THE COHORT EFFECT: INSIGHTS AND EXPLANATIONS

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ABSTRACT

The purpose of the report is to achieve a greater understanding of the United Kingdom 'cohort effect' by exploring research in other fields and analysing population mortality data by cause of death in more detail. The 'cohort effect' in this context is the observed phenomenon that people born in the U.K. between 1925 and 1945 (centred on the generation born in 1931) have experienced more rapid improvement in mortality than generations born either side of this period.

In a Continuous Mortality Investigation (CMI) Bureau working paper published in 2002, a similar trend was noted in the mortality experience of male pensioners and males with life assurance policies. The CMI Bureau investigation showed peak rates of improvement for the cohort born in 1926. Interim projection bases for future mortality experience were produced as a result of the study. The projections made various assumptions about the extent to which the observed cohort effect would continue to shape the pattern of future mortality improvement.

This report suggests that it is highly likely that the cohort effect has been caused by a number of different factors in combination. Prevalence of smoking from one generation to the next has certainly been one such factor. Furthermore, an analysis of patterns of cigarette smoking suggests that there is a degree of inevitability in some element of likely future improvement, especially for mortality at older ages from conditions strongly linked to smoking.

However, trends in heart disease and breast cancer mortality suggest that smoking is not the only factor. The differences between lung cancer and heart disease trends by year of birth are especially interesting. The report shows that there are two 'sub-cohorts' of the 1925 to 1945 cohort: an earlier group where the improvements may be largely due to smoking; and a later one where other factors, such as diet in early life, may have played a greater role.

Historic patterns of smoking behaviour by socio-economic class provide an explanation for the five-year difference in the year of birth showing the fastest improvements, i.e. the difference between 1926 for the CMI Bureau investigation and 1931 for the general population. It is also notable that the second 'sub-cohort' of high improvement, applying to people born in the early 1940s, can be seen in both population and CMI experience.

A case study examining Japanese mortality experience shows that strong cohort trends can be projected well into old age. This does not provide proof that the U.K. cohort effect will do the same. However, it does counter arguments that year of birth effects will inevitably wear off with age. It is especially interesting given recent epidemiological research linking early life experience with markers of ageing.

There are a number of reasons to believe that the U.K. cohort effect will have an enduring impact on rates of mortality improvement in future decades. These include historical patterns of smoking behaviour and the impact of early life experience on health in later life. There appears to be little evidence to support the idea that the width of the generation experiencing rapid improvement will reduce with time.

KEYWORDS

Mortality; Longevity; Year of Birth; Cohort Effect; Smoking; Cause of Death; Lung Cancer; Heart Disease; Breast Cancer

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1. Introduction

1.1 The purpose of the report is to achieve a greater understanding of the United Kingdom 'cohort effect', by exploring research in other fields and analysing population mortality data in more detail.

1.2 First of all, in Section 2, the report briefly overviews evidence for the existence of the U.K. cohort effect, and discusses methods of graphical presentation. In Sections 3, 4 and 5, research in other disciplines is explored. Specifically, insights into the cohort effect are sought from epidemiology, social science and demography. With this background, possible explanations are discussed in Section 6, with particular emphasis placed on the role of smoking behaviour. In Section 7, trends in specific causes of death in England and Wales are analysed. Understanding of the cohort effect is sought by modelling the impact of year of birth on rates of mortality change. An interesting case study of international mortality improvement is discussed in Section 8, namely that of Japan. Finally, in Section 9, conclusions are drawn and areas for further research highlighted.

1.3 Throughout this paper the term 'mortality improvement' is used to signify the reduction in the rate of mortality for a given age from one year to the next. The mortality rates used are central, rather than initial, rates. So, the mortality improvement rate for age x in calendar year $t = 1 - m_{x,t}/m_{x,t-1}$. Where multi-year periods are reported, average annual improvement rates have been calculated, using log-linear regression fitted to values of m_x in successive calendar years, unless otherwise stated.

2. Evidence for the U.K. Cohort Effect

2.1 *Population Experience*

2.1.1 Reports published by the Government Actuary's Department (GAD) (1995, 2001, 2002) have highlighted the existence of a cohort of the U.K. population which has experienced relatively rapid mortality improvement. The generations born between 1925 and 1945 (centred on the generation born in 1931) have experienced more rapid improvement than earlier and later generations. This feature has been noted for both males and females in the U.K., and is sometimes referred to as the U.K. 'cohort effect.' This is purely a descriptive term for the observed trend, and does not a have a specific statistical meaning.

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2.1.2 The GAD (2002) states that it is not yet understood precisely why members of the generation born around 1931 have been enjoying such lower death rates throughout their adult life than preceding generations, or why the rate of improvement slowed down for following generations. However, it does note that men in this generation, in particular, have smoked fewer cigarettes than those in preceding generations.

2.2 *Assured Life Experience*

2.2.1 Willets (1999) suggested that a similar generational effect could be seen in U.K assured life experience. More substantial evidence for this was published in a Continuous Mortality Investigation (CMI) Bureau working paper, which investigated the possible existence and impact of such an effect (2002). The CMI Bureau working paper noted the existence of a similar trend, centred on a slightly earlier generation. Data for male assured lives provided clear evidence of year of birth related effects in mortality improvement, with the cohort centred on births in 1926 the most pronounced.

2.2.2 The working paper also described an analysis of data for male life office pensioners, retiring at or after normal retirement age. A similar cohort effect was noted in this data set, with the peak improvements also occurring in the 1926 cohort.

2.2.3 These cohort trends were incorporated into projections of future mortality outlined in the paper. The mortality projections assumed that the 'width' of the generation experiencing rapid improvement would reduce with time. For the period 1992 to 2000, the width was taken to be 33 years (i.e. those born between 1910 and 1942). It was then assumed to reduce linearly to one year (i.e. 1926) by the end of the 'cohort period'. The 'cohort period' was taken as being ten, 20 and 40 years for 'short cohort', 'medium cohort' and 'long cohort' projections, respectively.

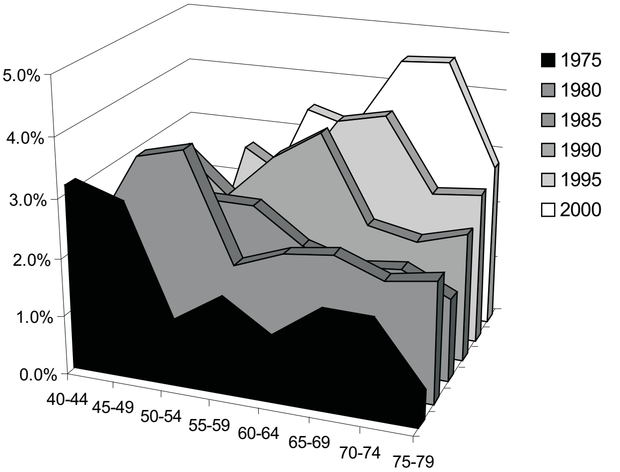
2.2.4 If the cohort effect is projected forwards into future years, we can expect rapid improvements in mortality rates for people in the U.K. in their 60s and 70s in the first decade of the 21st century. In the next decade, rapid improvement would be seen for people in their 70s and 80s, and so on. If not adequately allowed for now, the impact of this would include increased annuity reserves and increased funding levels for final salary pension schemes. The consequences of such projections have been much discussed in recent years (e.g. Willets, 1999; CMI, 2002).

2.3 *Graphical Representation of Cohort Effects*

2.3.1 Cohort patterns in mortality improvement can be appreciated most readily through graphical representation of past trends. GAD and CMI Bureau reports have successfully used coloured 'contour maps' to illustrate improvement patterns. This approach involves deriving smoothed rates of improvement by age and calendar year. Different ranges of improvement rates are denoted by different colours, which are then plotted on a two-dimensional surface. Cohort effects can easily be seen as diagonal blocks of colour.

2.3.2 Willets (1999) used an alternative method of presentation, showing improvement rates by decade using three-dimensional block graphs. Alternative versions of these graphs, constructed using individual age GAD data for males and females in the England and Wales population, are given as Figures 1a and 1b. Each block in the graphs represents a calendar year, and, for each calendar year, average annual mortality improvement rates are shown by age group. The improvement rates have been derived using log-linear regression on data for periods of five years centred around each calendar year (e.g. 1998 to 2002 for year '2000'). The average for each age group is the mean improvement rate for the five individual ages within the group. Figures 1a and 1b indicate that the greatest improvements in the 1970s were experienced by people then in their 40s, in the 1980s by people in their 50s, and in the 1990s by people in their 60s. Now, at the beginning of the 21st century, the greatest improvements are being experienced by men and women in their late 60s or early 70s.

2.3.3 The data used to produce Figures 1a and 1b are given in Tables 1a and 1b. The age groups showing the fastest improvement are highlighted, and can be seen to move diagonally, indicating that the same birth cohort has consistently experienced the most rapid mortality improvement.



Data source: GAD

Figure 1a. Average annual mortality improvement rates by age group and calendar year for males in the population of England and Wales

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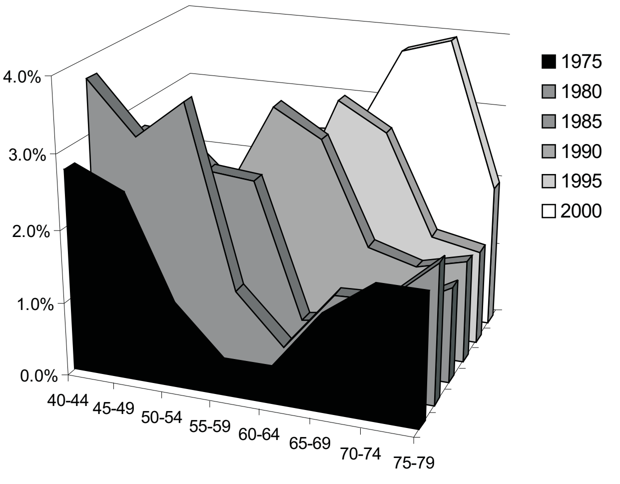

Data source: GAD

Figure 1b. Average annual mortality improvement rates by age group and calendar year for females in the population of England and Wales

Table 1a. Average annual mortality improvement rates by age and decade for males in the population of England and Wales

	Calendar year					
Age group	1975	1980	1985	1990	1995	2000
40-44	**3.1%**	2.1%	1.6%	0.1%	0.3%	0.9%
45-49	**2.9%**	**3.5%**	**2.8%**	**3.1%**	0.4%	0.2%
50-54	1.0%	**3.7%**	**2.6%**	**2.3%**	2.9%	1.7%
55-59	1.5%	1.8%	**2.6%**	**3.1%**	2.4%	3.5%
60-64	1.0%	2.1%	2.0%	**3.6%**	**3.6%**	3.2%
65-69	1.6%	2.2%	1.7%	2.1%	**3.8%**	**4.5%**
70-74	1.6%	1.9%	1.8%	2.0%	2.5%	**4.6%**
75-79	0.5%	2.1%	1.4%	2.2%	2.6%	2.8%

Data source: GAD

2.3.4 The equivalent information for females is given in Table 1b. The figures in Table 1b indicate that exactly the same ‘cohort effect’ has applied for females as for males. This is notable, given that the relative importance of different causes of death varies by gender.

2.3.5 An alternative method of illustrating cohort trends is to compare average rates of mortality improvement for different birth cohorts. An example of this approach is given in Figure 2, which uses population data for

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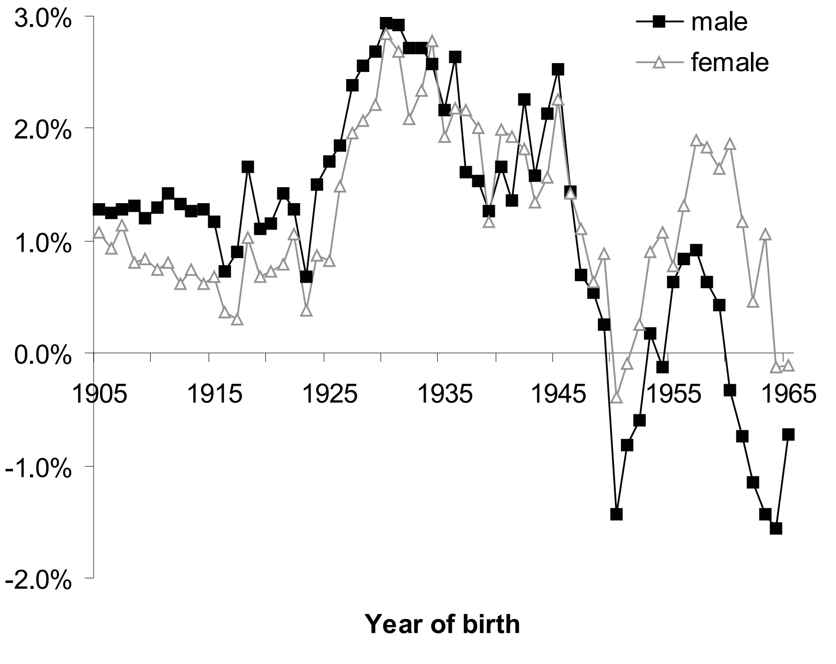
Table 1b. Average annual mortality improvement rates by age and decade for females in the population of England and Wales

	Calendar year					
Age group	1975	1980	1985	1990	1995	2000
40-44	**2.7%**	**3.7%**	1.0%	2.7%	1.6%	2.3%
45-49	**2.4%**	**3.0%**	1.6%	2.6%	1.3%	0.3%
50-54	1.0%	**3.6%**	**2.5%**	2.0%	1.7%	1.6%
55-59	0.4%	1.1%	**2.4%**	**3.2%**	1.7%	2.5%
60-64	0.4%	0.5%	0.6%	**2.8%**	**3.2%**	2.5%
65-69	1.2%	1.3%	0.7%	1.4%	**2.8%**	**3.7%**
70-74	1.7%	1.3%	1.0%	1.2%	1.4%	**4.0%**
75-79	1.7%	1.9%	1.3%	1.4%	1.3%	2.0%

Data source: GAD



Data source: GAD

Figure 2. Average rates of mortality improvement by year of birth, smoothed using five-year rolling averages and gender, over the period 1961 to 2002 for the population of England and Wales

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Table 2. Average annual rates of mortality improvement by birth cohort and gender for the population of England and Wales over the period 1961 to 2002

Birth cohort	Male	Female
1900-1924	1.2%	0.8%
1925-1944	2.2%	2.0%
1945-1959	0.4%	1.0%

Data source: GAD

ages 20 to 89. It is clear from this graph that mortality has improved more rapidly for people born in the period 1925 to 1944. This is further illustrated by the figures in Table 2.

