair damaged body tissue and organs that could not previously be healed. Stem cell therapy is an example. It is currently an experimental technique that has had a series of successful proof-of-concept innovative operations to replace or regrow damaged body parts. It holds out the promise of being able to repair some debilitating conditions like strokes, damaged heart tissue, and diseased lungs, that reduce life expectancy significantly today, and so could potentially have an impact on population-level mortality improvement rates if and when they were applied as treatments. Regenerative techniques are currently at early-stage development, with pioneering operations and experimentation. From precedents of new medical developments in the past, new techniques at this early stage will take a long time to go from proof-of-concept to standard practice and become widely available as a conventional treatment. Refinements, overcoming set-backs, clinical trials and demonstration of safety require a significant amount of time. The timing from 'bench to bedside' (research phase to widespread availability as a treatment) from precedents such as penicillin, stains, tuberculosis treatments, antibiotics and other medical innovations varies from 25 years to 60 years. This means that it is extremely unlikely that new treatments currently being publicized in successful research experiments will become available fast enough to influence mortality improvements in the 20 year timeframe under consideration for this LTR assessment.

Figure 14: Scenario 4: 'Trend Neutral' assumptions for the projection of annual mortality improvements to 2032



6.1.5. Modeling scenario 4: trend neutral assumptions

In modeling the 'trend neutral' assumption, mortality improvement rates are maintained at their current levels. This holds for lifestyle rates, including the assumptions that smoking continues to decline at current rates, and obesity continues to increase along its recent trajectory. Medical intervention progress continues with CVD mortality improvement trends at current levels and no spectacular changes to the rate of progress of cancer mortality erosion. The resulting overall mortality improvement rate falls gradually as cancer and other causes of death begin to dominate mortality as time progresses, but overall rates of mortality improvement are still running at around 2.0% by 2032.

6.2. Scenario 5: Further Acceleration of Mortality Improvement

To balance the study, we also consider the potential for mortality improvement rates to increase, rather than decline. There is no obvious bounding constraint that would prevent a higher level of improvement rate occurring. In this

scenario we explore plausible upper limits to trends that could be sustained over the period of interest, and analyze the outcome.

A marked increase in the rate of mortality improvement would require processes to happen more quickly: smoking rates and lifestyle changes would occur at a faster pace than they have previously, medical treatments would improve their effectiveness more rapidly, and their expansion to treat more of the population would happen faster.

6.2.1. *Lifestyle changes to achieve further acceleration of improvement*

It is feasible for smoking rates to reduce much more rapidly than has been observed in recent years. In a study of policy to combat smoking, a 'wipe-out' scenario is envisioned where smoking prevalence could decline at twice the recent rate, becoming almost eradicated within the next 20 years.[30] This requires aggressive measures by the government to ban and tax smoking, combined with less tolerance of smoking by public opinion.

The rate at which healthier lifestyle are adopted by the population could also increase in the future. Lifestyle changes so far have mainly been occurring in the higher socioeconomic groups, and those with higher educational attainment. A rapid adoption of similar healthier diets and exercise regimes across the manual and routine laboring socioeconomic groups could involve larger numbers of people changing their lifestyle and accelerate mortality improvement rates.

6.2.2. *Medical intervention trends to achieve further acceleration*

Medical intervention scenarios similarly could be more optimistic than those that are consistent with a perpetuation of recent trends. Preventative medication could be rapidly accelerated, through for example programs to provide universal provision for statins and antihypertensives for the over-50s. Universal provision of the 'polypill' is estimated to be able to reduce ischemic heart disease events by 80%.[31]

Health economists have proposed that strategic reorganization of the NHS could result in very marked improvements in population health metrics, if for example, health care emphasis were to shift from remedial care of medical conditions to one that was focused on preventative treatments and strong engagement with personal lifestyle decisions.

Increased resources for health measures and improvement of performance metrics for the NHS could also greatly improve mortality rates. In this scenario we envision that health care provision statistics in the U.K. climbs to the top of world rankings for national health systems, with performance metrics for the NHS by 2020 on a par with those currently attained by U.S. privatized health care.

Significant improvements could also occur in cancer treatments, over and above those that would result from U.K. NHS performance standards matching those of countries with the best cancer outcomes. New technologies for low-cost early-stage cancer detection could become commonplace within the 20 year outlook. A significant shift in cancer mortality could occur just from a change in the economics of the new generation of cancer treatment drugs, to make them cheaper and easier to qualify for the cost effective metrics to make them available on the NHS. And cancer treatments could even be developed that are a lot more effective than they are today: genetic profiling of cancers is a relatively new technique that could be a turning point in targeting treatments of high efficacy. If current genetic profiling proved effective, it could become a mainstream diagnostic tool perhaps half-way through the 20 year window.

The nascent medical fields of regenerative medicine, such as stem cell therapy, nanotechnology and gene therapy could see early breakthroughs and strong benefits, and a rapid adoption of these techniques would have some limited but contributing addition to mortality improvements by 2032.

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[30] Future Foundation Projects (2005), *Quitting Smoking in the 21st Century*

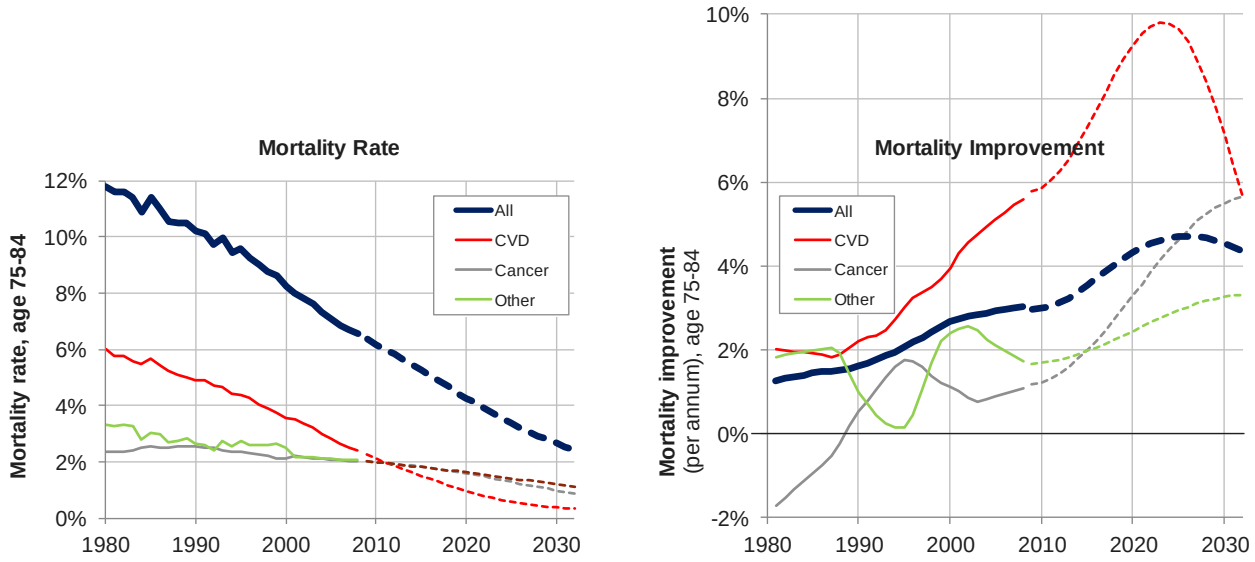
[31] Wald NJ, Law MR (2003), 'A strategy to reduce CVD by more than 80%

6.2.3. *Modeling scenario 5 – further acceleration*

Figure 15 shows the mortality rates and improvement levels that result from these plausible but optimistic assumptions. CVD improvements are initially accelerated by a factor of 3 from current levels, cancer mortality improvement by a factor of 5, and improvement in other causes of death by a factor of 2.

At this pace, CVD mortality rapidly approaches its bounding limits and almost achieves a 90% reduction from present day levels. In effect it becomes almost eradicated as a cause of premature death by 2032. In this scenario CVD improvement peaks at almost 10% in 2024, and then declines as it approaches it's bounding limits. This level of mortality improvement for a particular cause of death is not unprecedented: infectious disease mortality improvement peaked around 17% per annum in the 1950s.

Figure 15: Accelerations in mortality improvement for each cause of death to 2032



In addition, the cancer mortality rate halves, from about 2% to 1%, which corresponds (for example) to the elimination of lung cancer and cancers of the digestive system. These types of cancer benefit most from changes in lifestyle risk factors such as smoking, diet and alcohol intake.

