RESEARCH REPORT
STUDY PAPER 190
APRIL 2023

Forecasting inequalities in survival to and after retirement by socioeconomic status in Denmark and Sweden

Cosmo Strozza, Marie-Pier Bergeron Boucher, Julia Callaway and Sven Drefhal

THE ROCKWOOL FOUNDATION
RESEARCH

STUDY PAPER 190 APRIL 2023

Forecasting inequalities in survival to and after retirement by socioeconomic status in Denmark and Sweden

Published by:

Address:
The ROCKWOOL Foundation Research Unit
Ny Kongensgade 6
1472 Copenhagen, Denmark

Telephone +45 33 34 48 00
E-mail: kontakt@rff.dk
en.rockwoolfonden.dk/research/

April 2023

Forecasting inequalities in survival to and after retirement by socioeconomic status in Denmark and Sweden

Cosmo Strozza[1], Marie-Pier Bergeron Boucher[1], Julia Callaway[1], Sven Drefhal[2]

[1]Interdisciplinary Centre on Population Dynamics, University of Southern Denmark, Odense, Denmark

[2]Department of Sociology, Stockholm University, Stockholm, Sweden

Abstract

In Denmark and Sweden, statutory retirement age is indexed to life expectancy to account for mortality improvements in their populations. However, mortality improvements are not equal across sub-populations. For example, in Denmark and Sweden, mortality improvements have been slower for individuals of lower socioeconomic status (SES), and uniformly raising the statutory retirement age could disproportionally affect these groups. The aim of this study is twofold: to quantify the effects of indexing the statutory retirement age on mortality inequalities in Denmark and Sweden; and to forecast mortality trends after age 50 in Denmark to assess how indexation of the pension age will affect future Danish sub-populations.

We use Danish and Swedish registry data (1987-2019), to aggregate individuals aged 50+ based on their demographic characteristics and SES. We compute period life tables by year, sex, and SES for Denmark and Sweden to estimate the probability of surviving until retirement age and the age at which the remaining life expectancy equals 14.5 years (the number of years Danish pension policy assumes one will live in retirement), among other measures. We forecast mortality for the SES groups in Denmark by using two coherent versions of the Mode model and the Li-Lee model until 2040.

Mortality inequalities are comparable in Denmark and Sweden, even though the latter has generally higher survival to and after retirement. We also find that indexing retirement age to life expectancy in Denmark will have two main consequences. Inequalities in survival across SES groups will not reduce as they would have if there was no indexation. On the other hand, time spent in retirement will be reduced generally, and even more for those with higher SES.

1. Introduction

Countries with the highest life expectancies are experiencing unprecedented population ageing. More people in recent cohorts are reaching statutory pension age than in previous ones, and when they retire, they are living longer (Burger et al., 2012; Vaupel et al., 2021). This phenomenon poses unique challenges to the financial sustainability of pension systems (Sanderson & Scherbov, 2010, 2015). To rectify this, both Denmark and Sweden, as well as several other European countries, have implemented policies that index the statutory pension age to life expectancy. In other words, as life expectancy increases, so does retirement age.

Life expectancy calculations are performed at the national level, and do not account for mortality differentials across sub-groups within the same country. For instance, a social gradient in mortality has been observed in most countries with high life expectancies, including those with higher national incomes, social transfers, and healthcare expenditures, and among both men and women. These socioeconomic inequalities have persisted, and, in many cases, increased, over time (Clouston et al., 2016; Mackenbach et al., 2017). Understanding changes in mortality across different sub-groups is, therefore, essential to assess the consequence of pension policies on socioeconomic inequalities in mortality. Some of the consequences of the recent pension policy reform can be anticipated by forecasting mortality. In this paper, we take advantage of a new forecasting method that uses different underlying assumptions on the rate of improvement (Bergeron-Boucher et al., 2022), and which has the potential to forecast mortality in Denmark more accurately. We extend the model to forecast mortality for subgroups of the Danish population. This paper has two objectives: (1) to quantify the differences in contemporary mortality developments after age 50 by socioeconomic status in Denmark and Sweden; and (2) to assess future impacts of these mortality developments, and consequent changes in statutory pension age, on inequalities in mortality in Denmark using two different forecasting models. These two objectives lay the framework for the two-part structure of the Results and Discussion sections.