2.3.6 An obvious issue with the figures given in Figure 2 and Table 2 is that each year of birth contains experience from a different range of ages. If experience were averaged for a particular range of ages, then each year of birth would contain experience from a different set of calendar years. Untangling the interaction between year of birth, age and calendar year is a major difficulty in the analysis of mortality trends by year of birth, and is discussed further in Section 5.2.

3. Insights from Epidemiology

3.1 *Historical Epidemiological Developments*

3.1.1 In recent years, epidemiologists have become increasingly interested in the impact of early life experience on health in later life. This has actually been a re-emergence of interest in an area which was much debated in the first 40 years of the 20th century.

3.1.2 Kuh & Davey Smith (1993) describe research at the beginning of the 20th century, which concluded that year of birth was more important than year of death in the prediction of mortality risk. Specifically, they refer to work by the actuary Derrick (1927). Derrick noted that age specific mortality rates plotted against year of birth were strikingly parallel, and interpreted this as indicating that each succeeding generation displayed a lower mortality risk at all ages. He commented:

> "... the age factor in the determination of mortality has varied very little over the last eighty years, and ... nearly the whole of the temporal change is due to an entirely independent generation influence, each generation being endowed with a vitality peculiarly its own, which persistently manifests itself through the succeeding stages of its existence ..."

In 1934, medical scientists, Kermack, McKendrick & McKinlay (1934) came to the same conclusion, i.e. that each generation carried with it the same relative mortality throughout life. As a result they argued that:

"... a good environment in childhood builds up a stronger constitution and raises the standard of physique of the adolescent to a substantial degree ... [and that] ... care of the children in their first 10-15 years of life is of supreme importance. It is at this period of life that improved environment exercises its effect most promptly, and furthermore the improved physique built up during this period would seem to be of decisive effect at all later ages."

3.1.3 Kuh & Davey Smith argue that these findings were complementary to emerging ideas in the 1930s in the science of nutrition, psychoanalysis and public health medicine. It was widely believed that poor nutrition in childhood would lead to poor health status in later life.

3.1.4 However, the conclusions of Derrick and Kermack *et al*. began to be challenged when it became apparent that predictions based on cohort trends were not being fulfilled in practice. In the 1930s, mortality rates for adults stopped declining or increased slightly as a result of higher deaths from lung cancer and heart disease. Kuh & Davey Smith describe how the 'generational approach' to forecasting mortality was eventually rejected by the Statistics Committee of the Royal Commission on Population in the early 1950s.

3.1.5 At the same time, epidemiologists' focus on nurture in early life was giving way to research into environmental risk factors in adult life for particular causes of death, especially lung cancer and heart disease. In the case of heart disease, much of the research was focusing on the 'classic' risk factors of blood pressure, smoking and cholesterol.

3.1.6 However, these factors alone failed to account for social and geographical differences in heart disease rates, and, in the 1970s and 1980s, some epidemiologists began to re-visit the idea that factors operating in early life could have a significant impact on health in later life. In the U.K., this work focussed on exploring the impact of weight at birth on adult high blood pressure and mortality from heart disease, e.g. Wadsworth *et al*. (1985) and Barker *et al*. (1989). Barker (1990, 1995) developed a hypothesis that fetal undernutrition in late gestation, which leads to disproportionate fetal growth, programmes later coronary heart disease.

3.2 *Recent Epidemiological Insights*

3.2.1 The idea that early life experience has an impact on health in later life has gained widespread acceptance in recent years. For example, in the Government White Paper *Saving Lives: our Healthier Nation* (1999), the following statement is made:

"There are influences in very early childhood, including while a baby is still in the womb, which determine a person's risk of developing coronary heart disease later in life. For example, small size at birth is an important risk factor for coronary heart disease in adult life. Some argue that these influences are related to nutrition."

3.2.2 Ongoing medical research in this field is helping to define the

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extent to which early life experience has an ongoing influence on mortality and morbidity.

3.2.3 Eriksson *et al.* (2001) published research showing that, irrespective of weight at birth, low weight gain during infancy was associated with increased risk of coronary heart disease.

3.2.4 Barker & Lackland (2003) found that areas of England and Wales with high stroke mortality were characterised, in the past, by poor living standards, demonstrated by high infant and maternal mortality and short stature in the adult population. People who were born in areas of high stroke mortality, rather than migrating into them, were at higher risk. They argued that stroke may originate through maternal influences associated with poverty.

3.2.5 Sayer *et al.* (1998) found associations between poor early growth in infancy and markers of ageing in later life (such as reduced grip strength and thinner skin). They suggested that ageing may be programmed by events in early life; a potential cause being impaired development of repair mechanisms.

3.3 *Possible Impact on Mortality Trends*

3.3.1 These insights from epidemiology are interesting, because they suggest that changes in early life conditions (in terms of maternal nutrition, birth weight and growth in early infancy) from one generation to the next could have a lasting impact on rates of mortality improvement.

3.3.2 Kuh *et al.* (2002) describe how epidemiologists have also begun to focus on the potential of a 'life course approach' to aid in understanding the variations in the health and disease of populations over time, across countries, and between social groups. They argue that:

> "A life course approach starts from the premise that various factors throughout life, independently, cumulatively, and interactively, affect health outcomes in later life. Thus, at the population level, explanations for disease trends need to be sought in the differential life experiences of successive birth cohorts or generations."

3.3.3 This is exactly what actuaries could, and indeed should, be doing, when seeking to explain patterns of mortality improvement.

4. Insights from Social Science

4.1 *Social Science*

4.1.1 Researchers in disciplines such as social science and economics have also been interested in the different life histories of people born in different generations. People born in different periods have often had very different social and economic forces shaping their lives. Where the differences are marked, the behaviours, attitudes and health characteristics of the

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generations can be very different. This theme is explored by social scientists such as Maria Evandrou and Jane Falkingham — see Evandrou (1997) or Evandrou & Falkingham (2000).

4.1.2 For instance, differences between the cohort born in 1916 to 1920 and the cohort born in 1941 to 1945 are interesting, given the marked difference in mortality rates by age experienced by these two generations, just 25 years apart in time.

4.1.3 People born in 1916 to 1920 experienced the depression of the 1930s in the latter part of their childhood and World War II in early adulthood. Many would have been forced to leave school at an early age, and then been involved in active service during the war. As discussed further in Section 6.5, the vast majority of this generation would have started to smoke cigarettes before or during the war.

4.1.4 In contrast, those born in 1941 to 1945 did not experience World War II (except as young children), and grew up under the umbrella of the welfare state. The time after the war was a relatively austere period of rationing, selective education and regeneration. However, when they entered the labour market in the 1960s the economy was relatively prosperous; the job market was buoyant; and many more people were able to stay on at school and enter higher education.

4.2 *Possible Impact on Mortality Trends*

Research of this nature is useful in at least two main respects. Firstly, it can help us to develop possible explanations for mortality trends which we have observed, and secondly, it can help us to put the task of mortality projection into a wider perspective. When we are trying to predict the life expectancy of people now aged 65, we should not forget that we have a vast amount of information about people of this age. Specifically, we have 65 years' worth of mortality and health data, and we know precisely what economic and social conditions have applied over the course of these people's lives. We can also compare this information with that for people born in previous generations.

5. Insights from Demography

5.1 *Period versus Cohort Effects*

5.1.1 One of the most comprehensive review papers produced in recent years on the topic of mortality projection in demography was 'Mortality Change and Forecasting; how Much and how Little do we Know?' by Tuljapurkar & Boe (1998). On the subject of the influence of birth cohort, the authors list a number of papers which indicate that a period analysis (i.e. one based on calendar year) is more appropriate than one based on birth cohort. They conclude that period effects have primacy over cohort effects, and that:

> "in general, cohort-specific effects have played a limited role in the analysis and forecasting of mortality."

5.1.2 However, it is worth noting that one of the papers which Tuljapurkar & Boe cite as evidence for this conclusion is 'A Relational Model of Mortality at Older Ages in Low Mortality Countries' by Himes, Preston & Condran (1994). This paper contains a few brief mentions of year of birth as a factor in mortality improvement, and no systematic analysis of cohort trends. The paper does show that mortality rates have fallen steadily over time in all developed countries.

5.1.3 Tuljapurkar & Boe do suggest that the potential for employing childhood conditions to predict adult mortality deserves to be explored further. They describe a theory of mortality developed by Fogel (1994), in which height and body mass are the key predictors of mortality change.

5.2 *Age-Period-Cohort Models*

5.2.1 The most common approach used in demography to analyse cohort trends is the age-period-cohort (APC) model. A simple linear APC model can be written as a model for log mortality rates, in which the effects of age, period (i.e. calendar year) and cohort (i.e. year of birth) combine additively (Tabeau, 2001):

$$\log \lambda_{ijk} = \mu + \alpha_i + \beta_j + \chi_k$$

where λ_{ijk} is the rate of mortality, μ is an intercept, $\alpha_i\,(i = 1, \ldots, I)$, $\beta_j\,(j = 1, \ldots, J)$, and $\chi_k\,(k = 1, \ldots, K)$ are the log-linear effects due to age, period and cohort, respectively. The usual constraints imposed on the parameters imply that $\Sigma\alpha_i = \Sigma\beta_j = \Sigma\chi_k = 0$. The model can be estimated using Poisson maximum likelihood (or weighted least-squares) methods. However, there is no unique set of parameters that results in an optimal fit, since age, period and cohort are linearly dependent (i.e. $j - i = k$).

5.2.2 In addition to this problem, the basic model can be criticised as being an overly simplistic representation of reality. In practice, the pace of mortality improvement over time has varied by age. The simple linear model assumes an age independent period effect. Furthermore, the impact of age on the pace of improvement has shifted with time, with an acceleration of the rate of improvement at higher ages. Wilmoth (1997) has described this trend as being the 'ageing of mortality improvement'.

5.2.3 Mortality improvements exhibited by each generation are also likely to vary by attained age. For example, if there were generational factors that impacted on heart disease mortality (say maternal nutrition *in utero*),

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these would have more impact on rates of improvement for middle aged and older adults than for younger adults, because heart disease is not a major cause of death (in relative terms) for younger adults. The impact of behaviours which have a negative impact on health (such as smoking) are also likely to accumulate over the lifetime of birth cohorts, and could have a greater impact on mortality at older ages.

5.2.4 Mortality improvements exhibited by each generation may also vary by period. Over the course of the 20th century, mortality improvement in developed countries has shifted from being largely due to the elimination of infectious diseases, to the reduction in mortality from chronic adult disorders, such as cancer and heart disease. Temporal patterns in the disease categories, giving rise to mortality improvement, will have a different impact on different birth cohorts, depending on the life histories of the different generations.

5.2.5 APC models have been modified by demographers to reflect some of these complexities. For more detail see Wilmoth (1990) or Tabeau (2001).

5.3 *Possible Impact on Mortality Trends*

5.3.1 Generally speaking, in the analysis and projection of mortality rates, demographers are currently placing much more emphasis on factors such as age and period than on year of birth.

5.3.2 On one level, this is very understandable. In developed countries, mortality rates for the very old are hundreds of times greater than rates for the very young, and, over the past century, we have seen massive improvements in medicine and standards of living, and consequent increases in life expectancy. Age and time are clearly factors which can, and have, had a massive impact on trends in mortality rates.

5.3.3 On the other hand, analysing trends by year of birth can help to explain some of the second order variations in the pace of mortality improvement. In comparison, this is a relatively minor point. However, when the purpose for projecting mortality is to price an annuity product, or to value a pension scheme, relatively small differences in rates of mortality improvement can have a significant effect on the answer.

6. Possible Explanations

6.1 *General*

It is likely that the U.K. cohort effect has been caused by a combination of different factors, which have produced very different life histories for generations born only a few years apart. Some of these factors are discussed in more detail below.

6.2 *World War II*

It has been suggested that a possible reason for the rapid mortality improvement experienced by the 1925 to 1944 generation is less to do with beneficial conditions applying to that generation, and much more to do with the adverse conditions applying to the previous generation. In particular, it may be relevant that World War II lasted from 1939 to 1945, so that most of those born after 1926 are unlikely to have experienced active service in any major conflict.

6.3 *Diet*

6.3.1 The diet in post war Britain may have had particular health benefits and a positive impact on the development of children growing up in this period. The period of food rationing lasted until the 1950s. However, average consumption of fresh vegetables, bread, milk, potatoes and fish was higher in the post war years than during the early 1990s (ONS, 1997). Conversely, consumption of cheese and meat was lower in the period after World War II.

6.3.2 Prynne *et al*. (1999) compared the food and nutrient intake of four-year-old children in 1950 with the diet of children of the same age in 1992/3. Compared with 1992/3, the 1950 diet contained substantially more bread and vegetables and less sugar and soft drinks, giving it a higher starch and fibre content. This made the 1950 diet more in line with current recommendations on healthy eating. The authors concluded that the relative austerity of post-war food supplies resulted in food and nutrient intake which, in many respects, may well have been beneficial to the health of young children.