The mortality rate from all other causes of death, particularly causes related to respiratory disease and dementia, drops from 2% to 1.2%.

The resulting overall mortality improvement is above 4.5% per year by 2032.

6.3. Summary of Scenarios for Potential Trend Continuation or Increase

In this section we examined the outcome of continued perpetuation of the recent trends and also a scenario for plausible but aggressive changes that could accelerate future mortality improvement rates.

For either of these scenarios to occur there are significant resource implications. The continuation of the status quo of mortality improvement implies continuity of growth in the funding that is applied to health care, from all sources including government funding for the NHS, private sector investment in medical research and individual decisions about family expenditure on health. It is not sufficient for funding to remain at the same level; it has to be increasing over the next 20 years.

For the scenario of acceleration in mortality improvement, funding increases have to significantly exceed the growth levels seen to date. One of the components of the scenario is that health care performance metrics for the U.K. NHS would improve to the levels of other countries, specifically the U.S. Although expenditure alone is not a determinant

of health care performance, it is a strong correlate. To match U.S. health care funding levels would require more than doubling the U.K. per capita budget for health care.[32] For this to occur, economic conditions would have to be more favorable than they have been.

Making an assessment of which of these scenarios are more likely to occur, and how much mortality improvement we should plan for in the future inevitably involves judgments about the economic outlook as well as medical advances and lifestyle projections. In fact the issues of medical progress, lifestyle changes, and economic progress are all closely linked.

In the next section we examine the relationship between economic growth and mortality improvement, to help guide assumptions about future long term mortality improvement rates.

7. MORTALITY IMPROVEMENT AND ECONOMIC OUTLOOKS

7.1. How Might the Next 20 Years be Different?

The past 20 years has been a period of high mortality improvement. The first set of scenarios explored the possibility of extreme trend reversal – a number of different hypotheses that might bring mortality improvement levels down from around 3% to below 1.5% by 2032. These consisted of exhaustion of CVD mortality improvement, failure of cancer treatments, and the obesity epidemic. None of these provided a convincing mechanism for a trend reversal.

In the absence of a mechanism to drive change, the default position would be an expectation of continuation of current trends. This was explored in the previous section, where another two scenarios were explored: one for continued trends as observed in the recent past, and another for accelerated improvements. With these it was also apparent that the primary determinant of which of these scenarios was the more plausible was the assumption that might be made about the resources available for future health care, which relied in turn on the economic expectations for the next 20 years.

In reviewing the evidence for what might be significantly different between the last 20 years and the next 20, there are two major shifts in the health care environment that have occurred in recent years that suggest that the future might be different to recent experience. The first is the 2008 economic crisis that has changed expectations about future economic growth: There is a real possibility that the growth of economic prosperity of the past 20 years will not be maintained at the same level for the next 20, and that this will have serious implications in health care funding and household health-related expenditure. The second is that there has been a major change in the economics of the pharmaceutical industry – the blockbuster drugs that have fuelled the recent wave of mortality improvement are likely to be the last of their kind. The economic crisis has accelerated the difficulties of the pharmaceutical industry, so both are related.

We consider these in the next sections.

7.2. The 2008 Economic Crisis as a Potential Change Mechanism

The economic outlook for the next 20 years will be influenced by the 2008 economic crisis. Economic growth could be materially different in the future from the recent past. The period from 1993 to 2008 saw almost uninterrupted high economic growth, with U.K. GDP annual growth rates consistently above 3% and occasionally achieving 5%. A similar period of high growth had preceded it, from 1982 to 1990. Figure 16 shows the historical growth trajectory of U.K. GDP and the dramatic fall after 2008. The economic crisis of 2008 caused a deep recession, reaching -6% annual reduction of GDP at its nadir. The impact on Europe has been more profound than in many other countries, and the past four years of economic downturn have changed assumptions and outlooks.

[32] U.K. health expenditure in 2008 was $3,487 per capita, 9% of GDP, U.S. health expenditure was $7,960 per capita, 17.4% of GDP. according to OECD figures of purchasing power parity in OECD (2011).

Figure 16: Historical trajectory of economic growth in U.K., and the impact of the 2008 recession, measured by U.K. Gross Domestic Product and annual growth rate[33]

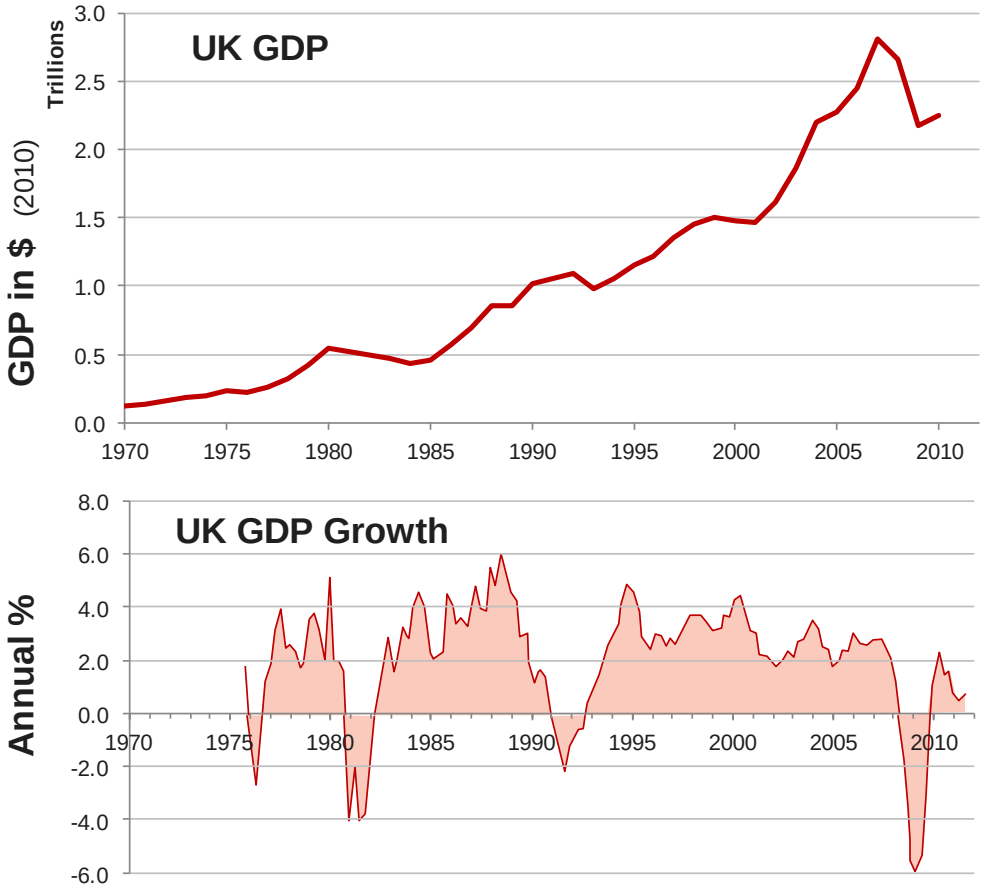
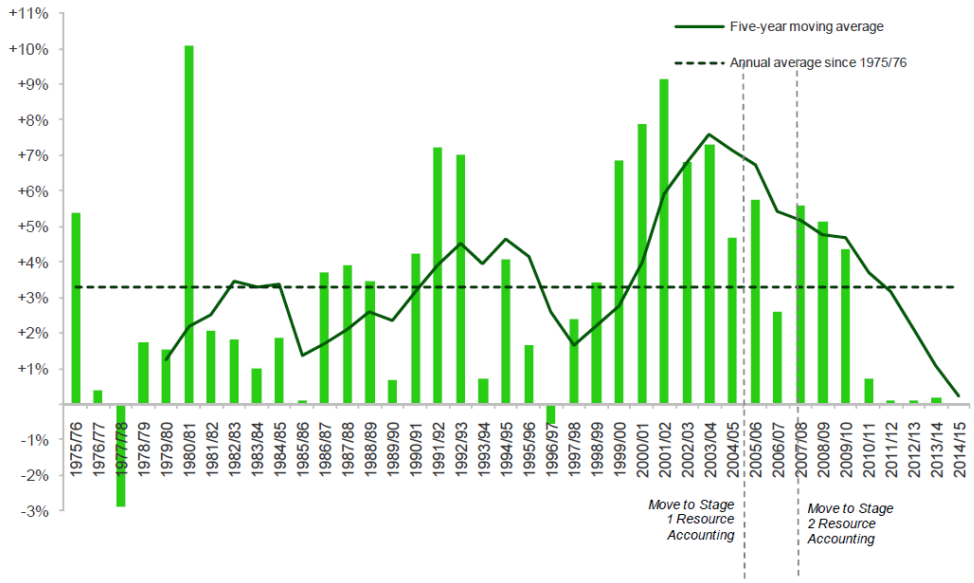


Figure 17: Historical funding increases for U.K. NHS and planned expenditure to 2015: Annual percentage change in real terms.[34]



33 World Bank (2012); *World Development Indicators and Global Development Finance*

34 Harker (2012); 'NHS funding and expenditure'; UK Government House of Commons

7.2.1. Funding freeze for U.K. NHS

The economic crisis and the U.K. budget deficit have caused a reset of expectations around future health care. Figure 17 shows official government figures for projected spending on the NHS, which after three decades of sustained growth, and averaging above 5% annual increase rate since 2002, will have its budget frozen at a rate of zero growth out until at least 2015 as part of the budget deficit measures.

