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# Insight into Stagnating Life Expectancy:

Analysing Cause of Death Patterns across Socio-economic Groups.

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## Abstract

This article analyzes the complexity of female longevity improvements. As socio-economic status is found to influence health and mortality, we partition all individuals, at each age in every year, into five socio-economic groups based on an affluence measure that combine an individual's income and wealth. We identify the particular socio-economic groups that have been driving the standstill for Danish females. Within each socio-economic group, we further analyze the cause of death patterns. The decline in life expectancy for Danish females is present for four out of five subgroups, however with particular large decreases for the low-middle and middle affluence groups. Cancers, smoking related causes, and other diseases particularly contribute to the stagnation. Moreover, cardiovascular and cerebrovascular diseases are found to be important for capturing the following catch-up in longevity.

*JEL classification*: J11; C53; G22
*Keywords*: Mortality; Affluence Groups; Health Inequality; Cause of Death;

## 1 Introduction

Over the last centuries significant increases in life expectancy have been observed for the developed countries (Oeppen and Vaupel, 2002). However, this observed decline in mortality rates is not a general pattern, as periods with gender-specific divergence between countries have emerged. In the Scandinavian countries in particular we have observed a decrease in the mortality rates for Norwegian and Swedish females, but a stagnating or in some cases even increasing mortality rate for Danish females in the period from 1980-1995, see Lindahl-Jacobsen et al. (2016b). A similar divergence has not been observed for Scandinavian males. This phenomenon is not unique to the Scandinavian countries. Meslé and Vallin (2006) showed that the USA and the Netherlands exhibit a similar slowdown in life expectancy as the Danish females over this period whereas e.g. France and Japan displayed stable, positive improvements in life expectancy. A profound understanding of stagnating mortality patterns are important for several reasons. From a policy point of view, it is important to establish the causes of the slowdown and in particular, what can be done to reverse these trends in order to better implement and target health policies. Second, knowledge about mortality trends by socio-economic groups and causes of death can help governments manage their health care costs, which is consistently increasing worldwide (Xu et al., 2018). Furthermore, many mortality forecasts published by statistical institutions use linear extrapolative methods (Stoeldraijer et al., 2013) which fail to provide reliable forecasts when departures from a linear trend are observed, for example during stagnating periods. A better understanding of stagnating patterns can be used to potentially improve existing methods by incorporating the underlying factors.

The observed stagnation in life expectancy for Danish females is well established in the literature, see Jacobsen et al. (2002), Jacobsen et al. (2004), and Lindahl-Jacobsen et al. (2016b). They argue that the stagnation is due to a cohort effect as higher mortality rates are observed for Danish females born between the two world wars. These cohort effects are not present in Sweden or Norway. This was further investigated in Lindahl-Jacobsen et al. (2016a) using cause of death data for Denmark. Despite several studies on the stagnation for Danish females, the socio-economic component of this stagnation has not been analyzed and in particular not by socio-economic cause-specific mortality. This is the main contribution of this article.

In general, the impact of socio-economic status on health and life expectancy is well documented and found to be positively correlated e.g. Van Doorslaer et al. (1997); Kunst et al. (1999); Saurel-Cubizolles et al. (2009); Brown et al. (2012). That is, individuals in lower socio-economic groups have poorer health and thus higher mortality rates. Using Danish data, Brønnum-Hansen and Juel (2004) investigate the impact of smoking on the social gradient in health expectancy for four educational groups. Further, Brønnum-Hansen and Baadsgaard (2012) find an increasing inequality in life expectancy using quartiles for disposable income, although modestly increasing for females. The ability to combine the socio-economic component with the cause of death data will allow us to get a more nuanced understanding of which underlying trends have been causing the slowdown in improvements of life expectancy. Further, Brønnum-Hansen and Baadsgaard (2012) find an increasing inequality in life expectancy using quartiles for disposable income, although modestly increasing for females. Despite arguing that health-related behaviours vary between social groups, Brønnum-Hansen and Baadsgaard (2012) choose survey-based smoking prevalence data to explain difference in developments in life expectancy rather than cause of death data. This article exploit the ability to combine the socio-economic component with the cause of death data which will allow us to get a more nuanced understanding of which underlying trends have been causing the slowdown in improvements of life expectancy.

This article uses the comprehensive Danish register data for the full population, allowing us to investigate the development of mortality across socio-economic groups for the past three decades. Following Cairns et al. (2019), who study Danish males, we construct an affluence measure for each individual which combines the individual's income and wealth in a composite variable. The gender-specific allocation procedure assigns each individual in each year and age into one of five socio-economic groups based on the individual's ranking in terms of the affluence measure. The main advantage is the ability to obtain five equally sized groups for each year and age. Another benefit of using the affluence measure is that it is possible for individuals to be well off by having a high wealth and a high income or by having either a high wealth or a high income independently. Finally, we decompose changes in life expectancy by cause of death across five socio-economic groups to explain which causes contributed to the stagnation and the following catch-up period for each socio-economic group.

A number of different indicators have been suggested to partition individuals into socio-economic groups. Van Doorslaer et al. (1997) use income for socio-economic status whereas Saurel-Cubizolles et al. (2009) use occupation, education level, income as well as residential area characteristics. Other studies using similar indicators include among others Elo and Preston (1996), Kunst et al. (1999), Brønnum-Hansen and Baadsgaard (2012), and Permanyer et al. (2018). We deliberately avoid using educational attainment as an indicator of socio-economic adherence to prevent a potential bias from the compositional changes in the levels of education (OECD, 2018). The main challenge with educational attainment is the ties in data, which forces the fractiles to vary across time. E.g. the lower educated group will contain a substantially larger share of the population in the beginning of the data period compared to the end. This finding is well documented in many developed countries (OECD, 2018). Moreover, several studies note that much of the change in life expectancy by education is caused by the compositional changes in proportions of different educational levels and not in the association between education and mortality (Brønnum-Hansen and Baadsgaard, 2012; Olshansky et al., 2012; Hendi, 2015). The relationship between education and life expectancy (Sasson, 2016) is well-documented in cross sectional or short time period studies. However we, analyze mortality development across three decades making education an unattractive indicator.

Few studies have analyzed mortality across both a financial indicator and cause-of-death for the entire population. Most studies like for example Blakely et al. (2005) and Fawcett and Blakely (2007) use self reported survey data. Tarkiainen et al. (2012) has previously accounted for both socio-economic differences and cause of death in a study of the Finnish population using a random sample 11% of the total population for a time period of 20 years. They analyze the gap in life expectancy in Finland using taxable income as a proxy for adherence to a specific socio-economic group. Tarkiainen et al. (2012) find that different mortality patterns are present across socio-economic status. The lowest socio-economic group in Finland experience lower increases in life expectancy compared to the other income quantiles due to alcohol related diseases and cancers.