6.3.3 Research showing that the season of birth is an important predictor in adult life expectancy may also be relevant. Gavrilov & Gavrilova (1999) argue that the seasonal lack of certain vitamins & nutrients (for example folic acid and vitamins B_{12}, B_6, C and E) may explain why people born in specific months have shown reduced life expectancy. If this theory is correct, then lack of certain foodstuffs in particular periods during and after World War II may have contributed towards the pattern of mortality improvement for those generations.

6.4 *The Welfare State*

6.4.1 The 1940s was a period of great social change in the U.K. The Beveridge Report, advocating the creation of a welfare state, was published in 1942, and two years later the Education Act established free secondary education as a universal right. In 1947, the National Health Service was launched.

6.4.2 As a result, the social environment in the U.K was very different for children growing up in the 1940s and 1950s, compared with previous decades.

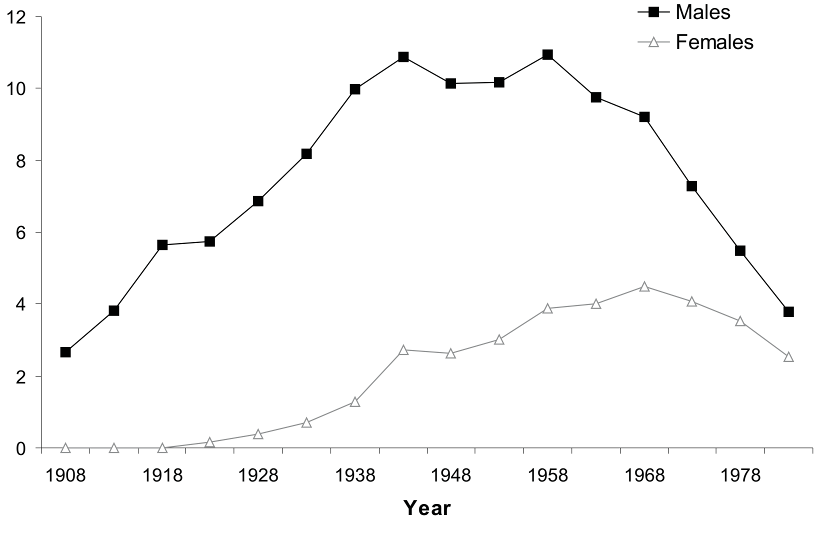
6.5 *Smoking Behaviour*

6.5.1 There have been strong cohort related patterns in diseases linked to smoking, such as lung cancer, and these patterns will be analysed in detail in Section 7. However, trends in cigarette smoking are illustrated by Figures 3 and 4. (ONS, 1997 & 2001).

6.5.2 Average cigarette consumption for males in Britain climbed steadily during the period from 1900 to 1940, stayed constant from 1940 to 1960, fell steadily during the 1960s, 1970s and 1980s, and has shown signs of stabilising in the 1990s.

6.5.3 Cigarette consumption for females has always been much lower than for males. The peak rate of consumption occurred in the 1960s, after slow, but steady, growth from the early part of the century. In the 1960s the average cigarette consumption of females was still less than half that of males. During the 1970s and 1980s consumption fell slightly, and then stabilised in the 1990s. Now, the prevalence of cigarette smoking is broadly similar for males and females.

6.5.4 During World War II, cigarettes were distributed free to those on active service. In the period after the war, the health consequences of cigarette smoking began to be investigated in earnest. The classic 'Doctors



Data source: ONS (1997)

Figure 3. Average cigarette consumption per person in Britain per day, by gender, over the period 1908 to 1983

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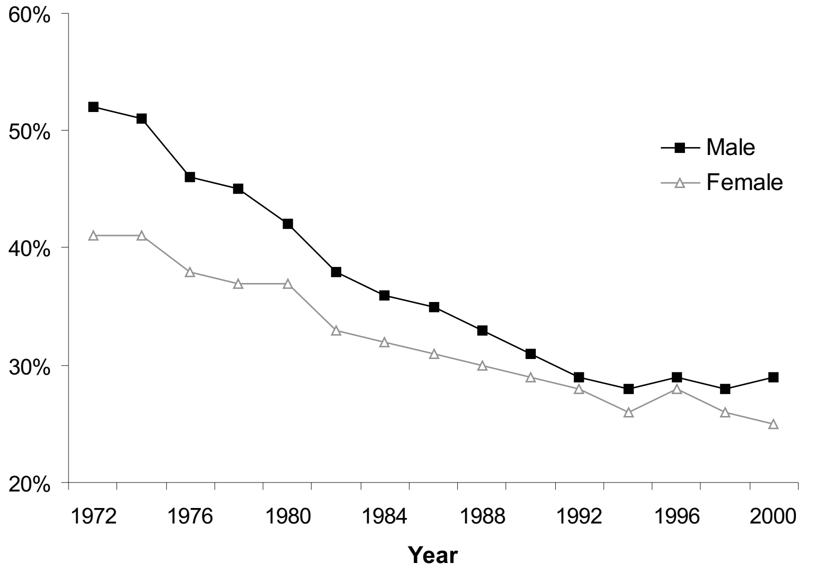

Data source: ONS (2002a)

Figure 4. Prevalence of cigarette smoking in Britain over the period 1972 to 2000

Study', which investigated mortality differentials between non-smokers and smokers, was initiated in 1951 (Doll *et al.*, 1994). Consumption of cigarettes began to fall as the health concerns began to emerge.

6.5.5 People born in different generations have, therefore, had very different smoking histories. The generation born around 1920 may have started smoking in the 1930s, been given free cigarettes during the war, and been smoking for, perhaps, 20 years before the health issues surrounding smoking first became the focus of medical research. On the other hand, those born around 1940 would have reached adulthood during a time when the links between health and smoking were becoming increasingly debated and analysed.

6.5.6 Evandrou & Falkingham (2002) examined trends in the prevalence of smoking by age, gender and socio-economic class. They estimated that, by the time when they reached age 60, approximately 95% of men born in 1916 to 1920 had smoked cigarettes at some point in their lives. Furthermore, upon reaching this age, roughly 45% continued to smoke cigarettes. In contrast, approximately 25% of men born in the period 1931 to 1935 were smokers upon reaching the age of 60.

6.5.7 Lifetime consumption of cigarettes (at any given age) has,

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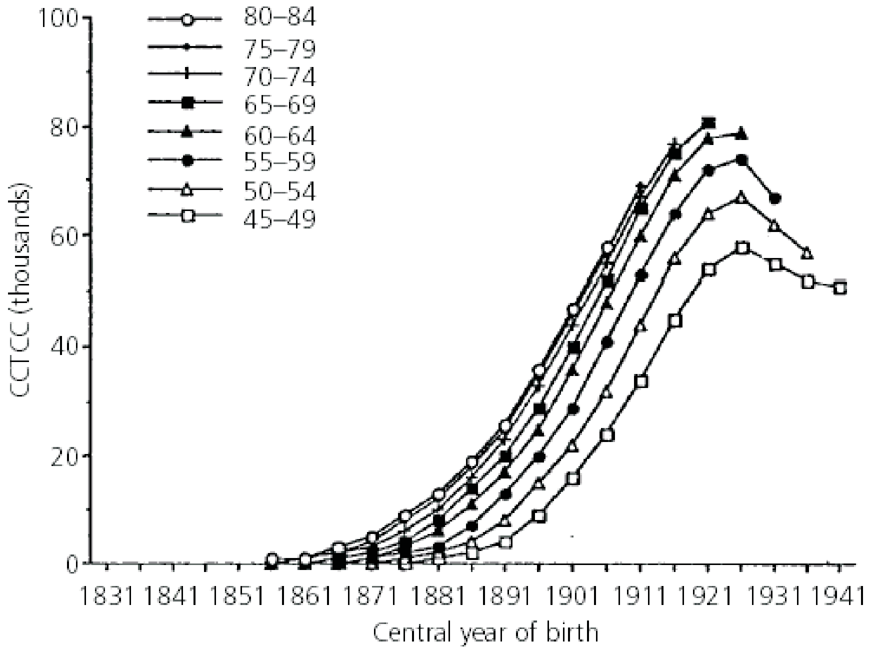


Figure 5. Female cumulative constant tar cigarette consumption (CCTCC) by age and central year of birth, U.K., taken from a factsheet produced by the Lung and Asthma Information Agency (1993), which is based on data originally produced by Lee *et al.* (1990)

therefore, been very dependent on year of birth. Figure 5 shows how a measure of lifetime tar exposure from cigarettes per adult for females has varied by age attained and year of birth. It is clear that the cohort of women born around 1925 consumed more cigarettes than those born before or after.

6.5.8 The equivalent data for males show a very similar pattern, except that the birth cohort showing the peak rate of consumption is somewhat earlier. Specifically, men born in the period 1900 to 1910 have had the greatest lifetime consumption.

6.5.9 Patterns of smoking behaviour are of great importance, because smoking is a risk factor in many of the major causes of death. In order to assess the role of smoking in influencing cohort trends in mortality, it is necessary to understand, for different diseases, how great a risk factor smoking is, and how the impact of smoking diminishes as the duration since giving up increases. There have been a great many medical studies which have examined such questions.

6.5.10 A review paper by Lee (2000) considered the results of 59 studies which have examined the epidemiology of lung cancer related to active smoking. Lee concluded that there is very strong evidence to suggest that lung cancer risk is related to the amount smoked, the age of starting to smoke (an earlier age associated with higher risk), and the duration of smoking. The majority of studies since 1975 (included in the Lee review) have recorded a relative lung cancer risk for those smoking around 20 cigarettes a day of between ten and 20 times that of never-smokers. Lee combined the evidence of studies investigating the relative risk of ex-smokers, and concluded that it takes ex-smokers six to eight years since giving up cigarettes to reduce their relative risk by 25%, 12 to 15 years to reduce it by 50%, and approximately 20 to 25 years to reduce it by 75%.

6.5.11 Given this evidence, it is clear that lung cancer is an obvious candidate for the existence of cohort related trends. Relative risk is related to the duration smoked, and lifetime consumption is strongly linked to year of birth. In addition to this, the relative risk for smokers is very high, and reduces slowly as the duration since giving up smoking increases.

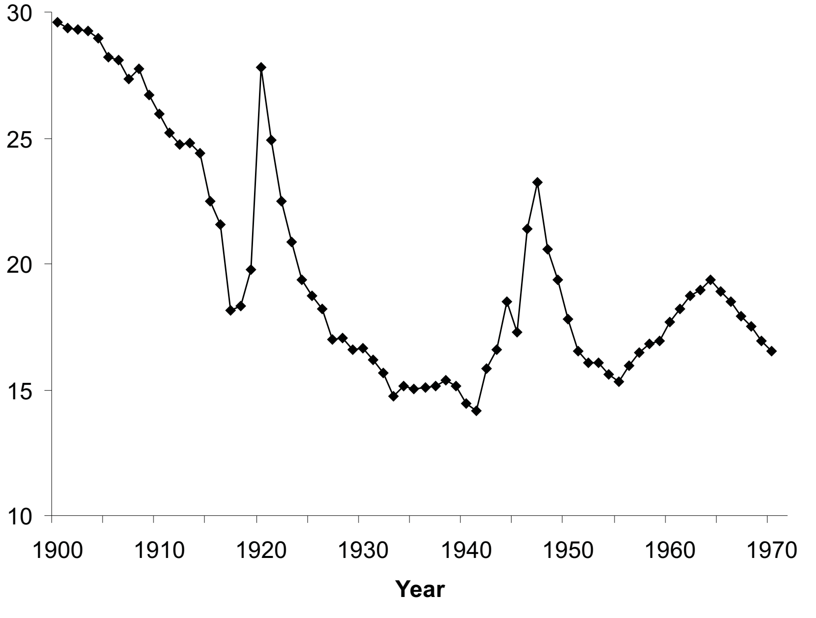
6.5.12 The relationship between smoking and heart disease mortality is quite different. A similar review paper by Lee (2001) considered the results of 48 studies that investigated the relationship between smoking and heart disease. The evidence from the studies investigating the relative risk of ex-smokers was combined, and Lee noted that the average relative risk of current smokers to never-smokers was 212%. This reduced to 156% for ex-smokers who had given-up smoking one to four years ago, 132% for those who had given up five to nine years ago, and 116% for those who had given up more than ten years ago.

6.5.13 The relative risk for heart disease is far below the equivalent figure for lung cancer mortality. It is also evident that the negative impact of smoking on heart disease mortality wears off more quickly upon giving up cigarettes. The relative risk of lung cancer mortality for ex-smokers who had given up 20 to 25 years ago was generally far higher than the relative risk of heart disease mortality of current smokers. As a result, cohort related trends caused by changes in smoking behaviour are far less likely to be a feature of heart disease mortality trends.

6.5.14 The probable impact of changes in smoking behaviour is discussed further in Section 7, where the mortality trends of individual causes of death — notably lung cancer and heart disease — are investigated.

6.6 *Birth Rates*

6.6.1 The experience of different generations should also be put into the context of the different sizes of the birth cohorts. Figure 6 shows how birth rates in England and Wales varied from year to year in the period 1900 to 1970. It can be seen that the number of births was generally falling over the period, but that there were three ‘baby booms’. These periods



Data source: www.mortality.org

Figure 6. Crude birth rates per 1,000 population, England and Wales, 1900 to 1970

of high birth rates occurred in the years immediately after World War I, then again just after World War II, and finally in the mid-1960s. It may be notable that the 'high improvement birth cohort' (i.e. 1925 to 1945) coincided with a trough of births relative to periods immediately before and after. The fact that the birth rate increased dramatically between 1941 and 1944 (by 31%) may be particularly relevant.

6.6.2 One possible consequence of rapidly changing birth rates is that the 'average' child is likely to be different in periods where birth rates are very different. For instance, if trends in fertility vary by socio-economic class, the class mix of a population will change.

7. U.K. Trends by Cause of Death

7.1 *Cohort Trends by Cause of Death*

7.1.1 Further insight into the potential causes of the U.K. cohort effect can be obtained through an investigation of mortality trends for specific causes of death.