One example of the effect of the spending freeze is that new specialist NHS cancer diagnostic centers originally planned for 2015 and beyond, have been postponed in favor of a strategy of continuing cancer care at existing facilities.[35] This will have implications for the future rate of mortality improvement for cancer as considered in scenarios above.

7.3. Crisis in Pharmaceutical Research and Development

The economic crisis has accelerated, and coincided with, a major readjustment in biotechnology research and funding. Major pharmaceutical companies are radically restructuring their business models and expectations of returns, as their drug development pipelines shrink, and their biggest selling drugs come off patent.[36] An illustrative example is that in 2008 Pfizer's Lipitor statin was the world's bestselling drug with sales of $12.4 Billion.[37] It came off patent in 2011, meaning that many countries, particularly those in the developing world can now obtain generic versions at reduced cost. This will have the positive effect of accelerating mortality improvement in many other countries outside the developed world. However this also has longer term implications for sustaining mortality improvement in countries like U.S. and U.K., as the drugs companies have failed to find the next blockbuster drugs to replace their income streams. Big investments by drugs companies in research and development have failed to produce the returns that they had hoped for. R&D returns have nearly halved over the past decade. As a result, the biotech industry is switching its business model away from drugs targeted on mass populations and more towards specialized niche markets, and emerging markets outside the developed world. This has significant implications, in that population-level mortality improvement has been driven by the rapid uptake of mass-market drugs. If the future development of new mass-market drugs for populations such as U.K. slows significantly, then this will have an effect on future mortality improvement.

Pfizer, GlaxoSmithKline (GSK), Novartis and other pharmaceutical companies have all announced large scale redundancy programs in the U.S. and Europe.[38] Several companies have sold off subsidiaries and broken up research operations. These measures are due at least in part to European government austerity measures - the chief executive of GSK claims that there has been a 5% cut-back in expenditure on drugs, and also a deliberate delay in the introduction of new oncological drugs,[39] and the chief executive of Pfizer has criticized European governments for “sacrificing the long-term future of science in their countries for the sake of short-term budget cuts”.

The global drug industry cut its research spending for the first time ever in 2010, after decades of increases, and now research investment looks set to decline further in future years. Overall expenditure on discovering and developing new medicines amounted to an estimated $68 billion in 2010, down nearly 3% on the $70 billion spent in both 2008 and 2009.

Reduction in funding medical research has the effect of extending research development timelines: For example, the chief executive of GSK claims that what would have taken just 10 years of research in good economic times, may take 12 to 15 years during a prolonged period of austerity.[40] This ‘trend moderation’ in medical intervention implies lower rates of mortality improvement in the next 20 years than has been seen in the last 20.

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35 Department of Health (2011); ‘Improving Outcomes: A Strategy for Cancer’.

36 KPMG (2011); ‘Future Pharma’.

37 Pfizer, (2010); ‘A History’.

38 InPharm.com (2012); ‘Europe’s pharma sector : living through the crisis’

39 BBC (2012), ‘Ministers deny GlaxoSmithKline claims of drug delays’

40 BBC (2012); ibid.

7.4. Relationship Between Economic Prosperity and Mortality

7.4.1. How might the economic downturn affect mortality improvement assumptions?

In this section we explore the relationship between economic growth and levels of mortality improvement, to help guide the assumptions that should be made about LTR levels. We explore different views of the economic future and discuss what these might mean in terms of mortality improvement levels.

It is well established that economic prosperity is closely linked to mortality levels. Wealthier countries today have lower mortality, and over time mortality improvement has tracked with the trend of economic growth.

Wealthy populations exhibit increased life expectancy because greater resources are available to invest in health care and healthier living conditions. Affluence improves educational standards and enables better individual lifestyle decisions. Wealthier societies invest in medical science which generates new beneficial applications and treatments. Within each population, more affluent socioeconomic groups tend to have longer life expectancy.

On an international level, life expectancy at birth and in the elderly is significantly greater in richer countries. A clear correlation exists between income per person and mortality rates. Both are illustrated in figure 18.

For each individual country there is a correlation between GDP per capita and life expectancy measured at different points in time. Figure 19 shows that this relationship has been relatively linear for United Kingdom and U.S. since the 1950s.

7.4.2. Income and mortality within the population

Within each society there are marked difference in mortality levels with affluence, educational attainment levels, and social groups. In the U.K. for example, substantial differences in mortality can be observed between the socioeconomic groups. In 2006, 'higher managerial and professional' occupations had an age period life expectancy of 18.8 years at age 65 compared with 15.3 for men in 'routine' occupations – a difference in life expectancy of 3.5 years.[41] Differences are not all financial, but the median level of earnings of the higher socioeconomic group is more than double that of the lower group.[42] Wealth (accumulated assets) is even more skewed in the population. In the age group 70-79, nearly 50% of those in the poorest quintile of wealth are reportedly in poor or only fair health, compared with 22% in the richest quintile.[43] Health differences related to income are most evident in the lowest income groups, with deprivation being a strong indicator of low life expectancy.[44]

7.4.3. Affluence and health

Affluence influences the level of health in individuals both directly and indirectly. The direct mechanisms are that more affluent households can afford to spend more on health and better living conditions. Higher income households are associated with clerical and service occupations rather than the harsher occupations of manual and routine labor. Affluence is also correlated with higher educational standards, and education level is closely linked with good health practices and outcomes. Better educated people recognize symptoms, self-diagnose, and consult doctors more often; they follow public health advice, and have good compliance with treatments that are prescribed.

Ill health can be a cause as well as a consequence of poverty. Single earner households have weaker social support networks, and stress levels and mental illness rates are notoriously high. Surveys of lifestyle risk factor prevalence in lower socioeconomic groups show that smoking levels are higher (despite smoking being an expensive habit), that high-fat cheap foods are a staple component of diet, obesity levels are higher, and personal health is a low priority in resource-constrained households.

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41 Office of National Statistics (2011).

42 Goldthorpe and McKnight (2004), 'The Economic Basis of Social Class'

43 Banks, Karlsen, and Oldfield (2004)

44 ONS, 2010, *Life Expectancy by Deprivation*

Figure 18: Income and mortality – Life expectancy and income per capita for 181 countries (left) and mortality rates for 75-84 yr old males in 36 countries.[45]