In summary, we find that subdividing the population into socio-economic groups reveals important sub-group specific mortality patterns which were hidden when analysing the total population. Further, we find that affluence measured by income and wealth is important as a socio-economic measure which enables a relevant disaggregation for studying mortality patterns by socio-economic status. Further insights were obtained by decomposing changes for each socio-economic group by cause of death which made it possible to detect which causes of death that dominated the changes in life expectancy. The results presented in this article find that the decline in life expectancy above age 50 for Danish females until 1995 is present in four out of five subgroups, however with particular large decreases for the low-middle and middle affluence groups. Interestingly, we find that the lowest affluence groups for Danish females have large improvements in life expectancy at the highest ages, i.e. 80-95 year old. We find that causes of deaths related to cancers, smoking related causes, and other causes contribute to the slowdown in female longevity. A decline in cardiovascular diseases had a positive effect on life expectancy, during the period with stagnating life expectancy, but not sufficient to off-set the negative effects from cancers, smoking related causes, and other causes. This is in line with the findings of Jacobsen et al. (2006) and Aburto et al. (2018) which shows that a higher number of cancer deaths explains a larger divergence between life expectancy in Sweden and Denmark during the period with stagnating life expectancy for Danish females. We find that all the socio-economic groups exhibit substantial improvements after 1995, which are primarily caused by fewer deaths from cardiovascular diseases.

## 2 Affluence Index and Data

### Indexation of Individuals into Subgroups

We subdivide the population into five subgroups on a yearly basis based on income and wealth using the affluence index allocation procedure of Cairns et al. (2019), who studied Danish males in the period from 1985 to 2012. The five groups are denoted G1 to G5, with G5 being the most affluent group. The affluence index can be thought of as an intuitive way of capturing total assets, both observed wealth and human capital as argued in Cairns et al. (2019). $K$ times income is an approximation of the individual's future income and this in turn reflects the individual's 'human capital' (Becker, 1975). Another benefit of the affluence measure is that it is possible for individuals to be well off by having both a high wealth and a high income or by having either a high wealth or a high income independently. By using both variables it is possible to assign the correct affluence groups (Cairns et al., 2019).

Cairns et al. (2019) defined an affluence index $A(j,t,x)$ for individual j aged $x$ in year $t$ as wealth plus $K$ times income in the preceding year, that is:

$$A(j,t,x) = W(j,t-1,x-1) + K \cdot I(j,t-1,x-1) \tag{1}$$

where $W(j,t-1,x-1)$ is the wealth for individual $j$, at age $x-1$ in year $t-1$ and $I(j,t-1,x-1)$ is the income of individual $j$, at age $x-1$ in year $t-1$ and $K$ is a constant. The procedure partitions individuals into five subgroups based on the rank of the affluence metric in a given year. We use one year lagged wealth and income as these are likely to be missing or measured with error in the year of death. At the main retirement age of 67, each individual is locked to remain in the assigned group for the remainder of their spell. The lockdown prevents an artificial fill up of the lowest socio-economic group by individuals who have spent their personal wealth on health care due to health problems (Cairns et al., 2019). Based on the results in Cairns et al. (2019) we use $K = 15$ as it was found to give a good fit and that it approximates the present value of the income stream to come. Further, $K$ is also working as a weighting factor to account for the fact that income is a flow variable whereas wealth is the stock of the accumulated wealth. The results were found to be robust to different choices of $K$.[1]

## Data

The Danish register data is available in complete form from 1985 to 2012 and contains individual specific data for a wide range of variables. For the analysis gender-, socio-economic-, and age-specific death rates are calculated, given by

$$m_{x,t,g} = \frac{D(x,t,g)}{E(x,t,g)}. \tag{2}$$

$m_{x,t,g}$ is the central death rate at age $x$ in calendar year $t$ for group $g$, $D(x,t,g)$ is the number of deaths, and $E(x,t)$ is the exposure-to-risk. We calculate life expectancy ($e_{x,t,g}$) and other life table measures using standard life table techniques following Preston et al. (2000).

The primary variables used for the affluence measure are the individual's income and wealth. Individual's income is measured as the gross annual income which includes wage income, unemployment benefits, gross income from being self-employed, social assistance (only from 1994), and pensions. Net wealth is defined as total assets minus total liabilities at year-end. The main assets include real property, bank deposits, securities including stocks and bonds, and cash holdings. The liabilities include all types of debt to private companies and the government. The assets also include shares held in firms and the value of larger durable goods such as cars and boats. For married couples the wealth is assigned by 50 % to each spouse.

Minor modifications to the data were necessary to handle e.g. missing observations. For income and wealth, 0.0154 % of the observations are missing and replaced with the mean of the individual's income or wealth. We could have chosen to drop these individuals from the analysis but included them to consider the whole population. Both approaches will produce almost identical results as the number of missing observations are very low. We focus on the ages from 50 and older as ensures that individuals have accumulated sufficient wealth and salary to represent their actual socio-economic group. Moreover these ages groups are of primary interest for among others pension funds. For all cause mortality the data are presented in single age and time intervals and top-coded at age 95 due to a small number of death counts at higher ages. As validation, death rates and life expectancies of the total sex-specific population are compared with data from the Human Mortality Database (2019) and almost identical results are found.

## Cause-specific data

Changes in life expectancy at age 50 are decomposed into cause specific contributions using the method by Arriaga (1984). More specifically, the change in life expectancy from the difference in mortality rates between age group $x$ to age group $x+n$, ($\Delta_x$), from period 1 to 2 is decomposed by:

$$\Delta_x = \frac{l_x(1)}{l_0(1)} \cdot \left( \frac{L_x(2)}{l_x(2)} - \frac{L_x(1)}{l_x(1)} \right) + \frac{T_{x+n},(2)}{l_0(1)} \left( \frac{l_x(1)}{l_x(2)} - \frac{l_{x+n}(1)}{l_{x+n}(2)} \right) \tag{3}$$

[1] Cairns et al. (2019) makes other sensitivity tests by experimenting with other income measures such as disposable and household income.

where $l_x$, $L_x$ and $T_x$ are the life table measures: people who reach age x ($l_x$), number of people alive between age x and x+n ($L_x$) and number of people alive above age x ($T_x$).

To decompose how much of the changes in life expectancy that is due to each cause- and age-specific groups we use the following decomposition:

$$\Delta_x^i = \Delta_x \frac{R_x^i(2)m_x(2) - R_x^i(1)m_x(1)}{m_x(2) - m_x(1)}, \tag{4}$$

where $m_x(1)$ and $m_x(2)$ are all-cause death rates for time period 1 and 2, $R_x^i(1)$ and $R_x^i(2)$ the proportion of deaths from cause $i$ in time period 1 and 2, see Preston et al. (2000) for further details.

Deaths in Denmark are classified using the International Classification of Diseases (ICD) revision 8 and 10 during the period from 1985 to 2012. For the purpose of this article we grouped the primary causes of death into eight major causes, which are: 1) smoking-related causes (defined as trachea, bronchus and lung cancers together with chronic obstructive pulmonary disease which are often found to be related to smoking[2] ), 2) cardiovascular, 3) diabetes, 4) cancers, 5) cerebrovascular diseases, 6) mental diseases, 7) external causes and 8) other causes. The main causes included in the external causes are accidents and suicides. Other causes comprise all remaining causes. The largest cause among other causes are ill-defined causes, pneumonia, and diseases of the nervous system. See Appendix Table A.1 for further details about the classification.