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7.1.2 The 20th century mortality database (ONS, 2001) provides information on every death registered in the population of England and Wales from 1901 to 2000. Specifically, for each death there is a record of the five-year age group, gender, year of death and four digit International Classification of Diseases (ICD) cause of death. This information can be combined with mid-year population estimates, to derive central mortality rates for specific causes of death.

7.1.3 The mid-year population estimates were either taken from the database itself or, in the case of more recent years, from the revised mid-year populations published in the wake of the 2001 Census.

7.2 *Trends in Lung Cancer Mortality by Year of Birth*

7.2.1 In England and Wales in 2001, lung cancer accounted for 10% of deaths for men aged 65 to 74 and 9% of deaths for women in the same age group (ONS, 2002b).

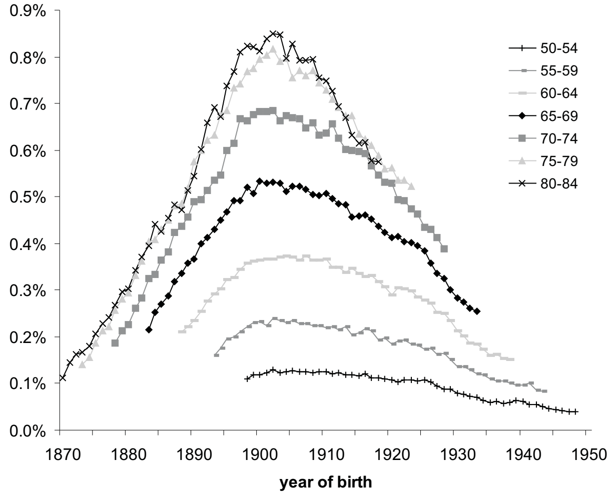
7.2.2 Cohort trends in lung cancer mortality in the U.K. have been the subject of analysis for many years. For instance, Caselli (1996) compared cohort effects due to lung cancer mortality in a range of developed countries, and noted that, for England and Wales, the generations born between 1910 and 1920 showed the first indications of a reversal of the tendency for lung cancer mortality to increase from one generation to the next.

7.2.3 Central mortality rates from lung cancer were derived for the period 1950 to 2000, which cover fours revisions of the International Classification of Diseases (i.e. ICD6, ICD7, ICD8 and ICD9).

7.2.4 Figures 7 and 8 show how rates of lung cancer mortality have varied for males and females by year of birth and age group over the period 1950 to 2000. As deaths have been assigned to five-year age groups, it was necessary to notionally assign each rate to the most suitable single year of birth. For instance, the mortality rate in year 2000 for the age group 50 to 54 years, was assigned to year of birth 1948.

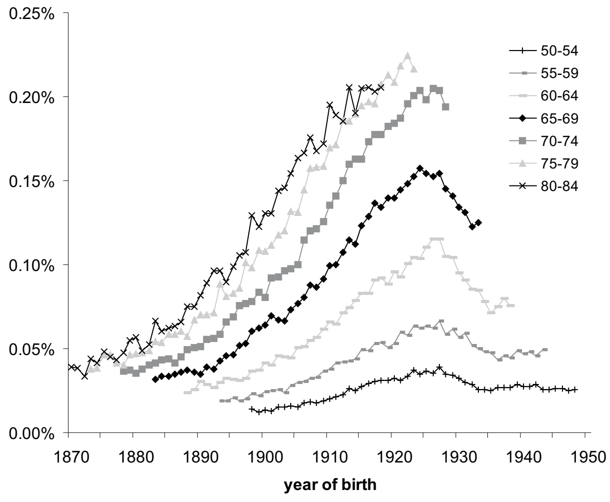
7.2.5 It can clearly be seen that, for successive generations, lung cancer mortality has steadily increased, reached a peak and then declined. For males, the peak occurred for those born in around 1900 to 1905. For females, the peak occurred for a later generation, i.e. those born in the period 1925 to 1930. It should also be noted that the shapes of the incidence curves are somewhat different for males and females. There is a much rounder top to the curve for males, with a much sharper peak for females.

7.2.6 The pattern of the graphs matches extremely closely the patterns of cumulative constant tar cigarette consumption, described in ¶¶6.5.7 and 6.5.8. For both males and females, the peak years of birth of cigarette consumption correspond with the peak years of birth of lung cancer mortality. This result is consistent with the finding, described in ¶6.5.10, that lung cancer risk is related to the duration in which a person has smoked.



Data source: ONS (2001)

Figure 7. Central mortality rates from lung cancer by years of birth and five-year age groups for males in England and Wales



Data source: ONS (2001)

Figure 8. Central mortality rates from lung cancer by years of birth and five-year age groups for females in England and Wales

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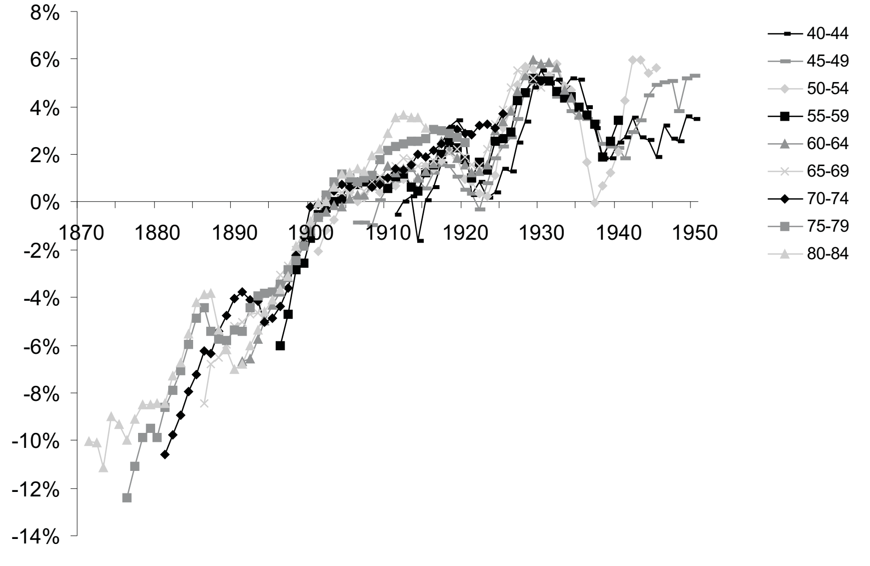
7.2.7 The inference that can be drawn from these figures is that future reductions in lung cancer mortality at older ages look virtually inevitable.

7.2.8 An alternative method of looking at trends is to determine annualised rates of mortality improvement by year of birth. This was achieved by first deriving rates of improvement for five-year age groups using log-linear regression. Specifically, the rate of improvement for calendar year x was calculated using data for the period from $x-3$ to $x+3$. The improvement rate for year x was then assigned to a single year of birth, using the approach described in ¶7.2.4. For example, for the age group 50 to 54, the rate of improvement for 1997 was derived by fitting a straight trend line to log mortality rates from 1994 to 2000. This rate of improvement was then notionally assigned to year of birth 1945. Figures 9 and 10 show the results of adopting this approach.

7.2.9 Figures 9 and 10 show that different age groups have experienced very similar patterns of mortality improvement by year of birth. This suggests that year of birth has been a much stronger factor than age in determining rates of improvement in lung cancer mortality. It is also



Data source: ONS (2001)

Figure 9. Average annual improvements in central mortality rates from lung cancer by years of birth and five-year age groups for males in England and Wales

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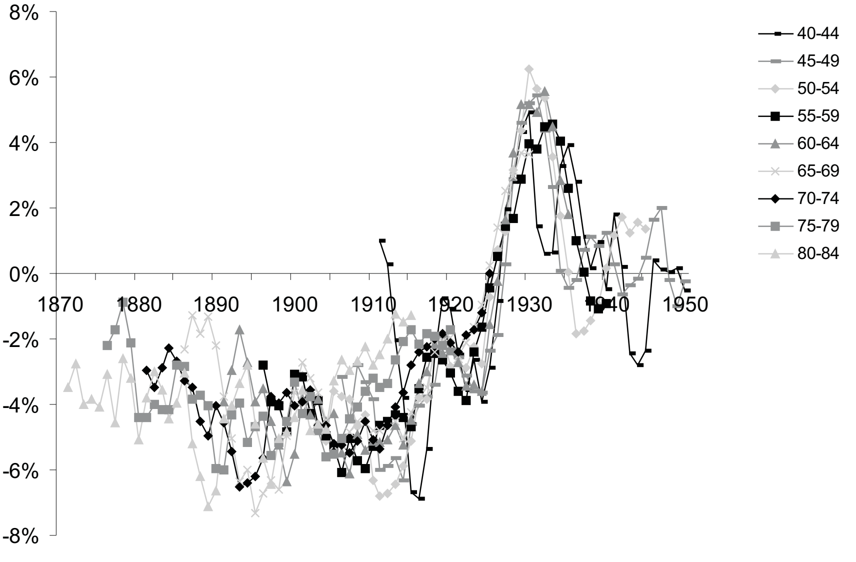
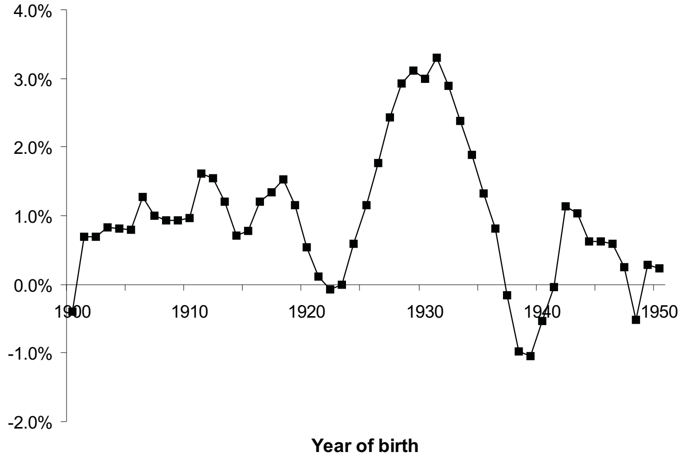


Data source: ONS (2001)

Figure 10. Average annual improvements in central mortality rates from lung cancer by years of birth and five-year age groups for females in England and Wales

apparent that, for both males and females, the greatest improvements have been experienced by people born in the period 1930 to 1935, irrespective of age. This is notable, given that the 'peak' years of birth, noted in ¶7.2.5, were 25 years apart for males and females.

7.2.10 In order to simplify this information and to allow for the changing pace of improvement over time, the following methodology was adopted. Firstly, average 'all-age' rates of improvement were calculated for each calendar year. These averages were simple arithmetic means of the improvement rates (fitted using log-linear regression) for the nine five-year age groups between ages 40 and 84. Deviations from the average were then calculated for each of the nine age groups for each calendar year. By definition, the sum of these deviations across all age groups and calendar years was zero. The deviations were then notionally assigned to single years of birth. The deviations for each year of birth were then averaged across all age groups. Essentially, these figures represent the average excess in improvement rate by year of birth, controlling for calendar year. Figures 11 and 12 show the result of applying this methodology to lung cancer mortality rates for males and females.



Data source: ONS (2001)

Figure 11. Average annual improvements in lung cancer mortality by year of birth in excess of the all age average for each calendar year for males in England and Wales

Data source: ONS (2001)

Figure 12. Average annual improvements in lung cancer mortality by year of birth in excess of the all age average for each calendar year for females in England and Wales

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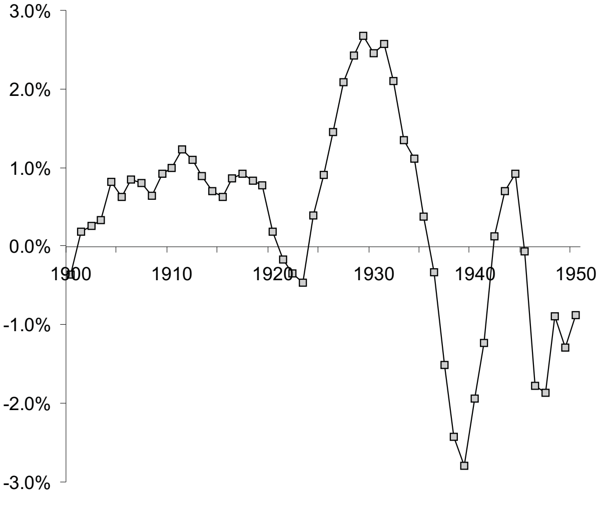
7.2.11 The approach described in ¶7.2.10 effectively allows for change in the pace of mortality improvement by calendar year. However, the average value for different years of birth has been derived from different age ranges. For example, the value for 1910 is based on data for ages in the range 45 to 84, whereas the value for 1940 is based on the age range 40 to 59. In order to allows for this factor, a more complex, but still relatively simple, model was constructed. As in ¶7.2.10, deviations from all-age average improvements were calculated for each calendar year. In order that the model could be fitted to a range of causes of death, the data were restricted to years covered by ICD8 and ICD9 (i.e. 1968 to 2000). All ages in the range 30 to 84 were included. A model was then constructed for the deviations from the average (δ), in which the effects of age and year of birth were assumed to combine additively, i.e.

$$\delta_{ij} = \alpha_i + \beta_j$$

where α_i $(i = 1, \ldots, I)$ and β_j $(j = 1, \ldots, J)$ are the effects due to age and year of birth respectively, and $\Sigma\alpha_i = 0$. The model was fitted using a basic least squares methodology.

7.2.12 The year of birth functions for males and females, i.e. β_j, fitted by applying the model to lung cancer data, are shown in Figures 13 and 14.