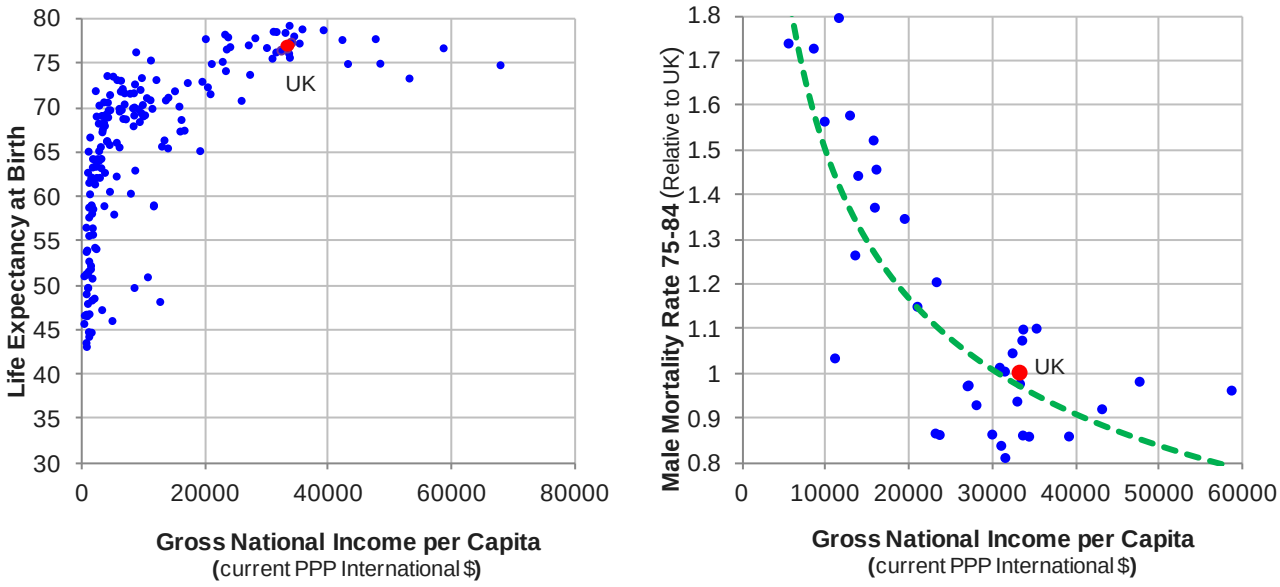
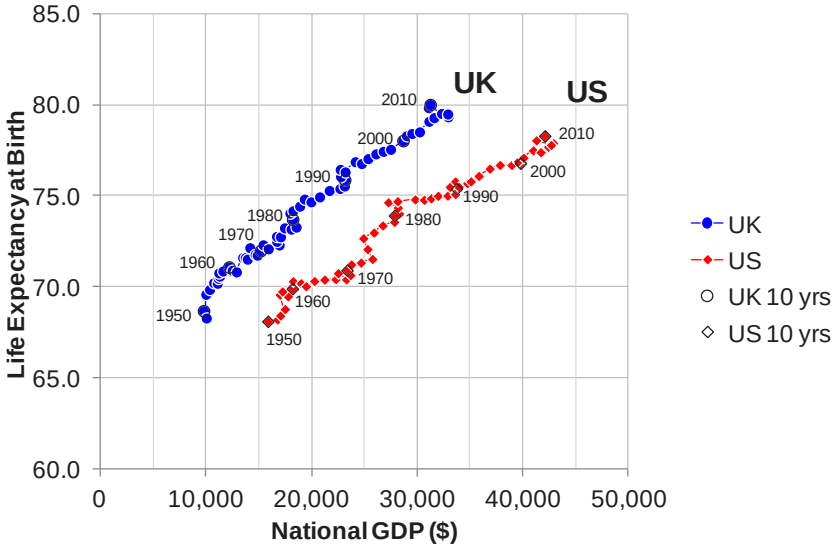


Figure 19: GDP per capita and life expectancy: Time series for U.K. and US.[46]



Extreme social collapse can cause rapid deterioration of lifestyle and reduce life expectancy. In the rapid deterioration of social and economic conditions in the Soviet Union during the 1970s, health deteriorated and life expectancy progress actually reversed, blamed on the high incidence of deprivation and alcoholism.[47] This level of social instability is not a phenomenon expected in developed democracies, but demonstrates the extreme conditions required to reverse mortality improvement.

While changing economic conditions affect the purchasing capabilities of households, the linkages between purchases and healthy lifestyle practice is relatively weak. Long term processes (more than 10 years) affect the

[45] 2005 data with incomes expressed in 2012 dollars. Sources: World Bank (GNI and life-expectancy data for 181 countries), Human Mortality Database (mortality rates by age and gender for 36 countries).

[46] Data to 2010 compiled from IMF World Economic Outlook (2011); and Human Mortality Database (2012).

[47] Ryan (1988) 'Life expectancy and mortality data from the Soviet Union'; in *British Medical Journal*

education level of households, and general affluence of living conditions. The available evidence suggests that lifestyle changes influencing mortality have only a weak relationship to short term economic conditions.

7.4.4. Economic conditions and mortality improvement

Over the long term, economic conditions play a major role in influencing the level of mortality improvement. Over the next 20 years, one can reasonably expect that life expectancy outcomes will be contingent (at least to some degree) on economic fortunes. In this section of the paper simple quantitative arguments will be used to translate views about economic growth in the U.K. into mortality improvement implications for the next two decades.

7.5. Time Lag in Economic Effects on Mortality

The mortality impacts from economic change are not immediate. In the initial period of an economic downturn – the first four years – studies suggest that mortality improvement can initially be *increased*. As consumer spending slows, purchase of cigarettes reduces, there are fewer cars on the road and so fewer traffic accidents, and other beneficial side effects of the initial population reaction to an austerity shock.[48] If it follows these precedents, then the 2008 economic downturn could initially spark a high peak of mortality improvement.

The deep shock to growth levels from 2008/2009 has yet to translate into longer term mortality effects. The -6% recession in 2008 and 2009 followed by weak growth to 2012 can be expected to have some influence on mortality improvement levels over the next four years and over the longer economic cycle. These longer term consequences are structural. Over the 20 year horizon a lower economic period of growth would translate into lower resourcing levels of the health care system, reduced funding for medical research, and less capability for individual households to contribute to their own health expenditure.

7.6. Income-related Influence on Mortality Improvement

Figure 18 depicts the association between male mortality at 75-84 and per capita income across 181 countries. This figure overstates the potential impact of income changes on mortality. Factors that correlate with income and also influence mortality include awareness of health issues and associated lifestyle choices. Such factors do not fully reverse if income does. To avoid overestimating the effect of long term income changes on population mortality, we assume that the relationship is only half as strong as that depicted in figure 18. With this adjustment, the relationship can be used as a first-order guide to the mortality implications of long term changes in income, i.e. the 'income-related influence on mortality improvement'.

Figure 20 translates the average annual growth rate in U.K. income per capita of 3.5% between 1994 and 2007 to approximately 0.75% per annum of income-related influence on mortality improvement. It is used to explore the macro-relationship between income growth and mortality improvement. It demonstrates that if future growth rates are significantly lower than the 3.5% annual rate of economic growth experienced prior to the economic downturn, then the penalty of a reduced mortality improvement rate can be expected to follow. So for example if the future economic growth rate averaged over the next 10 years were to be 2.5% instead of 3.5%, the effective LTR might be reduced by about 0.25%. If the economic growth rate stagnated to zero then this could be expected to impose a mortality improvement downgrade of around 0.75%.

7.7. Scenario 6: Trends Moderated by Economic Crisis – Future Growth Rate of 2.5%

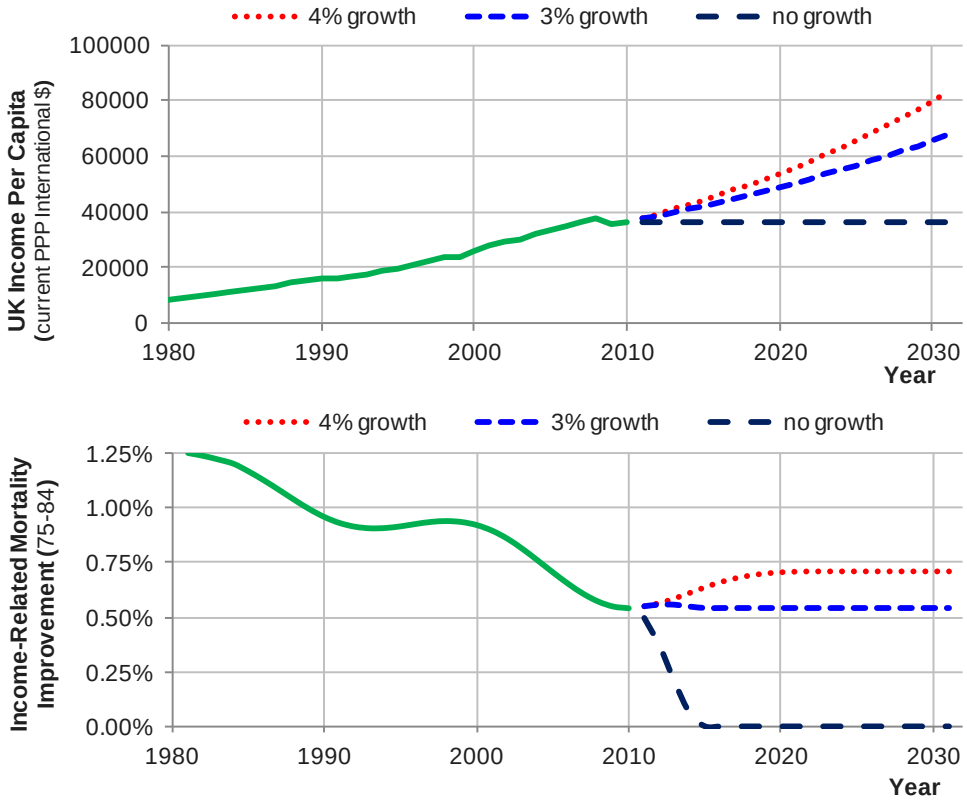
Scenario 6, shown in figure 22, is consistent with a gradual recovery from the recession shock of 2008/9 back to levels of similar growth (3.5% annually) from 2015 onwards. This is the current median outlook for GDP being