2. Background

2.1 Population aging and pension policies in Denmark and Sweden

The Danish pension system is made up of three 'pillars': the public national pension and the mandatory savings-based pensions (pillar I), labour market pensions (pillar II), and private pension savings (pillar III). Pillar I caters primarily to people with low incomes to ensure a minimum level of standard of living. Pillar II accounts for the fact that many individuals maintain coverage of pension income in relation to income as a business asset, and thus avoid significant drops in income when withdrawing from the labour market. The private pension schemes in pillar III provide flexibility for individuals to adapt their savings to specific needs and additional coverage. These pillars work in tandem to achieve the three aims of the Danish pension system: to enable savings to maintain a reasonable standard of living, redistribute funds from high-income to low-income individuals, and act as insurance against uncertainty, for example, loss of working capacity before retirement age (Whitta-Jacobsen et al., 2022).

Current Danish legislation mandates a gradual increase in the statutory retirement age as life expectancy increases. Each increase must be supported by a majority in parliament. Increases in the state statutory retirement age are adopted every five years with 15 years' notice. The state statutory retirement age is determined by calculating life expectancy at age 60 for the total Danish population, plus an assumed increase in life expectancy of 0.6 years during the notice period, subtracted from the assumed state statutory retirement age period of 14.5 years. The state statutory retirement age can be increased by a maximum of one year at a time, and it is rounded to the nearest half year by regulation. In 2020, retirement age was 66 and in 2025, it is due to rise to 67. In 2040, it is expected to be 70.

Sweden's pension system is similar to Denmark's in that it is comprised of three parts: a public pension from the state, an occupational pension from an employer, and savings or assets that an individual may have. The national public pension is based on one's total income in Sweden throughout their working life, and is divided into several further parts: income pension, income pension complement, premium pension, and guarantee pension. Most people who have worked in Sweden also receive an occupational pension from their employer. Those eligible for Swedish pensions can apply for income pensions from the month they turn 63, at the earliest, which is due to increase to 64 in 2026. At 66 individuals can receive the guaranteed pension, income pension supplement, and housing supplement, which is due to rise to 67 in 2026. Individuals in Sweden have the right to work to age 68, or later if their employer permits it (Pensions Myndigheten, 2023).

2.2 Social inequalities in mortality

Typically, when sub-populations are categorised according to their socioeconomic status (SES), three elements are considered: education, employment, and income (Berkman et al., 2014). The latter, if standardised, is practical for international comparisons (Eurostat, 2021). In research, these elements are employed individually or used in tandem to categorise SES groups for a more nuanced examination of a population.

The SES gradient in mortality is generally quantified by calculating summary measures, such as life expectancy or age-standardised death rates, which allow for sub-national and international comparisons. For example, these measures can be used to show differences in life expectancy between higher and lower SES groups, as in Brønnum-Hansen & Baadsgaard (2012), who found a widening social gap in life expectancy in Denmark over a 25-year period. These measures are effective when summarising inequalities among populations and sub-populations but hide variation within them. Quantifying lifespan inequalities – the variation in lifespan observed within a population or sub-population – enhances our understanding of the social gradient in mortality (van Raalte et al., 2018; van Raalte & Caswell, 2013). Lifespan inequalities have generally been decreasing over time, suggesting lower variation in lifespans. This has been attributed to mortality reductions at young and middle-ages (Vaupel et al., 2011). Additionally, it has been found that preventing deaths before life expectancy contributes to an increase in life expectancy and a reduction in lifespan inequalities (Aburto et al., 2020). While differences in life expectancy between low- and high-SES sub-populations have persisted and, in some cases, increased, many low-SES sub-populations have also experienced increased lifespan inequalities (van Raalte et al., 2018).

Despite robust welfare systems, this pattern is also seen in the Nordic countries (Mackenbach, 2012). Lower socioeconomic groups in the Nordics have experienced little improvements in life expectancy and no reduction in lifespan inequality, suggesting Nordic societies are failing in postponing early deaths to older ages among people of low SES (Brønnum-Hansen et al., 2021). Indexing statutory retirement age to life expectancy is, therefore, inherently unfair to those of lower SES. Studies that examine the implications of indexing pension age to life expectancy reach the same conclusion. Survival to pension age has been found to be unequal across different socioeconomic groups in Denmark over time, with larger inequalities seen in more recent cohorts of those who have reached pension age (Strozza et al., 2022). Indexing statutory retirement age to life expectancy has been found to magnify the inequalities experienced by those of lower SES, and make the financial cost of the system more sensitive to changes in mortality (Alvarez et al., 2021). It also primarily benefits those with a higher level of education, and implementation of a flexible pension scheme to account for health inequalities among occupational groups could reduce inequalities in disability-free life expectancy (Brønnum-Hansen et al., 2017, 2020).