Data source: ONS (2001)

Figure 13. Year of birth function in a simple model of lung cancer mortality improvements for males in the population of England and Wales

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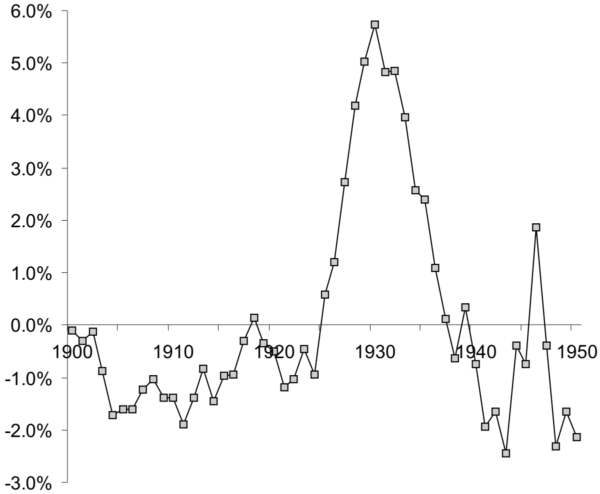

Data source: ONS (2001)

Figure 14. Year of birth function in a simple model of lung cancer mortality improvements for females in the population of England and Wales

7.2.13 Both approaches, as illustrated by Figures 11 to 14, clearly produce similar results. Improvement rates for males and females are much higher for a fairly narrow range of years of birth centred around 1930. It is interesting that the band of high improvement is so narrow, given that all cause mortality data show greater improvements for people born over a wider period, i.e. 1925 to 1945. In particular, the relatively low rate of improvement for people born in the early 1940s is in marked contrast to the high rate for people born a decade earlier.

7.2.14 The shape of the curves in Figures 7 and 8, and the finding that the cohort born around 1930 has experienced the most rapid improvements in recent decades, strongly suggest that lung cancer mortality at advanced ages will reduce substantially in future years. This is further illustrated by Figure 15, which shows how lung cancer mortality curves for two selected years of birth are following substantially different trajectories.

7.2.15 In Table 3, rates of lung cancer mortality at different ages are compared with rates from five years earlier, for the same age. It can be seen that the ratios for each year of birth have reduced with increasing age. This is significant, as it suggests that the historic pattern of improvement by year of birth is unlikely to diminish with increasing age. In fact, differences between generations may actually widen with age.

7.2.16 Given this pattern of reducing ratios with age, a crude method

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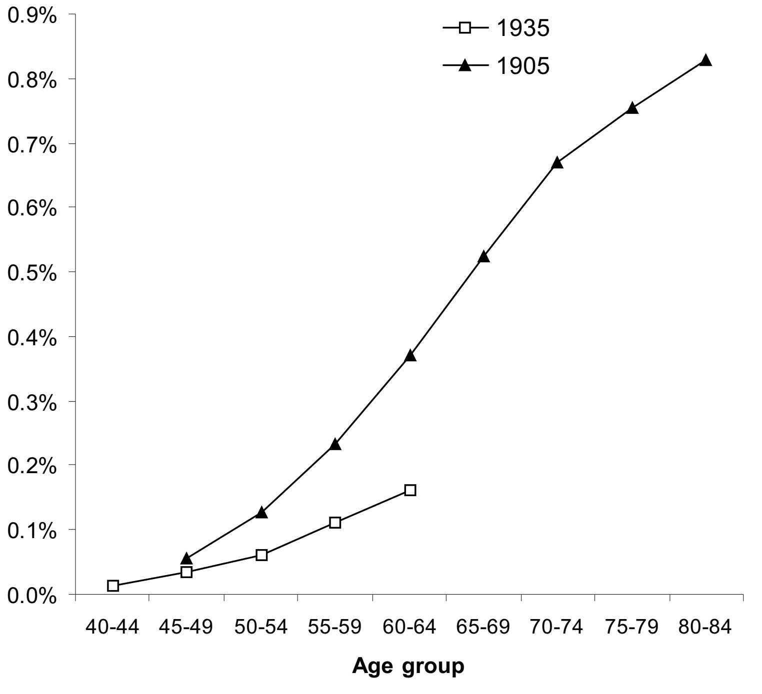

Data source: ONS (2001)

Figure 15. Central rates of lung cancer mortality for males in the population of England and Wales for selected years of birth

Table 3. Ratio of central mortality rates from lung cancer to rates from five years earlier, males in the population of England and Wales

Age group	Ratio of mortality rate to equivalent rate from five years earlier by year of birth					
	1910	1915	1920	1925	1930	1935
45-49	106%	96%	91%	103%	81%	81%
50-54	98%	94%	92%	100%	74%	75%
55-59	94%	95%	88%	94%	78%	81%
60-64	99%	91%	87%	96%	76%	76%
65-69	97%	90%	90%	93%	74%	
70-74	95%	94%	88%	82%		
75-79	97%	87%	89%			
80-84	90%	82%				

Data source: ONS (2001)

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Table 4. Ratio of central mortality rates from lung cancer to rates from five years earlier, males in the population of England and Wales, with projected values

Age group	Ratio of mortality rate to equivalent rate from five years earlier by year of birth					
	1910	1915	1920	1925	1930	1935
45-49	106%	96%	91%	103%	81%	81%
50-54	98%	94%	92%	100%	74%	75%
55-59	94%	95%	88%	94%	78%	81%
60-64	99%	91%	87%	96%	76%	76%
65-69	97%	90%	90%	93%	74%	**76%**
70-74	95%	94%	88%	82%	**74%**	**76%**
75-79	97%	87%	89%	**82%**	**74%**	**76%**
80-84	90%	82%	**89%**	**82%**	**74%**	**76%**

Data source: ONS (2001)

of projecting future rates of lung cancer mortality would be to assume that the ratios remain at their present levels in future years. This is illustrated by Table 4, where the projected values are highlighted, the other values are repeated from Table 3.

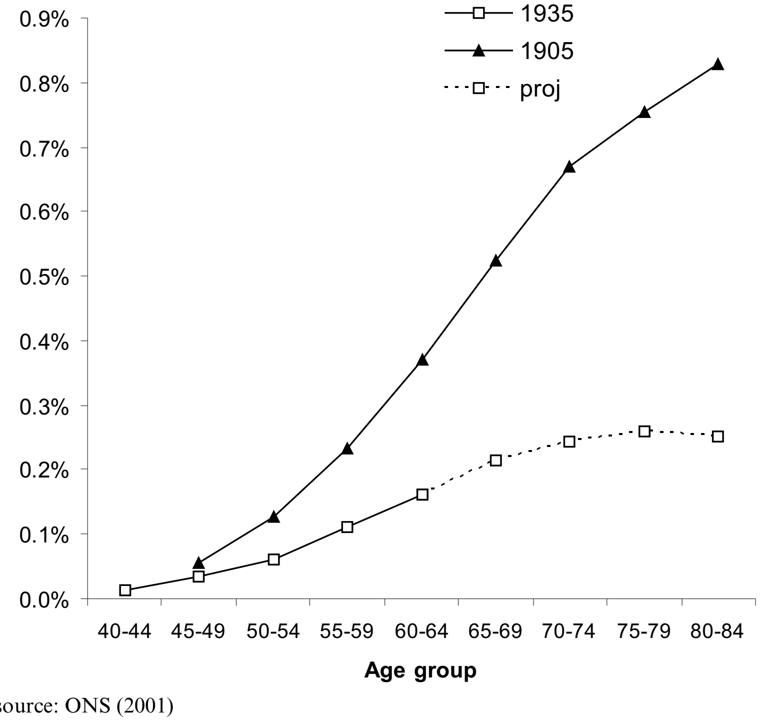
7.2.17 Future rates of lung cancer mortality for the generation born in 1935 were generated using this method and added to Figure 16. Whilst this method is extremely basic, it does serve to illustrate the point that future improvements in lung cancer mortality are likely to be highly significant at older ages.

7.2.18 Future rates of lung cancer mortality, projected using the method described in ¶7.2.16, were also used to calculate expected reductions in all-cause mortality. If all other causes showed no improvement, the projected improvements in lung cancer mortality would give rise to reductions in all-cause mortality of 0.46% p.a. and 0.24% p.a., for males and females respectively, in the age group 70 to 74 for the period 1997 to 2007. Table 5 shows how these figures compare with the equivalent numbers for the period 1987 to 1997. It is especially notable that the increases in lung cancer mortality for females aged 70 to 74 are likely to reverse.

7.3 *Trends in Heart Disease by Year of Birth*

7.3.1 The model described in ¶7.2.11 was also used to examine trends in other major causes of death. In England and Wales in 2001, ischaemic heart disease accounted for 27% of deaths for men aged 65 to 74, and 18% of deaths for women in the same age group (ONS, 2002b). Figures 17 and 18 show the results of applying the model to rates of ischaemic heart disease mortality (ICD codes 4100 to 4149) for males and females respectively.

7.3.2 Several points are noteworthy. Firstly, the years of birth showing high relative improvements are broadly those from 1925 to 1945. This is the same period of high improvement noted in all-cause analyses. However, the



Data source: ONS (2001)

Figure 16. Central rates of lung cancer mortality for males in the population of England and Wales for selected years of birth, with projected future rates for 1935

Table 5. Average annual improvements in all cause mortality for ages 70 to 74, due solely to actual or projected changes in lung cancer mortality, England and Wales population

	Improvement in all cause mortality p.a.	
	1987-1997	1997-2007
Male	0.31%	0.46%
Female	−0.09%	0.24%

years of birth showing the highest improvements are those in the early 1940s. This contrasts strongly with the equivalent lung cancer trends, where the peak years of birth were the 1930s, and the improvements for those born in the early 1940s — controlling for age and calendar year — have actually been very low or negative.

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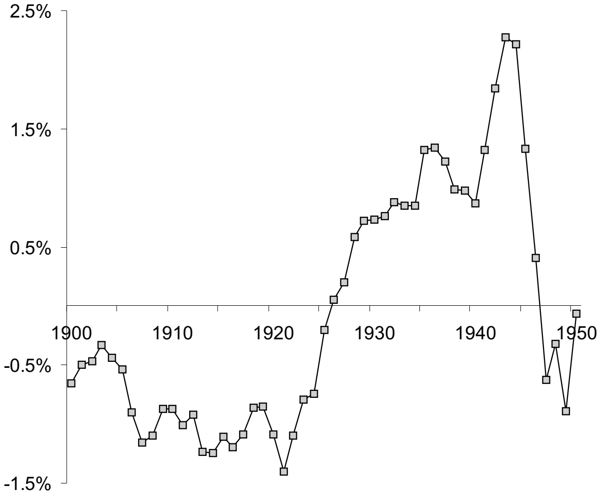
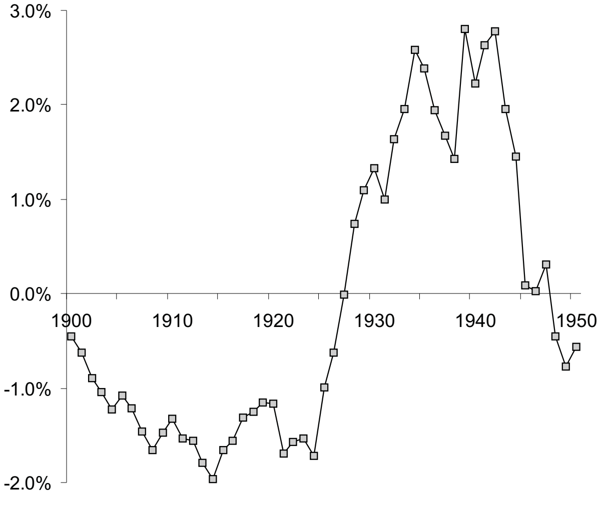


Data source: ONS (2001)

Figure 17. Year of birth function in a simple model of heart disease mortality improvements for males in the population of England and Wales



Data source: ONS (2001)

Figure 18. Year of birth function in a simple model of heart disease mortality improvements for females in the population of England and Wales

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Table 6. Comparison of changes in smoking prevalence and mortality from heart disease and lung cancer between 1978 and 1990 for males in sample age groups in England and Wales

		1978	1990	% reduction per annum
	Cigarette smoking prevalence	48%	34%	2.8%
Males aged 35-49	Heart disease mortality rate	0.103%	0.057%	4.8%
	Lung cancer mortality rate	0.019%	0.013%	3.2%
	Cigarette smoking prevalence	48%	28%	4.4%
Males aged 50-59	Heart disease mortality rate	0.473%	0.294%	3.9%
	Lung cancer mortality rate	0.145%	0.086%	4.3%

Data source: ONS (2001, 2002a)

7.3.3 This difference between trends in lung cancer and heart disease mortality is explored further in Table 6, in which changes in mortality are contrasted for two age groups over the period 1978 to 1990. Over the period in question, cigarette smoking prevalence amongst males in Britain fell most rapidly in the 50 to 59 age group. Lung cancer mortality also fell most rapidly in this age group. On the other hand, percentage improvements in heart disease mortality were actually greatest for younger males — i.e. those aged 35 to 49.

7.3.4 Further insight can be gained by looking at the most recent improvements in heart disease mortality. Rates of heart disease mortality reduced massively during the course of the 1990s. For males aged 50 to 59 the average rate of improvement between 1990 and 2000 was 5.9% p.a. Over the same period, the proportion of men in the same age group in Britain who smoked cigarettes declined only marginally from 28% to 27% (ONS, 2002a). On the surface, it would appear that changes in smoking prevalence played virtually no part in the improvement in recent heart disease mortality. However, this ignores the fact that the proportion of ex-smokers at various durations since giving up will have changed over time.