[48] Ruhm (2009) 'Economic conditions and health behaviours: are recessions good for your health?'

projected by the Bank of England, as shown in figure 21. For the period 2008 to 2032, this provides an average annual growth rate of 2.5%.[49]

The scenario models the effect of a reduced rate of medical intervention, as budgetary constraints limit the improvements driven by better health care, and medical research and development investment slows – medical research that would have taken 10 years to complete now takes 12.5 years, as a result of lower funding levels. This 'trend moderation' in medical intervention progress is consistent with the current commercial position of the pharmaceutical industry, and the current freeze in health care funding, as described in section 7.1.

Figure 20: Economic growth projections and their modeled trajectories of resulting mortality improvement



The rate of mortality reduction from medical intervention to treat and to use prescription drugs to reduce CVD mortality is similarly subjected to a time dilation of 80%. This is to reflect the current freeze in funding of the U.K. NHS and this assumes that health care funding gradually returns to growth levels similar to those before the economic crisis. Cancer mortality reduction is similarly slowed. The potential for new drugs being adopted is reduced and expenditure on diagnostic improvements and progress towards parity with comparable countries' cancer performance is postponed.

Lifestyle trends are less strongly linked to changes in affluence. The main drivers of health attitudes and practices are educational and income influences this over much longer time periods. Health-related discretionary expenditure by households is likely to drop, although this is likely to be most marked in the lowest income groups. Health outcomes can be expected to widen between disadvantaged groups and higher income groups. As with mortality linked to deprivation, this is likely to be of less relevance to pension scheme populations.

[49] Taking GDP growth estimates as a proxy for GNI per capita growth.

Figure 21: Bank of England projection for GDP growth to 2015[50]

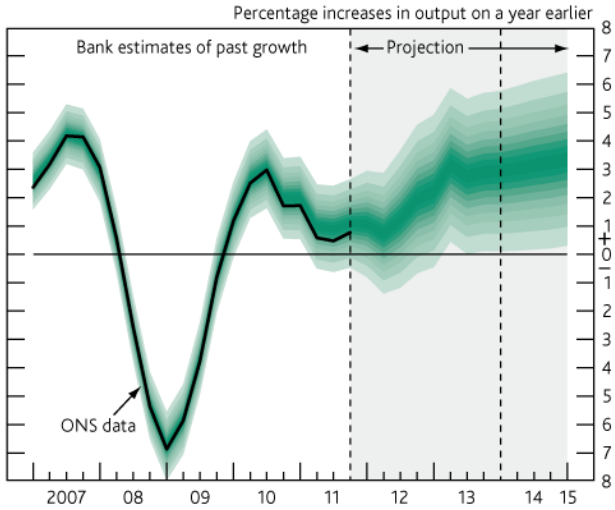
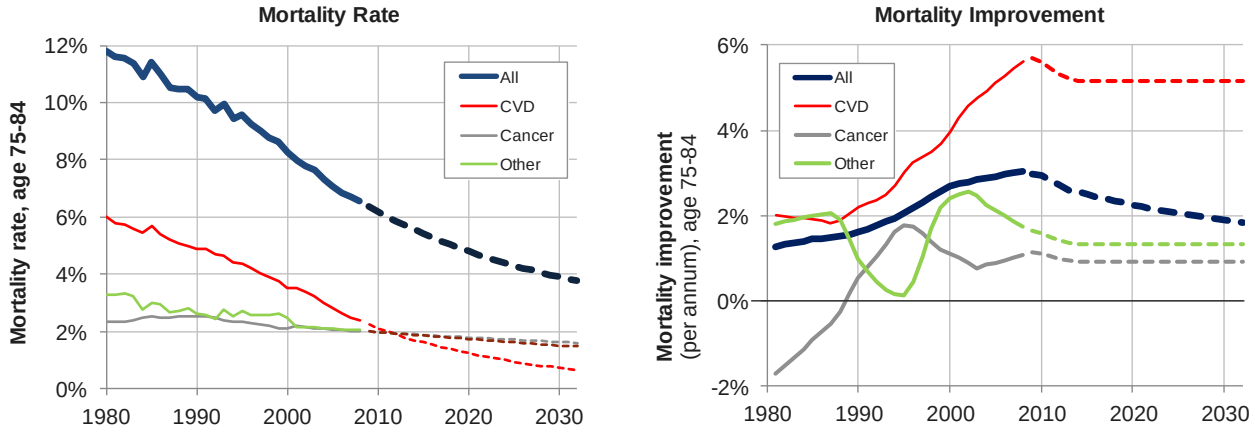


Figure 22: Scenario 6: Trends moderated by economic crisis



The projection in scenario 6 does not include the potential short-term increase in mortality improvement that might be expected to result from the onset of the economic crisis, as observed in other economic downturns, as described above. With that caveat, and assuming that future income growth averages 2.5% from 2008 to 2032, scenario 6 sees the long term mortality improvement rate dip below 2% by 2032.

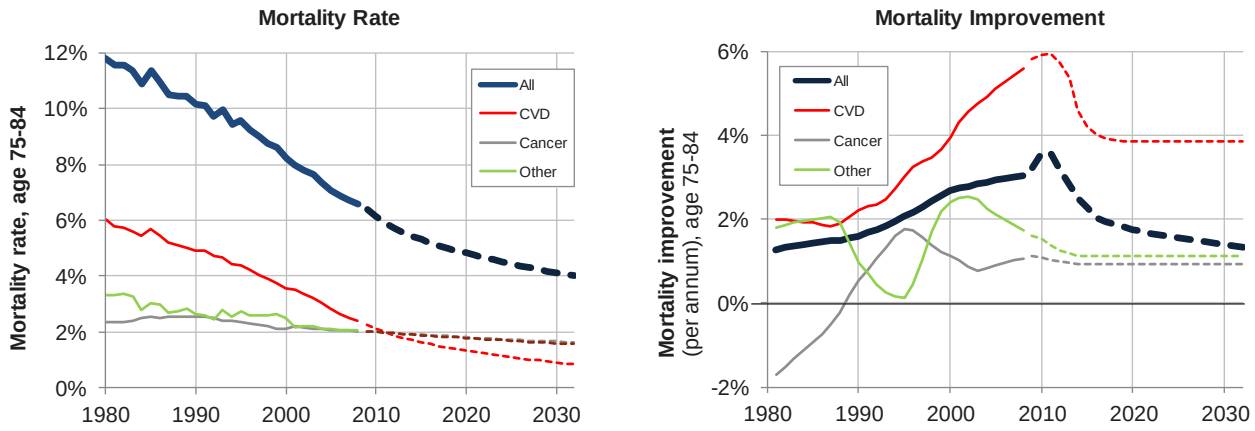
7.8. Scenario 7: Trends Moderated by Economic Stagnation

Scenario 7, shown in figure 23, explores the severity of income growth reduction that would be required to reduce the LTR to below 1.5%.

A continuation of the income growth observed over the past 20 years, (the 'trend neutral' assumption) leads to an LTR of around 2%. For the LTR to reduce to below 1.5%, the rate of average annual income growth would have to stay below 1% for the next 20 years, an effective state of economic stagnation for the foreseeable future.

[50] Bank of England: *GDP Fan Chart; Inflation Report February 2012*

Figure 23: Scenario 7: Trends Moderated by Economic Stagnation



In scenario 7, economic stagnation sees U.K. NHS spending remain at current levels – extending the current freeze on the U.K. government's health care budget – for the foreseeable future.