2.3 Forecasting mortality

The policy of indexing statutory pension age to life expectancy is recent and its potential consequences are yet to be observed. However, some trends can be anticipated by forecasting mortality. Forecasting methods are diverse and there is no consensus on which model should be used. One of the most used models to forecast mortality is the Lee-Carter (LC) model (Lee & Carter, 1992). The model forecasts age-specific death rates log-bilinearly, assuming constant rates of mortality improvement by age. The latter assumption is not adequate in many cases, with the age-specific rates of mortality improvements (ASRMI) changing over time. There is a tendency to observe slower rates of improvement at younger ages, but faster rates at older ages, referred to as a rotation (Li et al., 2013; Rau et al., 2008). Despite a mixed performance of the LC model, the model remains popular because of its simplicity; it is a powerful method and limited subjective judgement is required. Many national statistical offices, including those in Denmark and Sweden, use the LC model, or an extension of it, for official national forecasts (Bergeron-Boucher & Kjærgaard, 2022). However, other models have been developed to forecast mortality that account for changing ASRMI that tend to be more accurate, both in terms of life expectancy and lifespan variation (Bergeron-Boucher et al., 2022; Bohk-Ewald et al., 2017; Bohk-Ewald & Rau, 2017; Li et al., 2013). These models tend to forecast faster increases in life expectancy, by forecasting accelerating mortality decline at older ages. We aim to compare trends using a model from the LC family and another that accounts for changes in ASRMI to assess how both forecasts anticipate inequalities in retirement across SES.

3. Data and Methods

3.1 Danish and Swedish registry data

We used data from the Danish and Swedish registries from 1987 to 2019 to aggregate individuals based on their demographic and socioeconomic characteristics. The study population includes all residents in Denmark and Sweden during the study period, aged 50 years or more. Socioeconomic status (SES) is defined according to individuals' equivalised disposable family income (Eurostat, 2021). Disposable family income includes tax-free income plus imputed rent minus interest expenses, taxes, etc. For houseowners, an estimation of their potential rent is added to the total family income. The final amount is divided by the number of equivalent adults living in the household to reflect its size and age composition. All members of the household are weighted by a factor of 1 for the first adult, 0.5 for the second adult and each subsequent person aged 14 or older, and 0.3 to each child under the age of 14. Individuals residing in Denmark and Sweden were then classified based on the quartiles of the income distribution, computed by year, sex, and 5-year age classes until age 89 and those 90+.

3.2 Data analysis and measures

Period life tables by year, sex, and SES were computed for Denmark and Sweden using the aggregated data described in the previous section. Exposures are obtained as the average population alive between two calendar years. For this reason, our results pertain to the period from 1997 to

2019. Based on the period life tables calculated for each subgroup of the Danish and Swedish populations, we estimate two different groups of measures, those of mortality and longevity, and those of survival to and after retirement.

Measures of mortality and longevity

Life expectancy at age 50 is calculated to summarise population health over time by sex and SES. At the same level of detail, we calculate the average of the previous 10 years of the age-specific rates of mortality improvement (ASRMI). The ASRMI ($\rho(x,t)$) are calculated as:

$$\rho(x,t) = -\log\left(\frac{m(x,t+1)}{m(x,t)}\right),$$

where $m(x,t)$ is the death rate at time t and age x.

We also quantified lifespan inequalities calculating e-dagger ($e^{\dagger}$) (Vaupel & Canudas-Romo, 2003) over time by sex and SES. It is interpreted as the average remaining life expectancy at death, or alternatively the average years of life lost due to death in a population. It is calculated as follows:

$$e^{\dagger} = \sum_{x=0}^{\omega} d(x)e(x),$$

where $d(x)$ is the life table deaths at age x and $e(x)$ is the remaining life expectancy at age x.

As a measure of longevity, we calculated the modal age at death with the non-parametric approach of Ouellette & Bourbeau (2011) by year, sex, and SES. However, it can be arduous to estimate when non-smoothed or erratic trends are observed. Ouellette and Bourbeau suggested to use a P-Spline approach to smooth the age-at-death distribution and find the mode.

Measures of survival to and after retirement

To quantify inequalities in access to retirement, we estimated the probability of surviving between age 50 and the statutory pension age by year, sex, and SES. Complementary, we calculated remaining life expectancy at retirement over time to assess the number of years individuals are expected to live in retirement by sex and SES.

3.3 Forecast

The official national forecasts for Denmark and Sweden are based on extensions of the Lee-Carter (LC) model (DREAM, 2013; Lee & Carter, 1992; Statistiska centralbyrån, 2018). The LC model extrapolates age-specific death rates log-bilinearly, and is one of the most used models to forecast mortality. However, when forecasting multiple populations, the LC model tends to lead to crossover or divergence between populations in the forecast, even when convergence is observed. To forecast mortality between income groups and sex in a coherent way, we use the Li-Lee (LL) model, which is a coherent extension of the Lee-Carter model (Li & Lee, 2005). The model forecasts a reference population with the LC model and then forecasts the deviation from the reference using a stationary time-series model, imposing no long-term deviation between the population and the reference. The reference population is the mean death rates across income and sex. As the life expectancy between sexes has been converging in recent years, reaching similar levels for some income group, we use the total average as the reference, rather than sex-specific average, allowing us to forecast mortality across both income and sex dimensions and avoid crossover between mortality trends for females and males.