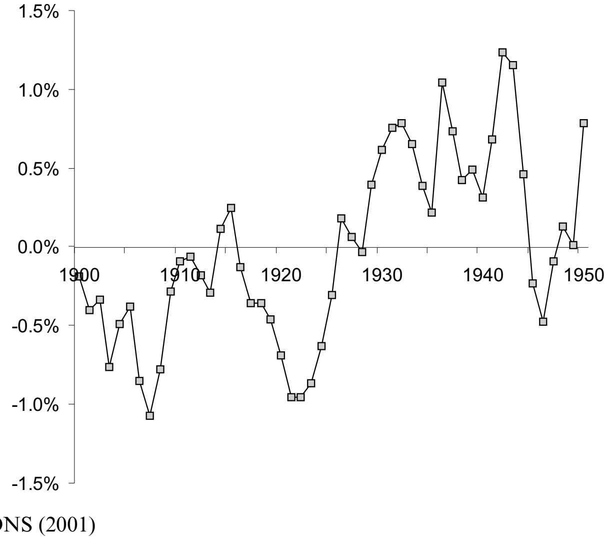
7.3.5 The percentage of the male population at various durations since giving up smoking was estimated using historic smoking prevalence data by age from the General Household Survey (ONS, 2002a). The relative risk factors for heart disease for current and ex-smokers, given in ¶6.5.12, were then applied to these proportions. This approach suggests that historic patterns of smoking prevalence would have lead to a reduction in heart disease mortality of just 0.35% p.a. for men aged 50 to 59 over the period 1990 to 2000. On this basis, trends in cigarette smoking prevalence explain just 6% of the actual improvement over this period.

7.3.6 Some part of recent improvements may have been due to smokers switching to lower tar cigarettes and a reduction in cigar and pipe smoking (ONS, 2002a). However, this analysis of trends in heart disease mortality suggests that factors other than smoking have accounted for a large part of recent trends. The high improvements for people born in the early 1940s are likely to be due, at least partially, to factors other than smoking. Given recent epidemiological research into the impact of early life experience on heart disease risk in later life (discussed in Section 3), the high rates of improvement for people born in the early 1940s may have their origins in the relatively healthy post-war diet and lifestyle enjoyed by this generation. The jump in birth rates between 1941 and 1944, highlighted in ¶6.6.1, could also be a factor.

7.3.7 It is apparent, however, that a detailed study of changes in smoking behaviour over the course of the 20th century would be very worthwhile. In addition to looking at prevalence of cigarette smoking, this study should also examine factors such as: average daily consumption by cigarette smoker; consumption of low tar versus high tar products; and consumption of other tobacco products.

7.4 *Trends in Breast Cancer by Year of Birth*

7.4.1 In England and Wales in 2001, breast cancer accounted for 6% of deaths for women aged 65 to 74 (ONS, 2002b). The improvement model produces interesting results when applied to breast cancer trends, which are shown in Figure 19. There are signs that women born in the period 1930 to 1945 have experienced higher relative rates of improvement.



Data source: ONS (2001)

Figure 19. Year of birth function in a simple model of breast cancer mortality improvements for females in the population of England and Wales

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7.4.2 This pattern is unlikely to be due to changing patterns of smoking behaviour, as smoking is not considered to be a major risk factor in breast cancer. A review paper by McPherson, Steel & Dixon (2000) made the statement that: "Smoking is of no importance in the aetiology of breast cancer."

7.4.3 The observed cohort effect may be partly due to the fact that the NHS Screening Programme for breast cancer was initiated in 1988. This was aimed — initially — at women aged 50 to 65, so would have most benefited those born in the 1930s and 1940s. However, it is notable that improvements in breast cancer mortality were also relatively high (compared with other age groups) for women aged in their 30s in the 1970s and in their 40s in the 1980s.

7.5 *Trends in other Categories of Death by Year of Birth*

7.5.1 Results of applying the model to major categories of cause of death are shown in Table 7.

7.5.2 It is notable that most of the major categories of cause of death show a period of relatively high improvement for people born between the mid-1920s and mid-1930s. Given historic patterns of cigarette consumption, this may be largely due to patterns of smoking behaviour. Only circulatory disorders show a period of high improvement extending to the mid-1940s.

7.5.3 The model was also applied to all cause rates of mortality for men and women, with the results shown in Figures 20 and 21. The pattern for males, especially, supports the idea that there may be two distinct 'sub-cohorts' within the 1925 to 1945 cohort. Those born in the period 1925 to 1935 may be experiencing rapid improvement largely as a result of historic

Table 7. Periods of birth identified by model as showing relatively rapid improvements in mortality by category of death

	Male		Female	
Cause of death	Periods where year of birth function exceeds 1%	Periods where year of birth function exceeds 2%	Periods where year of birth function exceeds 1%	Periods where year of birth function exceeds 2%
Infectious diseases	1922-37	1929-33	1926-39	1926-38
Cancer	1927-33	None	None	None
Circulatory disorders	1931-46	None	1928-45	1930-37
Diseases of the digestive system	1923-34	1925-30	1926-38	None
Respiratory disorders	1904-12 & 1925-33	1926-31	1901-05 & 1928-41	1929-40
Violent and accidental	None	None	None	None

Data source: ONS (2001)

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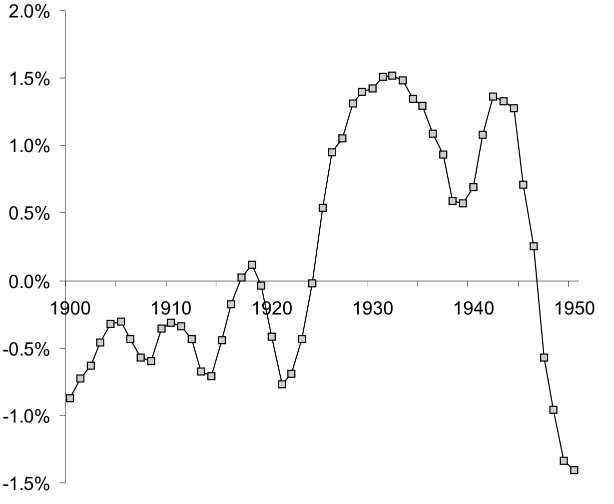

Data source: ONS (2001)

Figure 20. Year of birth function in a simple model of all cause mortality improvements for males in the population of England and Wales

Data source: ONS (2001)

Figure 21. Year of birth function in a simple model of all cause mortality improvements for females in the population of England and Wales

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patterns of smoking behaviour, whereas those born in the early 1940s may be experiencing high improvements, largely as a result of factors other than smoking.

7.5.4 If smoking is the major factor driving the rapid improvement seen in the earlier cohort, it provides a plausible explanation as to why the CMI Bureau investigation (2002) produced evidence of an earlier central year (1926 versus 1931, in the population of England and Wales). People in higher socio-economic classes, who are more likely to be 'assured lives', gave up smoking sooner than those in lower socio-economic classes. According to Evandrou & Falkingham (2002), in their review of smoking trends by social class:

> "there appears to be a lag in smoking cessation by socio-economic group by birth cohort, consistent with diffusion theory of behaviour change, where changes in health risk behaviour are adopted first among the middle classes and then diffuse through the population."

7.5.5 It is also worth noting that the CMI Bureau cohort investigation into male assured life experience also provides evidence of a second cohort of lives showing rapid improvement, although not as rapid as the earlier group. In the CMI Bureau investigation, the secondary effect can be seen for people born in the period 1937 to 1944.

8. Evidence from Japanese Mortality Experience

8.1 *The Japanese Example*

8.1.1 There are a number of examples of birth cohorts in countries other than the U.K. which have experienced more rapid mortality improvements than adjacent ones. For instance, MacMinn (2003) describes 'select birth cohorts' in Norway, Sweden, Denmark, France, Sweden, Italy, Austria, the U.S.A. and Japan. The example of trends in Japanese mortality experience is interesting, because there is evidence for a cohort of lives born around 1915 which has experienced more rapid improvement than earlier or later generations.

8.1.2 This example is notable, because this generation has continued to experience rapid improvement far into old age. This does not prove that the U.K. cohort effect will also continue to advanced ages. However, it does indicate that this is possible.

8.2 *Japanese Females*

8.2.1 The Japanese data used throughout this section were taken from the Human Mortality Database (www.mortality.org) maintained by the University of California, Berkeley (U.S.A.) and the Max Planck Institute for Demographic Research (Germany). The original data were supplied by the Japanese Ministry of Health & Welfare and Japanese Statistics Bureau.

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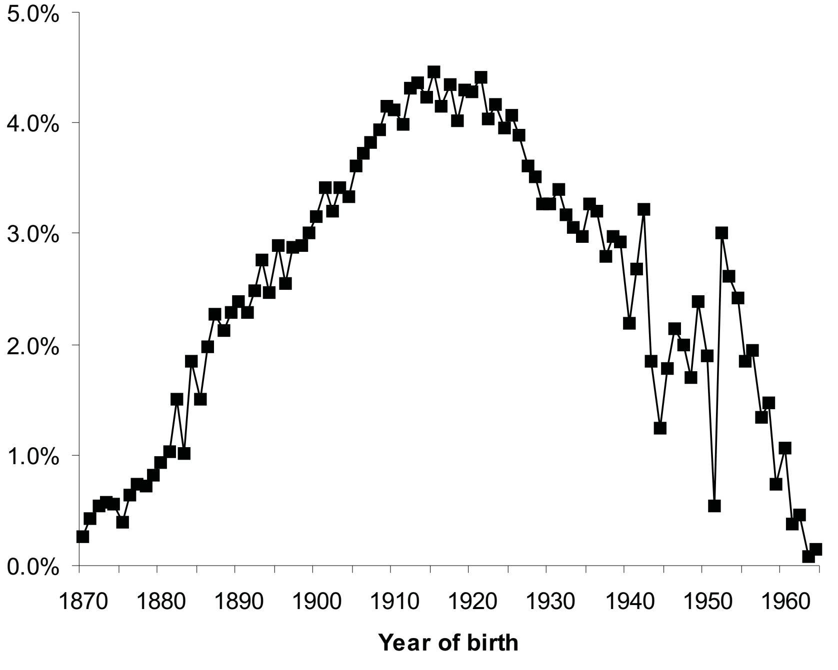

Data source: www.mortality.org

Figure 22. Average annual rates of mortality improvement in the Japanese population by year of birth (nine-year rolling averages) for females

Figure 22 shows that Japanese females born in the period 1910 to 1925 have experienced far more rapid improvement than generations born earlier or later.

8.2.2 An alternative method of presentation was developed to illustrate the trend in a different format. Firstly, log-linear regression was used to derive average rates of improvement for successive nine-year periods for all ages between 45 and 95. For example, for age 80 the improvement rate for year 1995 was calculated by fitting a straight line to log mortality rates for 80 year olds for years 1991 to 1999. This methodology was used to produce Table 8, which shows average annual improvement rates for nine-year periods, centred, successively, on 1954 to 1995. In this table, improvement rates that are lower than 95% of the maximum for each calendar year are not shown.

8.2.3 The clear diagonal pattern in Table 8 shows that the highest improvements in each calendar year have been experienced by females born in the same period (roughly 1910 to 1915). Table 9 shows the effect of showing rates in excess of 90% of the maximum, instead of 95%.

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Table 8. Average rates of mortality improvement (percentage per annum) over rolling periods of nine years, Japanese females aged 45 to 95, only values in excess of 95% of the maximum for each calendar year are shown

Year

Age	'54	'55	'56	'57	'58	'59	'60	'61	'62	'63	'64	'65	'66	'67	'68	'69	'70	'71	'72	'73	'74	'75	'76	'77	'78	'79	'80	'81	'82	'83	'84	'85	'86	'87	'88	'89	'90	'91	'92	'93	'94	'95
45	5.8	4.9	4.4		4.1		4.8	4.5	4.1	4.0																																
46		4.8	4.3	4.5	4.2	4.5		4.3					3.7	3.8	4.1																											
47					4.1																																					
48													3.6	3.9	3.9																											
49									3.9	4.1	4.4	3.8																														
50								4.3	3.9			3.9																														
51													3.6																													
52												3.7																														
53									3.9	4.1			3.6											4.6																		
54																3.9	3.7																									
55																																										
56																																										
57																																										
58																4.0	3.8	4.1	4.5	4.6			4.5																			
59																	3.7																									
60																		4.0																								
61																		4.0	4.3	4.6	4.8																					
62																				4.5	4.6																					
63																			4.5	4.6	4.9	4.8	4.5																			
64																				4.4	4.7	5.0	4.7	4.5																		
65																							4.7	4.5																		
66																								4.4																		
67																								4.5	4.9	4.5																
68																								4.4		4.3																
69																											4.1															
70																										4.4	4.3	4.3														
71																													4.5	4.7												
72																												4.4	4.6	4.5												
73																															4.8	4.5										
74																														4.5		4.4										
75																																4.4	4.2									
76																																4.3	4.1	4.1	3.5							
77																																			3.4							
78																																			3.5	3.3	3.1					
79																																			3.4		3.2					
80																																					3.2	3.0				
81																																					3.1	3.1	3.7			
82																																					3.1	3.1	3.7	3.7		
83																																							3.6	3.7	3.9	
84																																								3.6	4.0	3.7
85																																									4.1	3.7
86																																										3.7
87																																										
88																																										
89																																									4.0	3.6
90																																										3.6
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92																																										
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94																																										
95																																										

Data source: www.mortality.org

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Table 9. Average rates of mortality improvement (percentage per annum) over rolling periods of nine years, Japanese females aged 45 to 95, only values in excess of 90% of the maximum for each calendar year are shown

Year ('54–'74)