The trend moderation for medical intervention progress is more severe - i.e. a development that would have taken 10 years, now takes 15 years. Economic stagnation postpones the arrival of new medical advances, such as regenerative medicine, to beyond 2032.

The scenario shows slower improvements across all causes of deaths as separate fields such as CVD controls and cancer prognosis are simultaneously curtailed by the prevailing macro-economic conditions.

The projection in scenario 7 includes an illustrative potential short-term increase in mortality improvement expected to result from the onset of the economic crisis. This phenomenon could also occur in scenario 6, but is uncertain and we have chosen to show its potential form in the more severe scenario 7.

7.9. Commentary on Mortality Assumptions and Economic Outlooks

While RMS is not a specialist in economic forecasting, the scenarios of future mortality improvement considered are contingent on an implicit expectation about economic progress. This section has depicted a relationship between mortality improvement outcomes and prevailing macro-economic conditions.

Making assessments of long term mortality improvement rates is bound up implicitly with expectations about the future economic outlook. In this section we have provided a first-order estimation to make the link explicit, anchoring mortality improvement estimates to annual income growth per capita.

This link is necessary for a holistic approach to pension liability management, where future interest rate assessments and investment expectations should be aligned with mortality improvement estimates.

In the final section we discuss the LTR assumptions that would be appropriate to use in setting liability estimates.

8. CONCLUSIONS

This paper has examined the issue of estimating the LTR of mortality improvement for use in assumption-setting for pension liability assessment: i.e. the year-on-year rate of mortality change by 2032 for 80 year old males in the population of England and Wales.

Surveys of pension funds suggest that the large majority of funds assume a LTR of between 1% and 1.5%.

An historical analysis of mortality improvement shows periods of high and low mortality improvement though time. The past 20 years has seen a lengthy period where the mortality improvement rate has increased to about 3%. This

has been caused by a 'perfect storm' of lifestyle changes in the population, medical technological advance, and increases in national health care expenditure that have reduced all causes of death, but have their strongest impact on reducing premature deaths from CVD.

We examine a number of hypotheses that might cause a reduction in long term mortality improvement rate to a level between 1% and 1.5% by 2032, exploring each through a modeled scenario.

Figure 24 shows a summary of the scenarios presented in this paper.

8.1. Three hypotheses Ruled Out as Sole Drivers of Extreme Trend Reversal

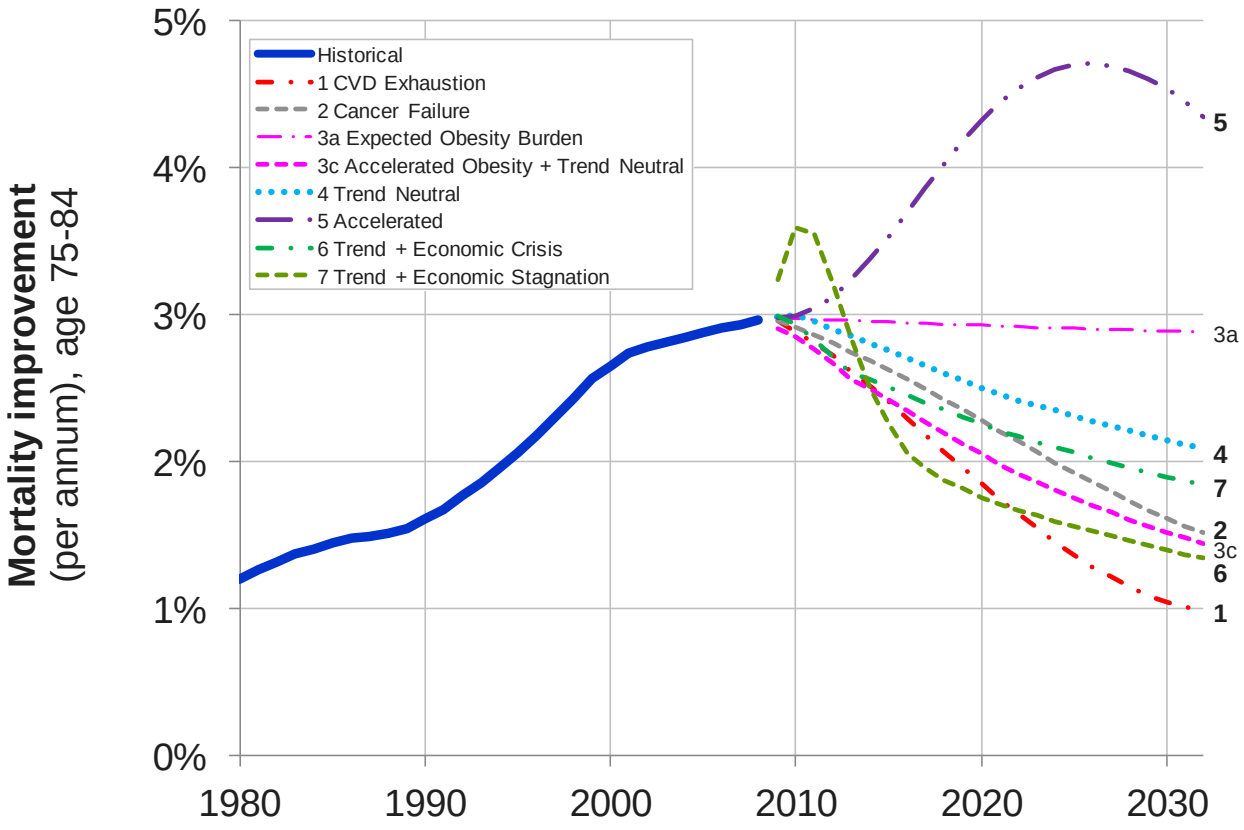
Scenario 1 explores the possibility that gains from CVD might exhaust within this period. We estimate that 'exhaustion' would mean CVD mortality rates dropping to below 2 per 1000 for an 80 year old man. Current rates in 2012 are around 18 per 1000, and current annual rates of reduction of CVD deaths (4% a year) could be maintained until 2032 without approaching this limit. The scenario manages to reduce mortality improvement levels to 1% by 2032 but only by assuming that CVD mortality improvement slows to zero within 20 years, which has no rationale from any current evidence.

Scenario 2 explores the possibility that cancer improvements as hoped and planned for by the medical profession could fail to materialize. Even using very pessimistic assumptions for cancer progress, the overall rate of mortality improvement does not fall below the 1.5% LTR level.

Scenario 3 tests the hypothesis that rising obesity levels in the population could impose a mortality improvement burden that will be sufficient to offset recent levels of mortality improvements and bring the LTR down below 1.5%. The burden on mortality improvement imposed by the current obesity epidemic is relatively light – about 0.1 percentage point - and can only increase by *acceleration* in obesity prevalence. Bringing the LTR below 1.5% requires at least an eight-fold increase in the burden, which requires obesity levels in 80 year old men to rocket up from 20% today to over 60% by 2032, or to put it another way, the average 80 year old man would gain 13 kg (2.1 stone; or 30 lbs).

From these explorations we conclude that there are no obvious individual causal mechanisms to suggest that LTRs of mortality improvement will suffer an extreme trend reversal and reduce to levels below 1.5% by 2032.

Figure 24: Summary of scenarios presented in this paper



Scenario 1: Rapid exhaustion of the rate of reducing premature cardiovascular deaths (CVD improvement slows to zero over 20 years)

Scenario 2: Failure to Reduce Cancer Mortality (Cancer mortality improvement slows to zero over 20 years)

Scenario 3a: Expected Obesity mortality improvement burden (difference from 3% Mortality Improvement)

Scenario 3c: Accelerated Obesity burden applied to Trend Neutral projection: Rapid increase in obesity epidemic leads to 60% of 80 year old men being obese by 2032.

Scenario 4: 'Trend Neutral' Assumptions where underlying current trends of mortality reductions in CVD, cancer and other causes of death are maintained, together with continuation of lifestyle trajectories.

Scenario 5: Further Acceleration of mortality improvement: CVD approaches bounding limits by 2032; cancer mortality rate halves (elimination of lung cancer and cancers of digestive system); mortality rate from all other causes drop to 60% of today's rates by 2032.