Due to small cause-specific death counts when disaggregating on both socio-economic groups, age, and year, it is necessary to aggregate ages and years such that life table measures can be calculated. Hence, the cause-specific analysis use data in age groups of five from age 50 to 90+ and in time periods of two years from 1985 to 2012. Results of the decomposition are aggregated considering the stagnation period from 1985 to 1994 and compared with the following period of the same length, 1995 to 2004. This will ensure that we measure the continuous process in the change of life expectancy most accurately. The relative size of each cause of death is shown in Fig. A.1, in the appendix, where the proportion of deaths are presented for the Danish females by socio-economic group.

## 3 Empirical Analysis

We first illustrate the study period with stagnation in life expectancy at age 50 for the total population in Denmark, Norway, and Sweden using data from the Human Mortality Database (2019). Danish females' life expectancy declines slightly from 29.89 years in 1980 to 29.82 years in 1995 compared with an increase in life expectancy from 31.46 to 32.33 and 31.61 to 32.88 for Norwegian and Swedish females, respectively. Life expectancy of Danish males also falls below the life expectancy of Swedish and Norwegian males but follows a similar increasing trend in the years 1985 to 1995. Thus, the life expectancy pattern observed for Danish females is unique for the Scandinavian populations.

Figure 1 around here.

[2]Smoking related causes could have been defined broader considering more causes as smoking related (Aburto et al., 2018). It is however not the purpose of the study to define smoking related causes, thus we label the listed causes as they are highly associated with smoking (Preston et al., 2011)

### Development in Life Expectancy across Affluence Groups

Figure 2 presents life expectancy at age 50 and 65 for each of the five socio-economic groups, for Danish females. For Danish females, we clearly observe a stagnation for the groups G2 to G5, and for the groups G2 to G4 even a decrease from 1985 to 1995. For example, the G3 group life expectancy at age 50 decreases from 30.90 in 1985 to 30.01 in 1995. Hence, disaggregating by socio-economic status reveals subgroups with different mortality patterns compared to the aggregated level. The clear ranking of life expectancies across subgroups persists across ages, as for age 65 in Figure 2, although the differences between the subgroups decrease with age. The same degree of stagnation is not present for Danish males where life expectancies for most groups are increasing over the whole period, see Figure X in the Appendix. Neither is a stagnation found for any socio-economic group among Norwegian females or males (Kallestrup-Lamb and Rosenskjold, 2017).

Figure 2 around here.

## 3.1 Life expectancy by socio-economic group

In this section, we analyze all-cause mortality by first calculating the rates of improvements by age and next decomposing the improvements in life expectancy using the method presented in equation 3 and 4 but using socio-economic groups instead of cause of death. Analysing the rates of improvement gives an overview of the mortality patterns by socio-economic group and the decomposition analysis quantifies the socio-economic group specific contributions.

### Rates of mortality improvements

Socio-economic differences in mortality are analyzed by their rate of mortality improvement to identify patterns in the mortality changes. Figure 3 shows the annual rate of improvements in death rates for Danish females across socio-economic groups. Similar plots are shown for males in the appendix in Figure A.2. The rate of improvement, $\rho(x,t)$, is calculated using smoothed death rates which allows us to detect the dominating mortality trends where, $\rho(x,t+1) = -ln\left[m(x,t+1)/m(x,t)\right]$ (Rau et al., 2018). The death rates are smoothed using P-splines following the method by Camarda (2012).

Figure 3 shows that the standstill in life expectancy from 1985 to 1995 is primarily due to ages from 65 and older for the groups for low-middle to high-middle socio-economic groups in particular (less pronounced for G5), indicated by the grey areas for these ages with negative improvement rates from 0.5% to 3%. This clearly illustrates the effects from specific cohorts, born between the two world wars, on the total life expectancy as identified by among others Lindahl-Jacobsen et al. (2016b). Surprisingly, the lowest affluence group had an improvement in mortality for ages 70 to 90 in the same period with improvement rates up to 4%. The improvement rates show a similar pattern for the groups G2 to G5 during the whole period which is not shared by the group G1. For example, for females aged 50 to 55 in the years 1995 to 2005 show stagnating mortality for G1 and improvement rates around 2 % for the groups G2 to G5. Similarly, in the subsequent catch-up period, Danish females around age 65 (in the years 2004 to 2010) show high improvement rates for the groups G2 to G5 but not for G1. Thus, the lowest socio-economic group shows dissimilarity towards the other groups. The total population is the aggregation of the five socio-economic groups and because four of the five groups display a similar patter they dominate the improvement rates for the total population. The aggregated level is thereby concealing relevant dissimilarities between group G1 and the remaining socio-economic groups.

Similar results are found for Danish males where G2 to G5 show a similar pattern throughout the sample period that differs from that of G1.

Figure 3 around here.

**Decomposing by socio-economic group**

Figure 4 shows the age and socio-economic group specific decomposition of changes in total life expectancy at age 50. We decompose the period with stagnating life expectancy (1985 to 1994) and a subsequent period of equal length (1995 to 2004).

Figure 4 around here.

The decomposition in Fig 4. and the improvement rates in Fig 3 show a similar result but the decomposition quantifies the group specific contributions to the total life expectancy. The results are not identical because Fig 3 is based on smoothed rates to identify the main patterns. Age groups 50 to 60 for all socio-economic groups and age groups 65 to 95 for the lowest group contribute to positive changes in life expectancy. In contrast, most of the age groups from age 65 to 95 for the four highest socio-economic groups contribute negatively to changes in life expectancy. In the period from 1995 to 2004 all age groups (except age group 95 for G1) contribute to an increasing life expectancy. The decomposition analysis clearly shows the importance of studying the stagnation in life expectancy by socio-economic group as large differences in the mortality patterns are present by socio-economic groups.

## 4 Decomposition of life expectancy by cause of death

The unique data set used in this article allow us to combine socio-economic information with cause of death data and thereby further decompose mortality patterns for Danish females. The combination of socio-economic group based on affluence and cause of death has not previously been studied and adds to the existing knowledge about the stagnation in life expectancy for Danish females from 1985 to 1994.

Figure 5 shows that the period of stagnation, for Danish females, was primarily caused by increases in the number of deaths from cancers, smoking related causes, and other diseases for the socio-economic groups G2 to G5. These causes had a negative effect on life expectancy. During the period from 1985 to 1994, most of the socio-economic groups are experiencing a decrease in deaths from cardiovascular diseases and thereby experiencing a positive effect on life expectancy, but not sufficient to offset the negative effects as life expectancy is decreasing or stagnating. The lowest socio-economic group also experiences a decrease in deaths from cardiovascular diseases for all age groups and especially for ages 70 to 85 and for cerebrovascular diseases for ages 70 to 85. These improvements are the main reason for the narrowing life expectancy gap between the lowest socio-economic group and the other groups during these years.