Age	'54	'55	'56	'57	'58	'59	'60	'61	'62	'63	'64	'65	'66	'67	'68	'69	'70	'71	'72	'73	'74
45	5.8	4.9	4.4	4.2	4.1	4.1	4.8	4.5	4.1	4.0	4.1							3.8		4.3	
46		4.8	4.3	4.5	4.2	4.5	4.4	4.3				3.6	3.7	3.8	4.1	3.7	3.6				
47		4.6		4.1	4.1				3.8					3.7				3.7		4.3	
48		4.5		4.2	3.8	4.1				3.8	4.1	3.6	3.6	3.9	3.9						
49									3.9	4.1	4.4	3.8									
50							4.3	4.3	3.9	3.9		3.9									4.6
51									3.9	3.8			3.6								
52										3.9		3.7	3.5				3.5				
53									3.9	4.1	4.1	3.7	3.6								
54												3.5				3.9	3.7	3.8		4.3	
55												3.5					3.5			4.3	
56												3.5									
57																	3.5	3.7			
58																4.0	3.8	4.1	4.5	4.6	
59																3.6	3.7	3.7			
60																3.7	3.6	4.0	4.1		
61																	3.6	4.0	4.3	4.6	4.8
62																		3.9	4.3	4.5	4.6
63																		3.9	4.5	4.6	4.9
64																				4.4	4.7
65																					4.4
66																				4.2	
67																3.7					
68																	3.6				4.6
69																		3.7			
70																					
71																				4.2	
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93																					
94																					
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Year ('75–'95)

Age	'75	'76	'77	'78	'79	'80	'81	'82	'83	'84	'85	'86	'87	'88	'89	'90	'91	'92	'93	'94	'95
45																					
46																					
47																					
48																					
49																					
50																					
51																					
52																					
53			4.6																		
54																					
55																					
56																					
57																					
58		4.5	4.3																		
59																					
60																					
61																					
62																					
63	4.8	4.5																			
64	5.0	4.7	4.5																		
65		4.7	4.5																		
66			4.4																		
67		4.3	4.5	4.9	4.5	4.1															
68		4.3	4.4	4.6	4.3	3.9															
69						4.1	4.1														
70			4.2	4.4	4.4	4.3	4.3	4.2	4.2												
71						4.1	4.0	4.5	4.7	4.3											
72					4.3	4.1	4.4	4.6	4.5	4.4											
73						3.9			4.3	4.8	4.5	3.9		3.3							
74						3.9			4.5	4.4	4.4	3.8									
75										4.5	4.4	4.2	3.8	3.2							
76						4.0			4.2		4.3	4.1	4.1	3.5							
77					4.3	4.0								3.4							
78						4.0					4.1		3.8	3.5	3.3	3.1	2.8				
79														3.4	3.1	3.2	2.9				
80														3.2	3.1	3.2	3.0		3.4		3.5
81														3.3	3.0	3.1	3.1	3.7	3.4		3.4
82														3.3	3.1	3.1	3.1	3.7	3.7		3.5
83																2.9	3.0	3.6	3.7	3.9	3.5
84																2.9	2.9	3.5	3.6	4.0	3.7
85																	2.9	3.4	3.5	4.1	3.7
86																		3.4	3.5	3.9	3.7
87																		3.4	3.5	3.8	3.6
88																				3.7	3.4
89																			3.4	4.0	3.6
90																				3.8	3.6
91																					3.6
92																					
93																					
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95																					

Data source: www.mortality.org

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Table 10. Average rates of mortality improvement (percentage per annum) over rolling periods of nine years, Japanese males aged 45 to 95, only values in excess of 90% of the maximum for each calendar year are shown

Year ('54–'74)

Age	'54	'55	'56	'57	'58	'59	'60	'61	'62	'63	'64	'65	'66	'67	'68	'69	'70	'71	'72	'73	'74
45	4.2	3.5	3.6	3.6	3.2	3.1	3.4														
46		3.4			2.9	3.1															
47	3.9	3.4			2.9	2.8			2.8												
48		3.3			2.9	2.9			2.7	2.9											
49														2.9							
50						3.0	3.5	3.6	2.9												
51									2.8	2.8	2.9	2.9									
52									2.8	2.9	2.9										
53									2.6	2.8	3.0										
54										3.0	3.1	3.2	3.1	3.1	3.1						
55											3.2	3.0	2.9	3.0	3.3						
56																					
57										2.8										3.9	4.0
58														2.8	3.3	3.8	4.0	4.2	4.2		
59																				4.2	3.9
60															2.9	3.5		3.8		3.9	
61																		3.9	4.4	4.3	4.2
62																				4.2	4.1
63																			4.1	4.2	4.3
64															3.0					4.0	4.0
65																				4.1	4.2
66																				4.2	4.1
67																				4.1	4.1
68																					
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92																					
93																					
94																					
95																					

Year ('75–'95)

Age	'75	'76	'77	'78	'79	'80	'81	'82	'83	'84	'85	'86	'87	'88	'89	'90	'91	'92	'93	'94	'95
45					3.5	3.6	3.6														
46							3.4	3.5	4.0												
47								3.4	3.9	3.9											
48									4.1	4.4	4.3										
49											4.3	4.3									
50											4.1	4.3									
51												4.3	4.7	4.1							
52													4.3	4.0	3.5						
53														3.9	3.7	3.4					
54															3.4	3.4	2.9				
55																3.1	3.0				
56																	2.7				
57																		3.1	3.0		
58																			3.1	3.0	2.6
59																				2.8	2.7
60																					2.8
61	3.7																				
62	3.8	3.4		3.3																	
63	3.9	3.8																			
64	4.0	3.7	3.6	3.3																	
65	3.9	3.7		3.3																	
66	3.8	3.8	3.9	3.4																	
67	3.9	3.8	3.7	3.7																	
68			3.7	3.7	3.7	3.5	3.3														
69				3.6	3.5	3.6															
70				3.3		3.4	3.5	3.4													
71								3.4													
72								3.2													
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Data source: www.mortality.org

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Table 11. Average rates of mortality improvement (percentage per annum) over rolling periods of nine years — Japanese males aged 45 to 95 — only values in excess of the average for each age are shown

Year

Age	'54	'55	'56	'57	'58	'59	'60	'61	'62	'63	'64	'65	'66	'67	'68	'69	'70	'71	'72	'73	'74	'75	'76	'77	'78	'79	'80	'81	'82	'83	'84	'85	'86	'87	'88	'89	'90	'91	'92	'93	'94	'95
45	4.2	3.5	3.6	3.6	3.2	3.1	3.4	2.8																2.7	3.1	3.5	3.6	3.6	3.0	3.0	3.1	2.6	2.8	3.4	2.5							
46	3.7	3.4	2.6	3.1	2.9	3.1	3.1	3.0		2.3	2.3															2.3	2.8	3.4	3.5	4.0	3.6	3.7	3.1	2.7	3.0							
47	3.9	3.4	3.0	2.6	2.9	2.8	3.2	2.9	2.8	2.7	2.7	2.8	2.5	2.4													2.6	2.9	3.4	3.9	3.9	3.7	3.9	3.2	2.5	2.5						
48	3.7	3.3	3.0	3.0	2.9	2.9	3.0	2.6	2.7	2.9	2.7	2.6		2.2		2.3												2.4	3.0	4.1	4.4	4.3	3.7	3.3								
49	3.3	2.8	2.5	2.4	2.7	2.6	3.0	2.8	2.5	2.5	2.8	2.6	2.5	2.9	2.9	2.7	2.5	2.2												2.7	3.9	4.3	4.3	3.8	3.0							
50	2.9	2.6	2.2	2.5	2.7	3.0	3.5	3.6	2.9	2.6	2.7	2.4			2.1	2.3	2.3	2.3	2.4	2.3	2.5									2.5	3.1	4.1	4.3	4.1	3.3	2.3						
51	2.6	2.4	2.2	2.2	2.3	2.5	2.9	2.8	2.8	2.8	2.9	2.9	2.4	2.2	2.3	2.2	2.2	2.5	2.6	2.4	2.5	2.1									2.5	3.1	4.3	4.7	4.1	3.2	2.5					
52	2.5			2.2	2.2	2.5	2.8	2.9	2.8	2.9	2.9	2.8	2.6	2.6	2.7	2.5	2.5	2.5	2.4	2.5	2.3											2.7	3.4	4.3	4.0	3.5	2.5					
53	2.2	2.2			2.3	2.4	2.9	2.8	2.6	2.8	3.0	2.7	2.7	2.6	2.7	2.8	2.8	3.0	3.1	3.0	2.8	2.2											2.7	3.3	3.9	3.7	3.4	2.3				
54	2.4			2.1		2.2	2.5	2.4	2.2	3.0	3.1	3.2	3.1	3.1	3.1	3.1	2.7	2.9	3.1	3.2	3.1	2.7	2.3											3.0	3.2	3.4	3.4	2.9	2.2			
55	2.2						2.5	2.6	2.3	2.7	3.2	3.0	2.9	3.0	3.3	3.3	3.4	3.0	3.0	3.2	2.9	2.5	2.1												2.3	2.3	3.1	3.0	2.6	2.1		
56							2.7	2.8	2.4	2.6	2.6	2.4	2.1	2.5	2.7	3.1	3.2	3.3	3.3	3.5	3.2	3.0	2.9	2.4												2.2	2.2	2.7	2.7	2.5		
57	2.3							2.3	2.3	2.8	2.8	2.8	2.6	2.3	2.9	2.9	3.1	3.2	3.8	3.9	4.0	3.5	3.1	2.8	2.2												2.1	2.2	3.1	3.0	2.6	
58							2.6	2.6	2.4	2.5		2.2	2.4	2.8	3.3	3.8	4.0	4.2	4.2	3.7	3.4	3.2	3.0	2.8	2.8	2.2													2.2	3.1	3.0	2.6
59								2.3		2.3	2.7	2.7	2.5	2.5	2.9	3.1	3.4	3.6	3.8	4.2	3.9	3.4	3.1	3.1	2.7	2.3															2.8	2.7
60										2.1	2.6	2.4	2.6	2.6	2.9	3.5	3.3	3.8	3.8	3.9	3.7	3.6	2.9	2.9	2.9	2.4	2.1													2.0	2.4	2.8
61							1.9			2.0	2.0	2.2	2.0	2.3	2.8	3.2	3.4	3.9	4.4	4.3	4.2	3.7	3.4	3.0	2.7	2.5	2.1															2.2
62							2.0				2.2	2.0	2.2	2.3	2.8	3.3	3.3	3.6	3.8	4.2	4.1	3.8	3.4	3.5	3.3	2.8	2.6	2.4	2.1	2.0												2.1
63												2.1		2.2	2.5	3.0	3.3	3.6	4.1	4.2	4.3	3.9	3.8	3.4	3.0	2.6	2.5	2.4	2.4	2.2												
64													2.1	2.3	3.0	3.2	3.1	3.4	3.7	4.0	4.0	4.0	3.7	3.6	3.3	3.0	2.6	2.5	2.4	2.3	2.4											
65	2.2	2.0									2.0	2.0		2.3	2.5	3.0	3.0	3.4	3.7	4.1	4.2	3.9	3.7	3.4	3.3	3.1	3.0	2.6	2.8	2.7	2.7	2.1										
66															2.4	2.5	2.7	3.2	3.8	4.2	4.1	3.8	3.8	3.9	3.4	3.1	2.8	2.8	2.5	2.6	2.7	2.5										
67											2.3					2.7	2.6	3.1	3.5	4.1	4.1	3.9	3.8	3.7	3.7	3.2	2.9	2.8	2.7	2.7	2.8	2.5	2.2									
68											2.1					2.3	2.6	2.6	3.1	3.5	3.7	3.5	3.4	3.7	3.7	3.7	3.5	3.3	3.1	3.1	2.8	2.3	2.1									
69															2.3	2.7	2.5	3.1	3.1	3.5	3.6	3.5	3.2	3.4	3.6	3.5	3.6	3.0	3.0	3.0	3.0	2.4										
70															2.3	2.4	2.4	2.7	3.3	3.4	3.5	3.2	3.2	3.3	3.3	3.3	3.4	3.5	3.4	3.4	3.1	2.8	2.2									
71															2.4	2.7	2.4	2.8	3.0	3.6	3.4	3.3	3.2	3.3	3.2	3.0	3.1	3.2	3.4	3.3	3.2	2.8	2.5									
72															2.1	2.5	2.4	2.6	3.0	3.3	3.7	3.1	3.0	3.0	3.2	3.1	3.1	3.0	3.2	3.7	3.3	2.7	2.3	2.1								
73											2.0					2.5	2.3	2.6	2.9	3.2	3.2	3.3	2.9	3.0	3.0	3.0	3.0	2.7	3.0	3.2	3.4	3.0	2.5	2.2								
74																2.3	2.4	2.6	2.9	3.1	3.2	2.9	3.0	2.8	3.0	2.7	2.6	2.6	2.8	3.2	3.2	3.2	2.7	2.6	2.1							
75															2.2	2.2	2.0	2.6	3.1	3.3	3.2	2.9	2.6	3.1	2.8	2.5	2.6	2.6	2.8	3.0	3.2	2.9	2.8	2.5	2.1							
76											2.0	1.9				2.2		2.2	2.6	2.9	2.9	2.8	2.8	2.8	2.9	2.5	2.5	2.4	2.7	2.9	3.0	3.1	2.7	2.7	2.2						2.2	2.1
77											1.8	1.9			2.1	2.1	2.2	2.4	2.6	3.0	3.1	2.8	2.6	2.7	2.6	2.6	2.3	2.1	2.4	2.7	2.8	2.6	2.7	2.6	2.4	2.0						1.8
78											1.8	2.2	2.0		2.0	2.2		2.3	2.2	2.5	2.7	2.7	2.5	2.6	2.6	2.3	2.7	2.2	2.6	2.6	2.6	2.3	2.1	2.3	2.0	2.0			1.8	2.0	2.0	1.8
79											1.8	1.7	2.0	1.7	2.1	2.0		1.7	2.2	2.4	2.5	2.7	2.8	2.8	2.8	2.5	2.3	2.3	2.3	2.6	2.6	2.5	2.0	2.0	1.8		1.7		2.0	1.9	2.4	2.0
80												1.7	1.8	1.7	2.2	2.2	1.7	2.1	2.0	2.4	2.4	2.8	2.6	2.7	2.6	2.4	2.3	1.8	2.1	2.1	2.4	2.2	1.9	1.9	1.7	1.7		1.7	1.9	2.0	2.4	2.4
81											1.7		1.7		2.1	2.2	1.9	2.0	2.3	2.3	2.5	2.5	2.3	2.5	2.3	2.1	2.0	1.9	1.9	2.4	2.2	2.2	1.9	1.9	1.6		1.7	1.6	2.2	2.0	2.3	2.0
82											1.7	1.9	1.8	1.6	2.0	2.2	1.6	1.6	1.7	2.0	2.0	2.3	2.1	2.6	2.8	2.5	2.2	1.9	2.1	2.2	2.4	1.8	1.8	1.7	1.5				2.0	2.4	2.4	2.2
83											1.7	2.1	1.9		1.9	1.8		1.6	1.5	1.6	2.2	2.3	2.6	2.7	2.8	2.4	2.1	1.7	1.8	2.1	2.0	2.1	1.6	1.8					1.8	1.9	2.6	2.2
84											1.5	1.5	1.9	1.6	1.8	1.9		1.4	1.5	1.6	1.8	2.3	2.5	2.7	2.6	2.2	2.0	1.6	1.7	2.1	2.1	2.1	2.0	1.6	1.4				1.6	1.9	2.3	2.3
85											1.6	1.9	1.6	1.4	1.8	2.0		1.5	1.4	1.6	1.8	2.1	2.3	2.3	2.8	2.2	2.2	1.7	1.7	1.8	2.0	1.7		1.6					1.7	1.9	2.4	2.1
86															1.8	1.8	1.3	1.5	1.4	1.9	2.0	2.2	2.2	2.7	2.6	2.7	2.1	1.8	1.9	1.9	1.9	1.5							1.5	1.7	2.2	2.3
87															1.4	2.0		1.5	1.5	1.3	1.8	2.1	2.0	2.4	3.0	2.5	2.5	1.7	1.7	1.7	1.4	1.3		1.2		1.2			1.5	1.4	1.9	1.7
88											1.5	1.4	1.3			1.4		1.2	1.4	1.8	1.8	2.2	2.1	2.4	2.4	2.3	2.0	1.7	1.7	1.7	1.7	1.3		1.2					1.5	1.5	1.9	1.8
89							1.6								1.3	1.7	1.3	1.7	1.5	1.3	1.6	1.6	1.8	2.2	2.4	2.0	2.1	1.8	1.8	1.7	1.6	1.3						1.3	1.6	1.7	1.9	1.7
90															1.7	1.6		1.1	1.2		1.2	1.6	1.6	2.0	2.4	1.9	1.9	1.8	1.9	2.0	1.9	1.7		1.2					1.6		1.7	1.2
91											1.2			1.3	1.8	1.8				1.2	1.1	1.1	1.3	1.9	2.3	2.0	2.0	1.7	2.1	2.0	1.9	1.4		1.1					1.1	1.4	1.7	1.5
92						1.3	2.1						1.1		1.5	1.7					1.2	1.9	1.6	2.2	2.4	2.0	1.9	1.3	1.4	1.8	1.8	1.5		1.1						1.3	1.9	1.6
93				1.5		1.5	1.4	1.4		1.1	1.5	2.2	1.6	1.1	1.2							1.4	2.2	2.6	2.8	2.5	2.2	1.3	1.2	1.4	1.9	1.6	1.2	1.2	1.3						1.2	1.0
94							1.2	2.5	2.3	1.6	1.5	1.5			1.3	1.2					1.7		1.3	1.7	2.1	1.8	1.5	1.0	1.4	2.2	1.9	1.6							1.1	1.3	1.6	1.1
95										2.4	2.1	2.8	1.9		1.0						0.8	1.6	1.3	1.9	1.4	2.0	1.8	0.9	1.3	1.6	2.1	1.4	1.1	0.7	1.0					1.1	1.3	1.2