Scenario 6: Trends Moderated by Economic Crisis – Future Growth Rate of 2.5%; health care expenditure freeze and reduction in medical research funding slows rate of improvement from medical interventions ('time dilation' of 80%); lifestyle trends unchanged; [Projection excludes potential increase in MI expected at onset of economic crisis]

Scenario 7: Trends Moderated by Economic Stagnation: average annual rate of GDP growth to 2032 drops below 1.25%; health care expenditure freeze and medical research slow-up continues indefinitely; Current trends are reduced to two thirds. [Projection includes illustrative potential increase in MI expected at onset of economic crisis]

8.2. Current Trend Continuity Sets benchmark for Future LTR Expectation

In the absence of a causal mechanism for change it is more logical to assume continuation of current trends.

In scenario 4 we explore a 'trend neutral' future where the current trends continue. The resulting overall mortality improvement rate falls gradually as cancer and other causes of death begin to dominate as leading causes of mortality, but overall rates of mortality improvement remain around 2% by 2032.

8.3. Potential Increase in Current Trends Demonstrate Economics Importance

In scenario 5, we flex the modeling further by exploring what could cause mortality improvements to increase from their recent levels, and the consequences and implications of this. We cite for example performance metrics achieved in the health care systems of other comparable countries, and explore what could happen if U.K. health care achieved by 2032 health outcomes currently enjoyed by U.S. private health care today. This would require more than doubling the health care budget per person. Optimistic assumptions about future medical progress and rapid healthier lifestyles being adopted by the population result in a LTR level of 4.7%.

This illustrates the main issue that future mortality improvement is inexorably linked to future levels of economic outlook.

8.4. Economic Outlook Explicitly Influences Mortality Improvement Levels

The 2008/2009 recession has reset the economic outlook for the short and medium term. This has resulted in several identifiable processes that will influence future mortality. For example U.K. health care expenditure is frozen until at least 2015. Drug companies are restructuring to adjust to new economic conditions, involving slower rates of research progress.

We explore the qualitative and quantitative linkage between population-level mortality improvement levels and national economic growth. A significant component of future mortality improvement levels can be influenced by the level of economic growth sustained over a period of a decade or more. Short term responses of mortality to an economic downturn are likely to be a temporary boost to mortality improvement, but sustained downturns produce structural 'mortality improvement burdens', mainly from lower health care budgets and slower medical advances, with only limited impact on lifestyle trends. We propose an explicit relationship between the benchmark of 'trend neutral' projections and 10-year average annual growth expectations.

8.5. A future GDP Growth Rate Reduced by a Percent Gives an LTR 1.75% to 2%

Scenario 6 models the continuation of current trends, but with the processes likely to be impacted by a lower rate of economic growth. This scenario takes the 2008/2009 recession and Bank of England median projections for growth rates out to 2015 and applies the resultant 10-year average annualized growth rate of 2.5% to explore the impact on mortality improvement rates – i.e. a percentage point lower than the recent GDP growth rate. This suggests that the mortality improvement rate will drop into the range 1.75% to 2.0% by 2032.

8.6. To Achieve an LTR Below 1.5% Requires Long Term Economic Stagnation

In scenario 7, we use this model to explore how much economic growth would have to slow to achieve mortality improvement rates of below 1.5%. Economic growth would have to drop to between 0% and 1.25% annual rate of GDP growth. This means economic stagnation for the foreseeable future.

8.7. Making Recommendations

Figure 24 shows all scenarios developed for this paper. They are conceivable future trajectories. Some of them are more likely to occur than others. The uncertainty about which trajectory will actually come to pass is dependent on the complexity of the processes involved in mass movements of populations and economic development. Some of

the processes that will determine the actual trajectory are dependent on random discovery – such as medical breakthroughs. Others are dependent on future economic conditions.

8.7.1. Probabilistic modeling is better than best estimates

When assessing the provision of reserves for future liabilities, it is important to consider the range of potential outcomes and their likelihoods. RMS prefers probabilistic analysis over the simple use of one 'best estimate' assumption. A fully probabilistic model provides useful information about the uncertainty structure and the likelihood of different levels of outcomes, including the extremes that would cause different degrees of underfunding. Models of extremes that properly capture the tail risk are useful in structuring de-risking activities, where a pension scheme is looking for protection against those versions of the future that could cause financial difficulties.

In this paper we are not trying to capture the full probabilistic structure of future mortality improvement. We are instead describing the views of the future that correspond to different levels of best estimates.

8.7.2. Best estimates

The future trajectory of mortality improvement will be significantly affected by the level of economic growth seen in the economy over the next 20 years.

RMS does not produce economic forecasts. The models of mortality improvement are described here to enable those who have a view about economic projections to set appropriate assumptions that are consistent with them. The RMS models describe the way that health care, lifestyle changes, and medical advances are likely to control the levels of mortality improvement, within different economic growth environments.

Table 3 provides a summary narrative for different levels of assumption about the LTR.

8.8. Providing Context for LTR Decisions

It is complex to analyze the detailed drivers of mortality change and to make assessments of future mortality improvement rates for use in liability estimation.

Any projection will combine some component of historical experience with expectations of future differences. We have argued that using LTR rates of below 1.5%, as currently assumed by a large part of the longevity risk management industry, may be giving too much weighting to the pre-1990 historical past.

Where this might be due to lack of confidence that modeling can provide useable insights, we hope that this paper demonstrates the value of integrating 'cause of improvement' modeling into mortality projection techniques. Our analysis suggests that there is no future level of constant mortality improvement rate that should be expected. Instead there will be future waves of mortality improvement, as new causes arise, play out, and fade. Future mortality levels will be some composite of these waves of change over time.

The lengthy duration of the recent period of high mortality improvement has established that this is not a temporary aberration. The continuous process of increasing mortality improvement rate seen since the 1970s has established that this is a structural shift in the process and mechanisms of mortality improvement.

Our research suggests that the recent trends should be treated as the new default, rather than the earlier 20th century mortality improvement regimes that dominate the longer term historical record. We believe that the underlying processes that are driving the causes of improvement, such as medical technologies, processes of social change, and importance of health care, now endemic to our modern society and will be perpetuated into the future.

The prospect of the rate of annual mortality improvement undergoing an extreme trend reversal and dropping to a third of its current value is considered by RMS to be lacking a plausible causal mechanism.

We also recognize that it is very important that any projection of future mortality should not over-estimate mortality improvements. Where high and low projections are of equal uncertainty, it is natural and prudent to take a lower

projection. There are very real and immediate costs entailed in over-reserving. The costs of under-reserving are less immediate and can be adjusted over time.

This report sets out views of the future, with their equivalences as a level of LTR. We hope that this report provides narrative, explanation, and context to help users make their own decisions on what LTR is appropriate for them, and that fits their beliefs and assumptions.

By putting the mortality improvement views of the future into a framework of economic growth expectations, we hope this increases the usefulness of integrating longevity assumptions with assessments of investment returns and other components of pension risk management.

We hope this analysis provides a useful context for the many different components of the pension risk management industry to debate and manage the complexities of longevity risk.

Table 3: Assumed LTR of mortality Improvement for 80 year old male in U.K. that is prevailing in 2032