Another important difference between G1 and the other groups is that G1 experiences small negative effects on life expectancy from cancer deaths for age 50 to 65 and small positive effects for ages 70 to 90. In contrast, the groups G2 to G5 experience negative effects from cancers for the age groups 60 to 90. Also, the proportion of deaths due to cancers around 1985 to 1994 differs across socio-economic groups. The proportion of cancer deaths is lower for G1 compared to the other groups where only 15% of the deaths are due to cancers compared to 20% or higher for the other groups (Fig. A.1 in the appendix).

Similarly, negative contributions are found from smoking-related causes for the groups G2 to G5 at age groups 65 to 90. Negative contributions which are not present for G1. G1 has a slightly higher proportion of smoking-related deaths in 1985, with around 15% of the deaths due to smoking related causes. This is higher than the other socio-economic groups, and a negative association is found between the proportion of deaths from smoking-related causes and socio-economic status, where only 10% of the deaths for the group G5 is related to smoking (Fig A.1 in the appendix).

A negative contribution is found for other diseases for the groups G2 to G5, ages 60 to 90 in the period 1985 to 1994, whereas only a small negative effect is found for G1 in the period around these ages. Other causes account for an increasing amount of deaths from around 12% of the total number of deaths to around 18% in 1994 for most socio-economic groups (Fig. A.1 in the appendix). The increase in the proportions of other causes is a natural consequence of the large decline in the number of deaths from cardiovascular diseases as deaths must add up to the total number of deaths each year. Meaning that causes such as ill-defined causes, pneumonia, and diseases of the nervous system increase in relative size although only small or no increases in the number of deaths are found. The remaining causes are of less importance in explaining the stagnating life expectancy from 1985 to 1994. Although negative effects from cerebrovascular diseases are present for the groups G2 to G5 from 1985 to 1994, these are less pronounced compared to the effects of cancers, smoking-related causes, and other diseases.

To sum up, the stagnation period for Danish females is a combination of a reduction in cardiovascular deaths and an increase in deaths from cancers, smoking-related causes, and other diseases for the four highest socio-economic groups. The decomposition clearly illustrates the importance of considering both socio-economic and cause of death specific information as a much more complete understanding of the mortality patterns during the stagnation period can be obtained. More complicated underlying mortality patterns are present than from an aggregated perspective.

Figure 5 around here.

In the period after 1995, Danish females experience fast improvements in life expectancy due to reductions in deaths from cardiovascular, cerebrovascular diseases, and smoking-related causes (Fig 5). Especially, deaths from cardiovascular diseases declined both in the period from 1985 to 1994 and in the period from 1995 to 2004, but at a faster pace after 1995. Deaths due to smoking-related diseases went from having a negative contribution to the overall life expectancy in the first period to having a positive contribution after 1995.

The largest age specific improvements tend to take place at higher ages for the higher socio-economic groups in the period from 1995 to 2004. Meaning, that G1 to G3 experience the largest contribution from ages 50 to 65, G4 from ages 65 to 75, and G5 experience large improvements for all ages above 65. G5 also experiencess a large contribution to the positive change in life expectancy at 90, compared to G1 and G2 where improvements in mortality at ages above age 90 are less pronounced. Only a few causes are having a negative effect on life expectancy, in this period, and the effects are small and limited to a few age groups. For example, diabetes and other diseases have small negative effect on life expectancy for age groups 60 to 80 from 1995 to 2004, for most of the socio-economic groups. Also, G1 experiences an increasing number of deaths due to mental diseases for ages 50 to 65.

The decomposition of life expectancy for Danish males is shown in the Appendix in Figure A.3. Several of the socio-economic groups for males experience a reduction in the number of cancer deaths from 1985 to 1994, which is contrary to the Danish females.

# 5 Discussion

### Statement of findings and explanations

Decomposing mortality improvements by cause of death is important to explain life expectancy patterns and to understand mortality differences between countries. The study presented in this article stands out from the other studies on stagnating periods of life expectancy Meslé and Vallin (2006), Lindahl-Jacobsen et al. (2016b), and Aburto et al. (2018) by providing a much more complete understanding of the underlying mortality dynamics as both socio-economic status and cause of death information is considered.

We found that a stagnation in the improvements of mortality for Danish females in the years 1985 to 1995 was primarily caused by females aged 65 to 95 in low-middle to middle socio-economic groups. The stagnation was caused by an increasing number of deaths due to cancers, smoking related causes, and other diseases. In contrast, the lowest socio-economic group experienced improving mortality in the same period for females aged 65 to 90, due to fewer deaths from cardiovascular and cerebrovascular diseases. When analysing the total population, only very small increases in life expectancy are found in the period from 1985 to 1994. This is a combination of improving mortality conditions for the lowest group and worsening conditions for the four highest socio-economic groups. Analysing mortality aggregated for the total population as in Lindahl-Jacobsen et al. (2016b), thus, conceals major differences for the lowest socio-economic groups with mortality improvements very different from the total level. Further, we found that the mortality patterns for the four highest socio-economic groups are similar during the study period. This is both in changes in all cause mortality presented in section 3.1 and for cause-specific mortality in section 4. Although the patterns are similar, relatively large mortality differences persist between the groups during the years from 1985 to 2012.

The lowest group did not suffer from the same increase in the number of cancers and smoking-related deaths as the other groups. This supports earlier findings by Munch and Svarer (2005) which report a very low correlation between cancers and the lowest socio-economic groups. Their study differs from the analysis presented in this article by not combining income and wealth, a shorter study period, and by not quantifying the effect from specific causes on the change in life expectancy. Danø et al. (2003) argue that the lowest educational group does not suffer from breast cancer because the risk pattern, for example, smoking, of well-educated females had not spread to lower social groups for cohorts that from 1985 to 1994 are around 65 to 90 years. It is not possible to determine all underlying factors from the register data as these are likely to be behavioural e.g. diet, physical daily activity, smoking etc. Such information are not generally accessible not even from surveys as it relates to retrospective behaviour for individuals. For the four highest socio-economic groups, smoking-related causes, cancers, and other diseases are the main drives of the stagnation which supports findings by Jacobsen et al. (2006) and Aburto et al. (2018) who analyzed the stagnation for the total population without considering the socio-economic dimension.

### Policy implications

Understanding mortality differences and their development across socio-economic groups is of general interest. From a policy point of view, it is important to know whether a period of divergence, or convergence, is caused by specific subgroups or whether it is a population-wide trend. Governments often desire to implement health policies that reduce the social inequality and improve life expectancy for all groups in society. For example, mental diseases contribute negatively to changes in life expectancy for the two lowest socio-economic groups at ages 50 to 65 in the period from 1995-2004. Hence, public policies that bring down mortality from mental diseases will tend to decrease socio-economic mortality differentials. Moreover, knowledge about mortality trends by socio-economic groups and causes of death can help governments manage their health care costs, as a reverse social gradient in health care costs is found worldwide, see French and Kelly (2016) and Christensen et al. (2016).