Data source: www.mortality.org

Table 12. Average rates of mortality improvement (percentage per annum) over rolling periods of nine years, males in England and Wales aged 30 to 84, only values in excess of 70% of the maximum for each calendar year are shown

																Year																	
Age	'65	'66	'67	'68	'69	'70	'71	'72	'73	'74	'75	'76	'77	'78	'79	'80	'81	'82	'83	'84	'85	'86	'87	'88	'89	'90	'91	'92	'93	'94	'95	'96	'97
30	2.3								2.4	2.1																							
31						2.8		1.8																									
32																																	
33	2.4																																
34				2.1									3.1	2.4																			
35	2.6								2.5	1.9	2.0																						
36											2.1	2.5	2.2	2.5	3.1	3.0																	
37	2.2		2.2																														
38			2.7	2.8	2.9	2.1	2.8	2.4								2.7	3.9	3.1															
39						2.1	2.0									3.0		3.0															
40								2.5	3.1	2.3									3.0	2.6													
41								1.8	2.7	2.2	2.4							2.5															
42										2.4	2.2	3.3	3.2	2.9	2.6																		
43								2.0		2.7	2.7	2.7	2.6	2.9	2.3																		
44											2.1		2.3	2.5	2.7		2.9	2.8	2.6	2.5													
45									2.7	2.2	2.1	2.5	2.5	2.1										2.9	2.9	3.0							
46											2.5	2.4	2.4	2.7	2.3										3.0	3.3	2.9						
47														2.6	2.8	3.3	3.6	3.3	2.9							3.1	3.2	2.9					
48												2.3	3.0	3.0	2.7			2.5	2.9			2.6	2.7	2.6				2.9	2.4				
49											2.3	2.8	2.6	2.8	2.7			2.8	3.1	3.2	3.1	2.7	2.7	2.6									
50														2.8	3.1	3.3	3.6	3.3	3.3	3.0	2.8					2.8			2.7	3.1	2.6		
51														2.6	3.2	3.4	3.4	3.2	2.9	2.8	2.7	2.5		2.6					2.4	2.9	2.6		
52														2.6	3.1	3.8	3.4	3.5	3.4	3.2	3.1	3.2	2.7								2.7	2.9	
53															2.4	2.9	3.2	3.4	3.6	3.2	3.3	3.1	2.8	2.8									2.9
54																		3.3	3.3	3.3	3.3	3.4	3.2	3.4	3.3	3.1	2.7						
55																	2.8	3.3	3.4	3.4	3.8	3.4	3.1	2.9	2.7	2.9	2.9						
56																		2.7	2.9	3.0	2.9	2.8	3.3	3.4	3.6	3.7	3.3	2.8	2.5				
57																		2.7	2.6	2.7	3.2	3.3	3.2	3.2	3.0	3.1	3.2	2.9	2.5	2.5			
58																			2.7	2.8	3.1	3.4	3.5	3.4	3.4	3.3	3.2	2.9	2.8	2.4			
59																				2.5	2.8	3.2	3.4	3.7	3.7	3.7	3.3	3.1	2.9	2.7	2.8		
60																						2.8	3.2	3.4	3.5	3.6	3.2	3.2	3.1	3.0	2.7	2.7	
61																							2.9	3.5	3.6	3.7	3.7	3.6	3.4	3.1	3.0	2.8	2.9
62																							3.0	3.1	3.3	3.5	3.3	3.2	3.2	3.0	3.0	3.2	3.1
63																						2.5	2.5	2.7	2.7	3.1	3.1	3.2	3.3	3.4	3.5	3.4	3.4
64								1.8																		2.6	3.0	3.2	3.3	3.3	3.5	3.8	4.1
65																											2.7	3.0	3.2	3.4	3.3	3.4	3.9
66																												2.8	3.1	3.3	3.5	3.6	3.9
67																												2.6	2.9	3.2	3.3	3.6	3.9
68																														2.8	3.1	3.5	3.9
69																														2.9	2.9	3.3	3.6
70																															2.6	3.0	3.6
71																																3.0	3.4
72																																	3.1
73																																	
74																																	
75																																	
76																																	
77																																	
78																																	
79																																	
80																																	
81																																	
82	2.4																																
83	3.0	3.0	2.6																														
84		3.6	3.1	2.2																													

Data source: ONS (2001, 2002b)

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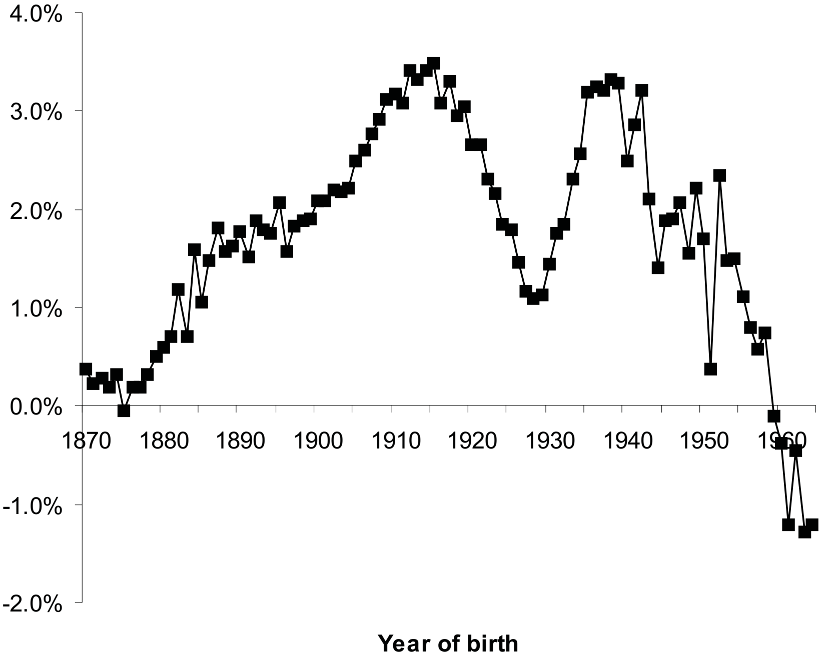
8.2.4 Tables 8 and 9 clearly demonstrate that the cohort of females born in the period 1910 to 1915 have continued to experience faster improvements than other generations of Japanese women. This trend has continued through the 1980s and 1990s, persisting even though the women in the select cohort are now aged in their 80s.

8.2.5 The annual rate of improvement for this cohort was approximately 4.5% p.a. when they were aged in their 60s. It is still running at around 3.5% p.a. for ages in excess of 80.

8.2.6 This pace of improvement has been rarely seen at such advanced ages. It is also notable that women in Japan already have the longest life expectancy of any country in the world.

8.3 *Japanese Males*

8.3.1 Mortality trends for Japanese males have followed a different pattern. Figure 23 indicates that there have been two select cohorts: males born in 1910 to 1920; and those born in 1935 to 1945.



Data source: www.mortality.org

Figure 23. Average annual rates of mortality improvement in the Japanese population by year of birth (nine-year rolling averages) for males

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8.3.2 The alternative presentation method used for females yields slightly different results for males, which are given in Table 10. The 1910 to 1920 cohort is overtaken by the later cohort in having the highest improvements rates in recent years.

8.3.3 The existence of both cohorts can be seen in Table 11, which presents the information in a slightly different way. In Table 11, the improvement rates in cells are only shown if they are in excess of the mean value for each age (averaged over the whole period 1954 to 1995).

8.4 *England and Wales*

8.4.1 For reference, the same approach used to produce Tables 8 to 11 was also applied to data for males in England and Wales. Table 12 shows rates of improvement in excess of 70% of the maximum for each calendar year.

8.4.2 The existence of two cohorts can clearly be seen, with the second, weaker effect, centred around 1944.

8.4.3 This format of presentation clearly shows that the cohort effect for males in England and Wales is not 'wearing off' with time or increased age. Indeed, rates of improvement have clearly accelerated for the 1925 to 1935 birth cohort as they have aged.

9. Conclusions

9.1 *A Convergence of Views*

9.1.1 Researchers in a wide range of disciplines, including epidemiology, social science and economics, believe that people born in different generations are likely to experience different health characteristics in later life. It is suggested that the experience of different generations — before birth, in childhood and in adulthood — is a powerful determinant of experience in later life and has predictive possibilities.

9.1.2 The epidemiologist Professor Michael Wadsworth (1991) has expressed this as follows:

> "... a degree of anticipation is possible within lifetimes ... through those things which make an imprint on life at one point, and which are carried forward on into later life."

9.2 *The U.K. Cohort Effect*

9.2.1 It is highly likely that the U.K. cohort effect is due to a number of different factors.

9.2.2 Prevalence of smoking from one generation to the next has certainly been one such factor. Furthermore, an analysis of patterns of cigarette smoking suggests that there is a degree of inevitability in some element of likely future improvements, especially for mortality at older ages from conditions strongly linked to smoking.

9.2.3 However, trends in heart disease and breast cancer mortality suggest that smoking is not the only factor. There appear to be two 'sub-cohorts' of the 1925 to 1945 cohort: an earlier group where the improvements are largely due to smoking, and a later one where other factors, such as diet in early life, have played a greater role.

9.2.4 The Japanese case study shows that strong cohort trends can be projected well into old age. This does not provide proof that the U.K. cohort effect will do the same. However, it does counter arguments that year of birth effects will inevitably wear off with age. It is especially interesting, given recent epidemiological research linking early life experience with markers of ageing.

9.2.5 There are a number of reasons to believe that the cohort effect will have an enduring impact on rates of mortality improvement in the U.K. in future decades. These include historical patterns of smoking behaviour and the impact of early life experience on health in later life. There appears to be little evidence to support the idea that the width of the generation experiencing rapid improvement will reduce with time.

9.3 *Further Research*

9.3.1 In many respects this report provides more questions than answers, and it certainly suggests areas where further research could be of use.

9.3.2 If we are to establish to what extent the U.K. cohort effect is likely to be projected forwards into the future, we need to understand why it has occurred. This report indicates that a detailed analysis of trends by cause of death may be helpful if this goal is to be achieved. It also suggests that more research into the forces driving international trends in mortality by year of birth could be beneficial.

9.3.3 Finally, it serves as a reminder that there is much to be learned from other disciplines. In particular, recent research in the field of epidemiology should be noted by actuaries faced with the task of projecting rates of mortality into the future.

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