Longevity Risk Category	LTR Range	LTR Representative Value	LE Increase for 80 yr old male	Lifestyle	Health care System Performance	Trends in reduction of mortality from CVD	Trends in Cancer Mortality and other causes of death	Biotech Advances
1	**Below 0.75%**	0.25%	+X.Y yrs	Social collapse leads to deterioration in average health, including rapid rise of obesity, with resurgence of smoking, alcoholism and increased deprivation.	Health care system performance declines to a level comparable with lowest levels in Europe.	Progress in reducing mortality from CVD drops to about 10% of its recent rate.	Cancer-related mortality is either static or sees gradual increases, due to lifestyle deteriorations.	Biotech industry stops investing in research that targets population-level mortality in Western countries.
2	**0.75% to 1.25%**	1.0%	+X.Y yrs	Smoking rates stagnate at current levels of around 20%. Healthier lifestyle adoption ceases within a decade. Stress and hypertension increase significantly.	Heathcare outcome metrics improve at only half the rate of the past 20 years. NHS budget is maintained at close to 2012 funding levels in real terms, for next 20 years.	Progress in reducing mortality from CVD drops to about half of its recent rate.	No further progress in reducing cancer-related mortality. Other causes of death see modest improvements.	Biotech industry refocuses on emerging markets and cuts back on investment in research that targets population-level mortality in Western countries.
3	**1.25% to 1.75%**	1.5%	+X.Y yrs	Population smoking rate declines slow. Obesity increases more rapidly than recent trend. Uptake of healthier living practices slows.	Health care outcome metrics improve at only two-thirds of the rate of the past 20 years, as result of health care budget reductions.	Progress in reducing mortality from CVD drops to about two-thirds of its recent rate.	Reduction in cancer mortality slows with treatment cost constraints. Improvements from other causes also slow.	Pharmaceutical industry cuts back on R&D - a 10 year project now takes 15 years. New progress is mainly in targeted therapies that are expensive and benefit only a minority of the population.
4	**1.75% to 2.25%**	2.0%	+X.Y yrs	Current rate of smoking decline continues from around 20% of population today to around 15% by 2032. Obesity trends continue at current rates. Uptake of healthier living practices continues.	Health care system continues to deliver mortality improvements at a similar level to recent years, or reduced if NHS funding freeze is lengthy.	Mortality improvement from CVD treatments, such as statins and blood pressure drugs, continues. Trend possibly moderated by health care funding reductions. Overall CVD improvement rate falls gradually over time with diminishing returns.	Cancer deaths continue current improvement trend, possibly with some moderation from treatment cost constraints. Other causes continue recent trends.	Pharmaceutical industry slows its development - a 10 year project now takes 12 years. New biotech breakthroughs occur at a similar rate or less, than the recent past.
5	**2.25% to 2.75%**	2.5%	+X.Y yrs	Smoking rates decline at a faster rate than in recent past, to 10% in 2032, as a result of increasingly pro-active government and social actions. Rates of obesity increase begin to slow, particularly in the young. Health awareness spreads rapidly.	U.K. improves health care outcome performance from recent years to achieve levels similar to European average by 2032. Health care funding levels grow at similar or better rates than recent past.	More aggressive provision of preventative treatments increases rate of mortality improvement from premature CVD deaths.	Better cancer diagnostics take U.K. to European average and provide increased levels of cancer mortality improvements.	Biotech industry produces new drugs for mass population conditions at a similar rate to the past. Niche targeted drugs and individualized therapies provide benefits for many people.
6	**2.75% to 3.5%**	3.0%	+X.Y yrs	Smoking rates decline rapidly, become 'de-normalized' - only 5% of population smokes in 2032. Obesity levels stabilize within 15 years. Healthy living, exercise, and careful diet adopted by all sectors of the population.	Health care system improves to achieve performance equal to highest quartile of European countries (parity with Denmark). Shift of funding emphasis from remedial medical care to preventative health care programs.	CVD mortality improvement rates nearly double as a result of pro-active screening of population, more aggressive treatment and other measures.	Cancer breakthroughs provide cheap new drugs that drive big improvements in cancer-related mortality.	Regenerative medicine provides new classes of treatments, reducing mortality for previously untreatable conditions. Targeted therapies are widespread, cheap, and drive significant additions to mortality improvement.
7	**Above 3.5%**	4.5%	+X.Y yrs	Smoking wipe out - by 2032 less than 3% of population smokes. Obesity levels are reducing by 2032. U.K. general population rapidly adopts good health practices.	By 2032 U.K. health care system becomes comparable with best performance anywhere in the world (e.g. U.S. privatized health care), enabled by doubling of per-capita funding.	CVD improvements reach 3 times current levels, peaking in mid-2020s, reducing from then on. CVD almost eradicated as a cause of premature death by 2032.	Cancer mortality halves, as mortality is eliminated from lung and digestive cancers. 40% reduction in mortality rates from respiratory disease, dementia, and all other causes.	Regenerative medicine (e.g. stem cell therapy, nanotechnology, gene therapy) has early breakthroughs, strong benefits, and a rapid adoption. Individualized therapies are the norm.

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10. ACKNOWLEDGMENTS

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Table 4: Summary

	LTR Range	LTR Rep Value	Dilation	Summary Description	Economic Outlook (10-Yr Annualized Growth Rate)	Health care System Performance	Lifestyle
1	Below 0.75%	0.25%	10%	Social collapse causing growing health care issues, deprivation and extreme deterioration in national health care service and performance. This would be consistent with a very lengthy economic recession in U.K.	Sustained economic recession	Health care system performance declines to a level comparable with lowest levels in Europe.	Social collapse leads to deterioration in average health, including rapid rise of obesity, combined with resurgence of smoking, alcoholism and increased deprivation.
2	0.75% to 1.25%	1.0%	40%	Trends of progress and improvement in reducing mortality slow to below half of their recent levels. This is consistent with long term economic stagnation (annual economic growth averages 0% to 1.0%); Progress in reducing mortality from the major causes of CVD and cancer is severely curtailed. Rates of reducing smoking slow to a stop and healthier lifestyle adoption ceases	Stagnation (0 to 1%)	Improvements in heathcare outcome metrics slow to below half of the rate of the past 20 years. NHS budget is maintained at close to 2012 funding levels in real terms, for next 20 years	Smoking rates stop reducing and healthier lifestyle adoption ceases within a decade
3	1.25% to 1.75%	1.5%	67%	Progress in reducing mortality by medical intervention is slowed significantly from those observed in the recent past, and lifestyle changes, such as smoking rate reduction and adoption of healthier lifestyles, slow significantly. Future rates of progress are only two-thirds of recent trends. This is consistent with expectations of long term U.K. economic growth rates of 1 to 2%	1% to 2%	Health care outcome metrics in U.K. stop improving at the past rate, as result of health care budget reductions. Rates of improvement are only two-thirds of those achieved recently.	The rate of reduction of smoking slows, to around two thirds of recent trend. Obesity increases more rapidly than recent trend. Uptake of healthier living practices slows.

	LTR Range	LTR Rep Value	Dilation	Summary Description	Economic Outlook (10-Yr Annualized Growth Rate)	Health care System Performance	Lifestyle
4	1.75% to 2.25%	2.0%	97%	Recent trends observed over the past 20 years continue, but are moderated by future economic conditions. The economic crisis of 2008/9 results in a reduction of the rate of progress in improving health care performance as a result of e.g. the current NHS funding freeze. New medical advances are slowed by reduced private sector funding. Economic outlook is consistent with Bank of England 2012 median forecast of U.K. economic growth.	2% to 3%	Health care improvement trajectories are maintained at recent levels	Current rate of smoking decline continues, obesity trends continue at current rates. Uptake of healthier living practices continues.
5	2.25% to 2.75%	2.5%	130%	Mortality improvement levels of the past 20 years are continued for the next 20 years. Any slowing of CVD improvement is offset by increased improvements from other causes of death. This most likely results from rapid increases in health care funding and subsequent improvements in health outcomes. The obesity epidemic slows its progress. Cancer diagnostics and prognosis standards in U.K. rapidly achieve those of the European average.	3% to 5%	U.K. achieves health care outcome performance similar to European average by 2032	Smoking rates decline at a faster rate than in recent past, as a result of increasingly pro-active government and social actions. Rates of obesity increase begin to slow, particularly in the young. Health awareness spreads rapidly.

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6	2.75% to 3.5%	3.0%	167%	The mortality improvement level of the past 10 years is perpetuated for the next 20 years. This is enabled by rapid economic growth which in turn is used to improve the funding and outcome performance indicators of the U.K. health care system. Smoking quickly dies out as a habit. Programs of proactive preventative medicine are funded that increase the rate of detecting CVD risk and increasing the rate at which CVD mortality is reduced.	Above 5%	NHS achieves performance of highest quartile of European countries (parity with Denmark). Shift of funding emphasis from remedial medical care to preventative health care programs.	Smoking rates decline rapidly, as a result of 'de-normalizing smoking' policies. Obesity levels stabilize within 15 years. Healthy living, exercise, and careful diet become a widespread practice across all parts of the population.
7	Above 3.5%	4.5%	275%	By 2032, U.K. NHS achieves health care performance outcomes of U.S. privatized health care today – enabled by a doubling of per capita funding. Major breakthroughs are achieved in reducing cancer mortality, eliminating for example lung and digestive cancers. Premature deaths from CVD are almost eliminated. The nascent medical field of regenerative medicine begins to have impact on reducing mortality	Significantly above 5%	By 2032 U.K. health care system becomes comparable with highest health outcome metrics anywhere in the world (e.g. U.S. privatized health care)	Smoking wipe out. Obesity levels reducing by 2032. U.K. general population rapidly adopts good health practices.