Knowledge about socio-economic mortality differences is also essential for risk management in pension funds and life insurance companies as it allows them to identify more accurate life expectancies across different socio-economic groups. This will, in turn, lead to a more reliable risk rating of customers, improved pricing, more accurate reserving calculations, and more effective hedging, see Cairns et al. (2019). In particular, according to Michaelson and Mulholland (2014), the pension industry has a substantial need to offload their exposure towards longevity risk. However, the financial market for trading this risk is currently very illiquid due to mismatches in demographics between the hedging and reference populations (e.g. the hedging population being the member portfolio of a pension company and the reference population being a national population). This mismatch is known as basic risk (Coughlan et al., 2011) and thus information about socio-economic specific mortality can inform the pension fund about the presence of basic risk and give guidance for adjustments of the hedge.

### Methodological considerations

Even though this article is based on high quality and highly reliable data, it is important to mention some data limitations which are present for all studies using cause-specific mortality data. First, it is complicated to determine the leading cause of death and involves subjective decisions made by medical doctors. Next, the data is limited by changes both in the ICD classification and the actual use of the classification. This problem is however minor as we are considering large groups of causes of death which are less affected by the changes. Further, we do not find any structural breaks in observed death rates during the years where the ICD codes change. Finally, the analysis works from the basis of the multi-decrement life tables which assume causes act independently. The assumption is necessary to make for the calculation of the standard multi-decrement life table. (Preston et al., 2000) Despite these limitations, we believe the presented cause of death decomposition produces reliable results and that the presented analysis increases our understanding of socio-economic and cause specific mortality.

Our article focuses on changes and decomposition of the expected length of life but the uncertainty surrounding the expected lifetime is equally relevant. This uncertainty is often measured by the coefficient of variation or life disparity (Aburto et al., 2018). Often a correlation is found between socio-economic status and life span inequality with low socio-economic groups having a larger variability around the age of death (Edwards and Tuljapurkar, 2005; van Raalte et al., 2011, 2014). For Denmark, Brønnum-Hansen (2017) analyzes life disparity trends by income dividing the Danish population into four income groups for both males and females. During the period from 1986 to 2014, the three highest socio-economic groups for both males and females are decreasing indicating that deaths occur with less variability over ages. The lowest socio-economic group experienced a constant life disparity for males and increasing for females indicating a higher variability. We do not measure life span inequality in this article as it has already been analyzed by Brønnum-Hansen (2017).

## 6 Conclusion

Concluding, we find that important socio-economic deviations are hidden if mortality is only studied at the level of the total population. Specifically, a period of stagnating Danish life expectancy from 1985 to 1994 can be explained by the four highest socio-economic groups. These groups experience a higher number of deaths from cancers, smoking-related causes, and other causes. The analysis shows the importance of analysing mortality both across socio-economic status and cause of death to understand the underlying patterns for the development of a populations life expectancy.

## 7 Acknowledgements

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# 8 Figures

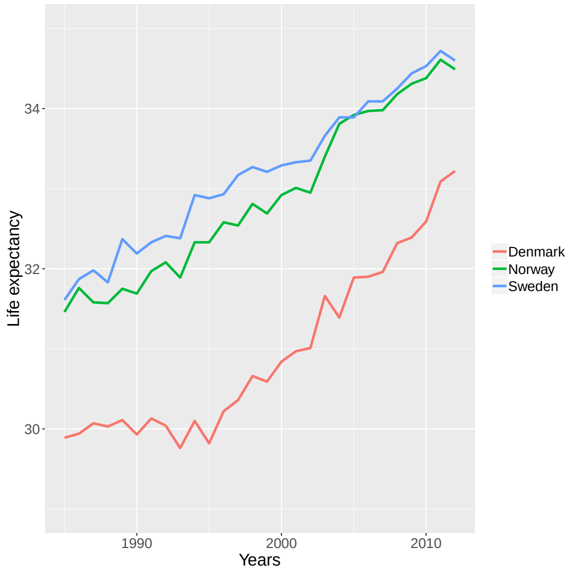


Fig. 1: Life expectancy at age 50, for females in Denmark, Norway, and Sweden for the years 1985 to 2014

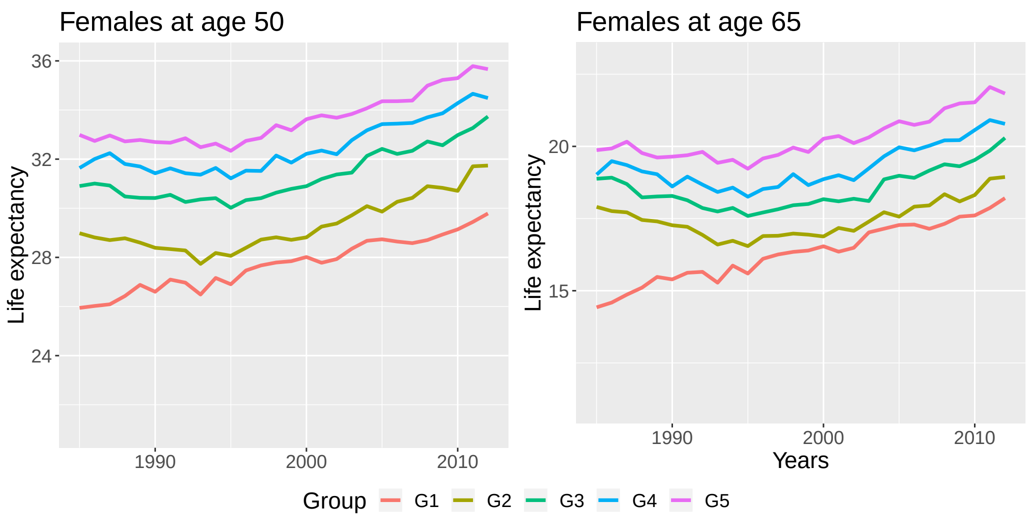


Fig. 2: Life expectancy at different ages 50 and 65 for Danish females in the period from 1985 to 2012

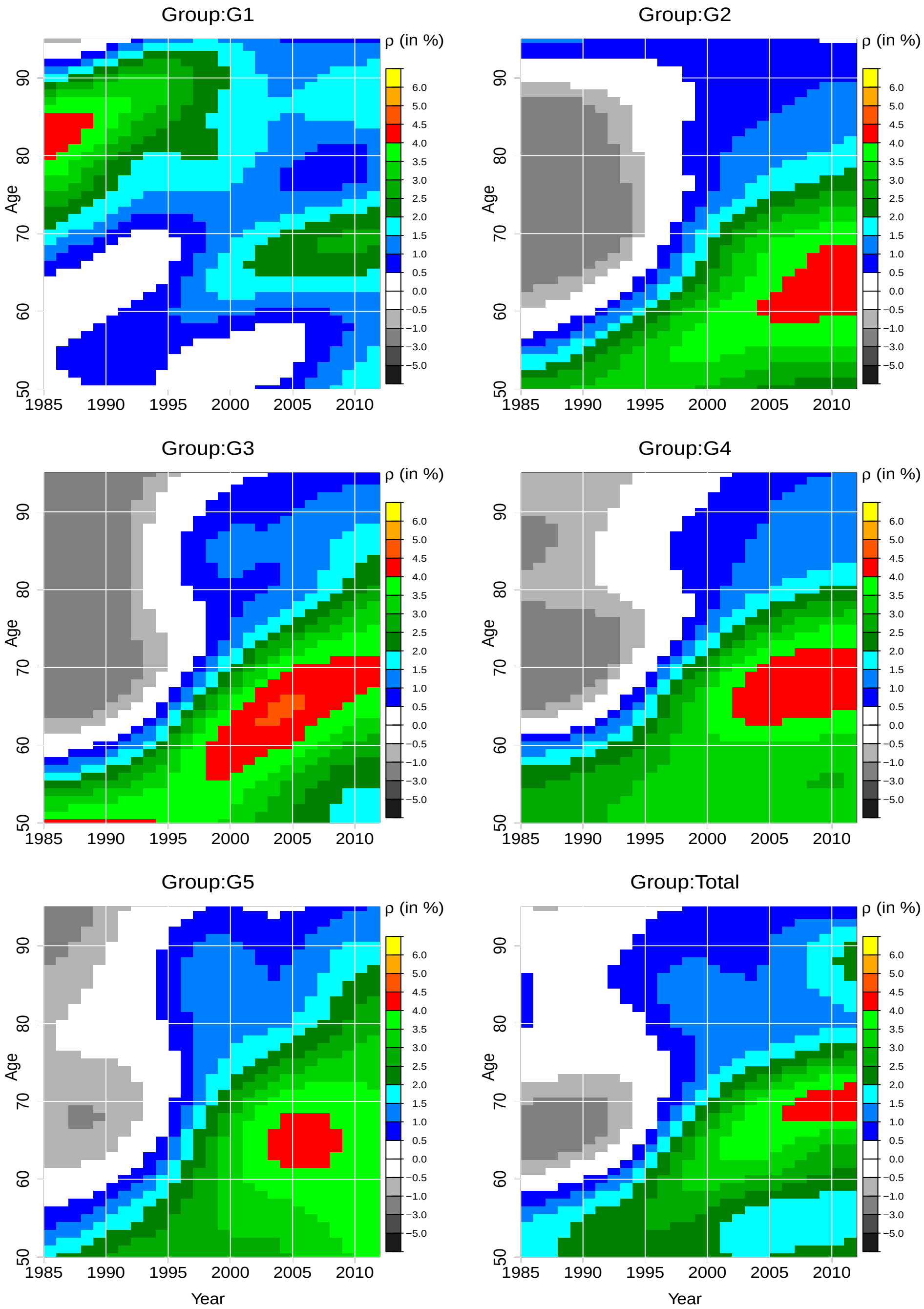


Fig. 3: Smoothed rates of mortality improvement by age and socio-economic groups for Danish females for the period 1985 to 2012

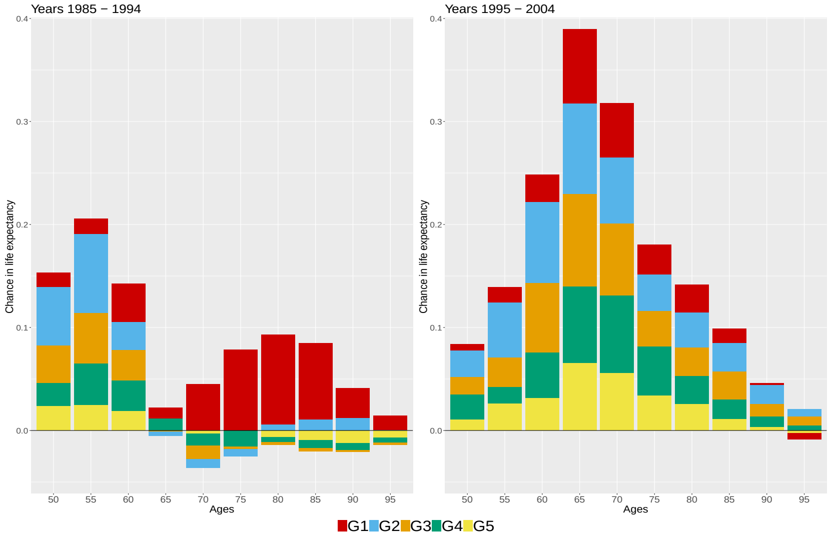


Fig. 4: Decomposition of total life expectancy at age 50 by socio-economic group for Danish females from 1985 to 2004

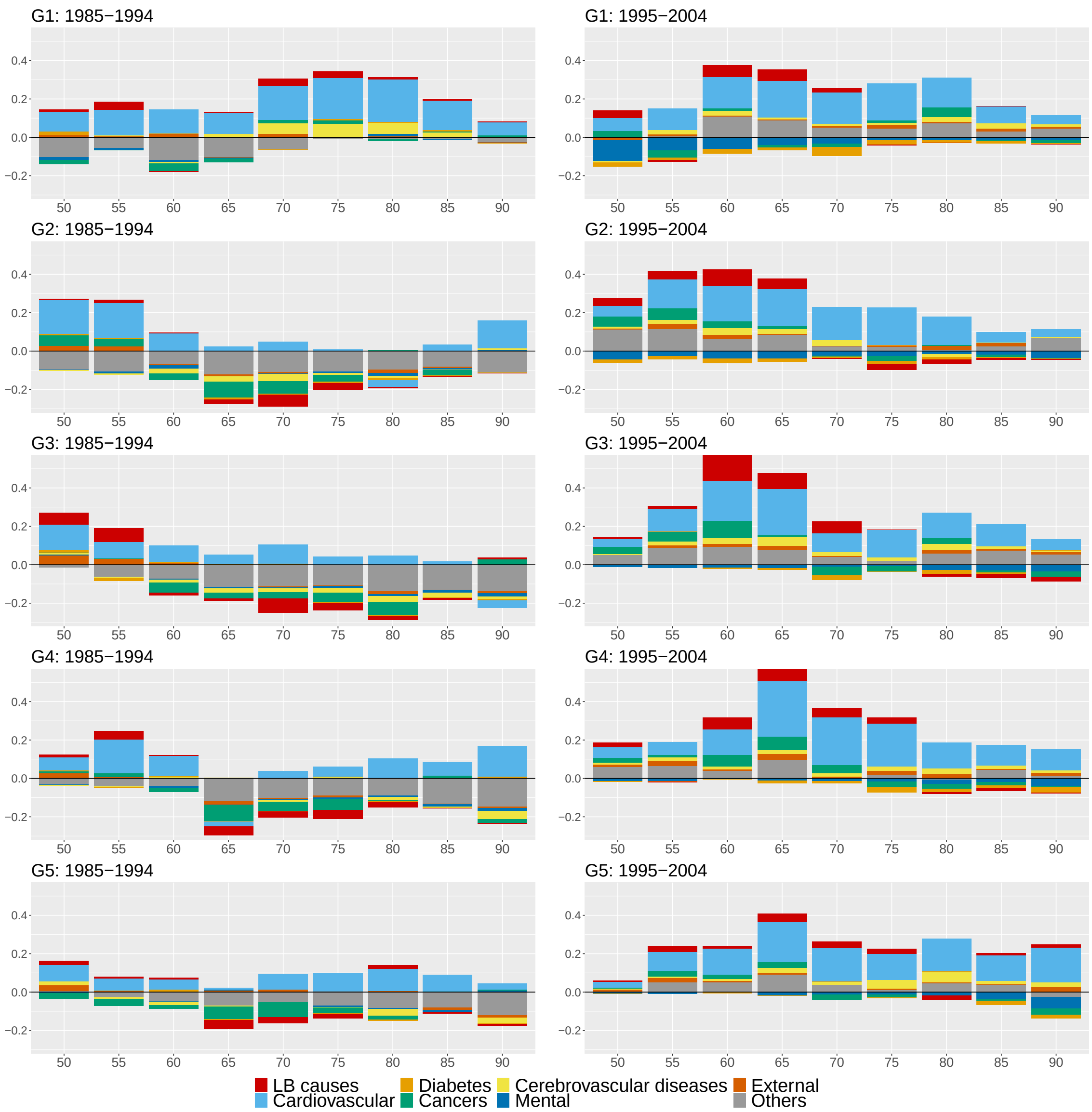


Fig. 5: Decomposition of life expectancy at age 50 by cause of death for the period 1985 to 2004 for Danish females

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# A Appendix

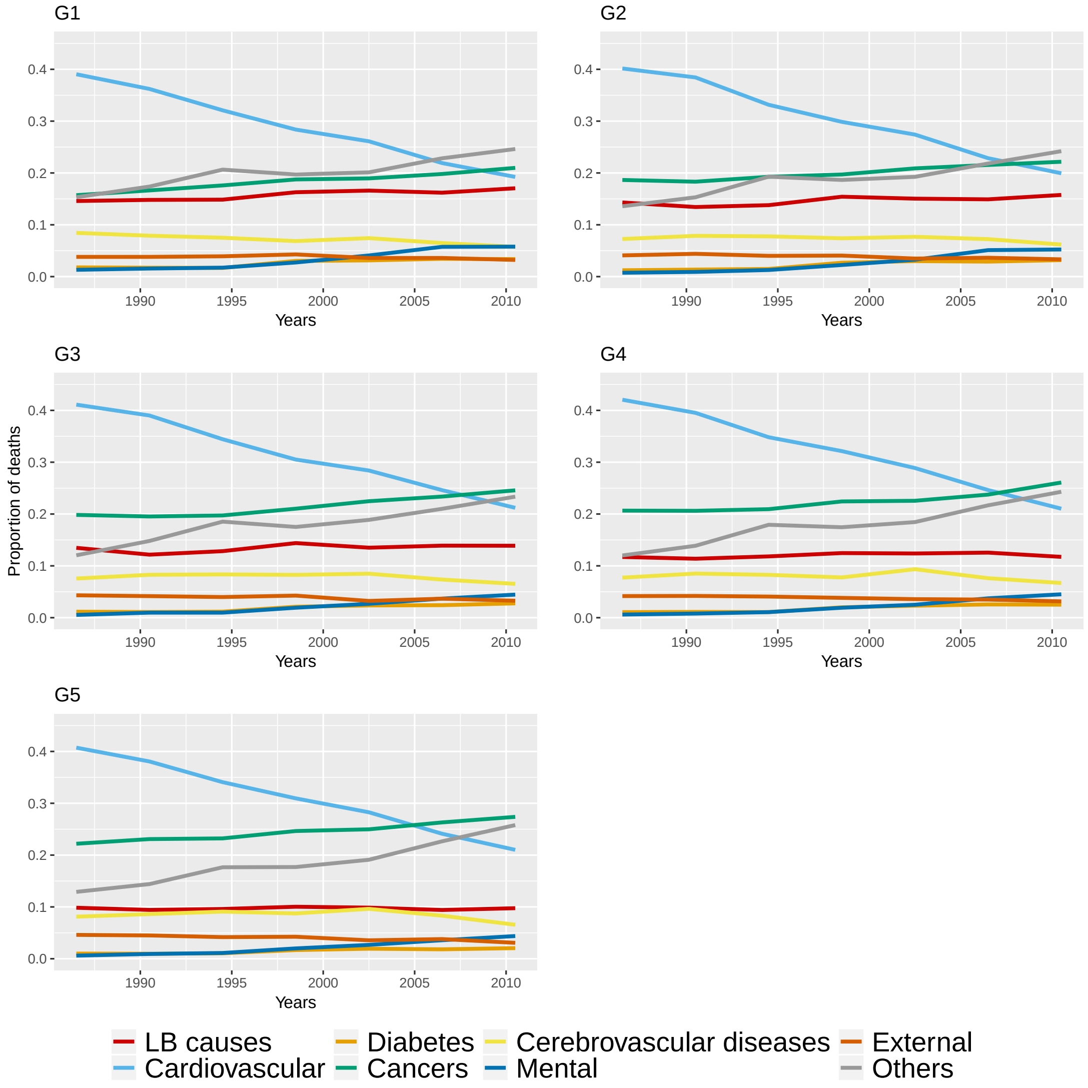


Fig. A.1: Proportion of deaths across socio-economic status for Danish females

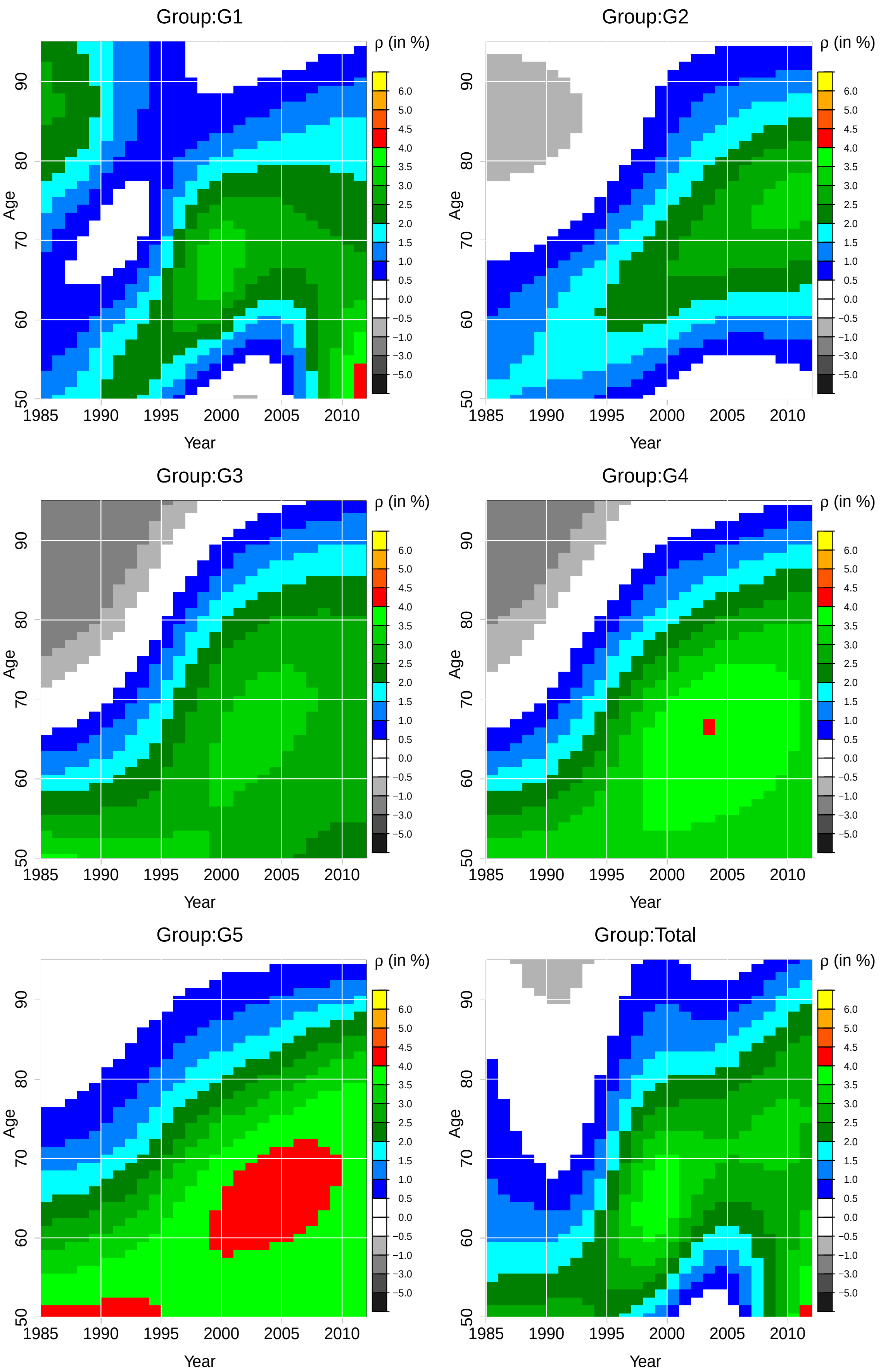


Fig. A.2: Smoothed rates of mortality improvement for Danish males from 1985 to 2012

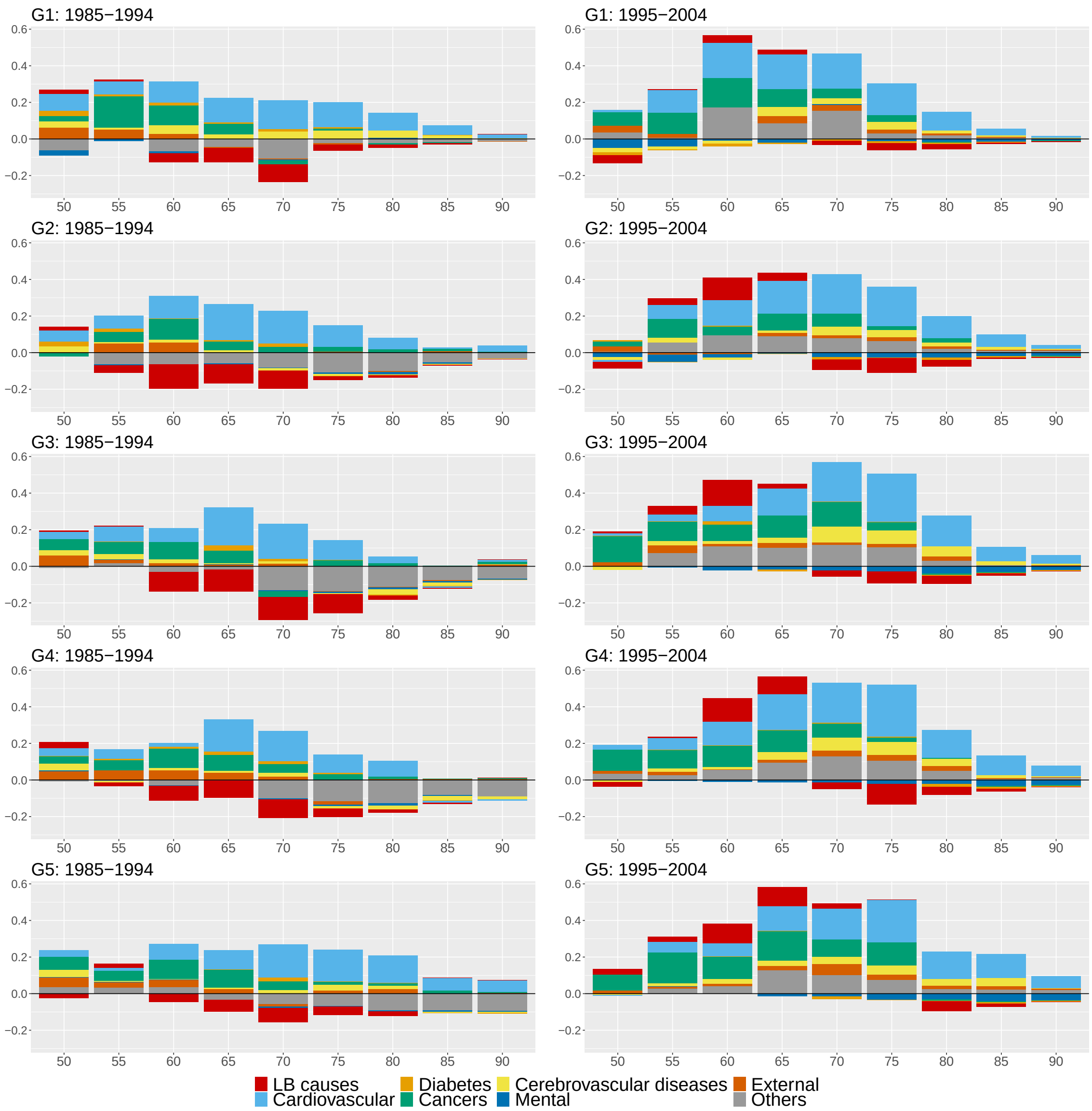


Fig. A.3: Decomposition by cause of death for selected time periods for Danish males

Table A.1: Cause of death classification in ICD10 codes

| Cause of death | ICD 10 |
|---|---|
| Smoking relate causes | C33-C34, J40-J44 |
| Cardiovascular | I00-I05, I20-I28, I30-I38,I40, I42, I44-I51, I70-I99 |
| Diabets | E10-E14 |
| Cancers | C00-C32, C37-C41, C43-C49, C50-C97, D00-D48 |
| Cerebrovascular diseases | I60-I69 |
| Mental diseases | F00 - F99 |
| External diseases | V01-V99, W00-X59, Y40-Y86, Y87.l- Y87.2, Y87-Y89, X60-Y36 |
| Others causes | All others |

From 1985 to 1994 Denmark is using the ICD8 system. We use the conversion table provided by the Danish ministry of health to convert death from ICD8 to ICD10 (Sundhedsstyrelsen, 2002)