The LC and LL models are, however, known to underpredict life expectancy, mainly due to their assumption of constant ASRMI on the long-term (Bergeron-Boucher & Kjærgaard, 2022). We therefore compare the LL model forecasts with that of a coherent extension of the Mode model. The

Mode model forecasts the age-at-death distribution using the modal age at death in two steps: forecast the modal age at death and forecast the age at death distribution centred around the mode using the compositional data analysis (CoDA) model of Oeppen (2008). Changes in the modal age at death have generally been more linear than changes in the age-specific death rates, providing a strong basis for extrapolation and forecast. In addition, the model allows us to account for rotating ASRMI, which tends to increase forecast accuracy (Bergeron-Boucher et al., 2022). Similar to the LL model, the reference population is the mean age at death distribution across income and sex as the reference population. We forecast the modal age at death for the reference population using a random-walk with drift and forecast the income-group deviation from the reference using a stationary process. The age at death distribution around the mode is forecast using a coherent compositional data analysis model (Bergeron-Boucher et al., 2017). Mortality is forecasted from 2019 to 2040 in Denmark only, as Swedish mortality by income is not comparable over time due to inconsistency in the time series of income. This issue results in incoherent mortality trends that do not allow us to accurately forecast mortality in Sweden by income quartiles.

By comparing these two models, based on the different rates of improvement assumption, we can derive more robust conclusions regarding the consequences of statutory pension age indexation for unequal access to retirement.

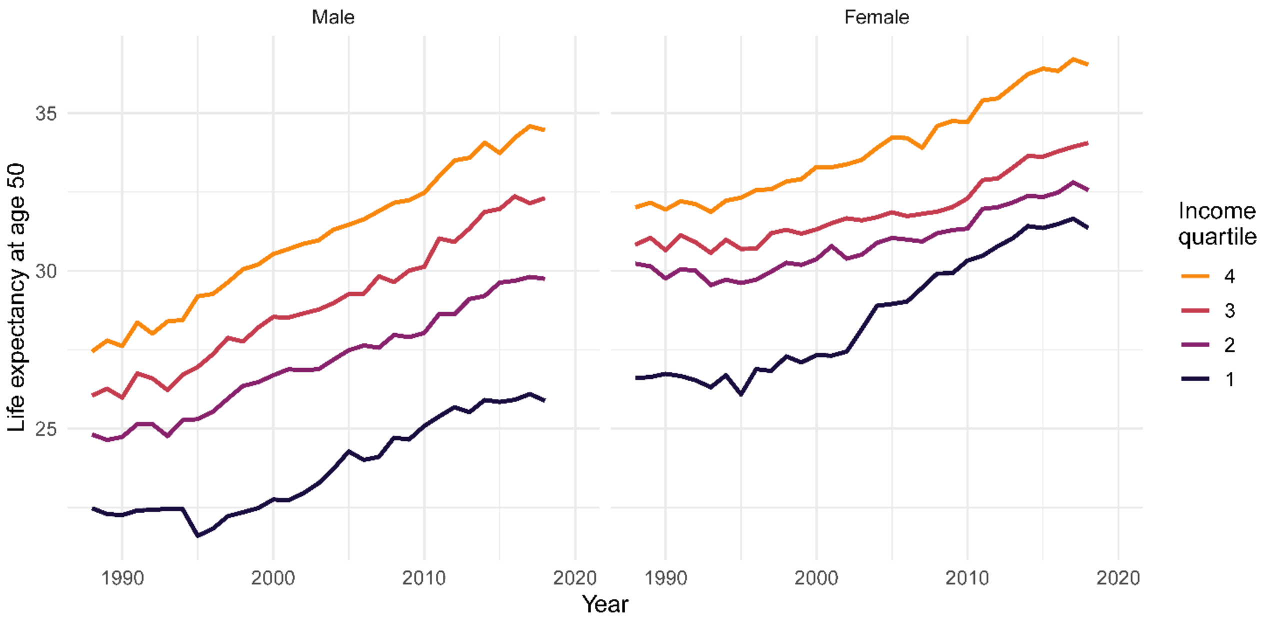
4. Results

4.1 Mortality and longevity in Denmark and Sweden

4.1.1 Assessing time trends in Denmark: socioeconomic inequalities in mortality and longevity

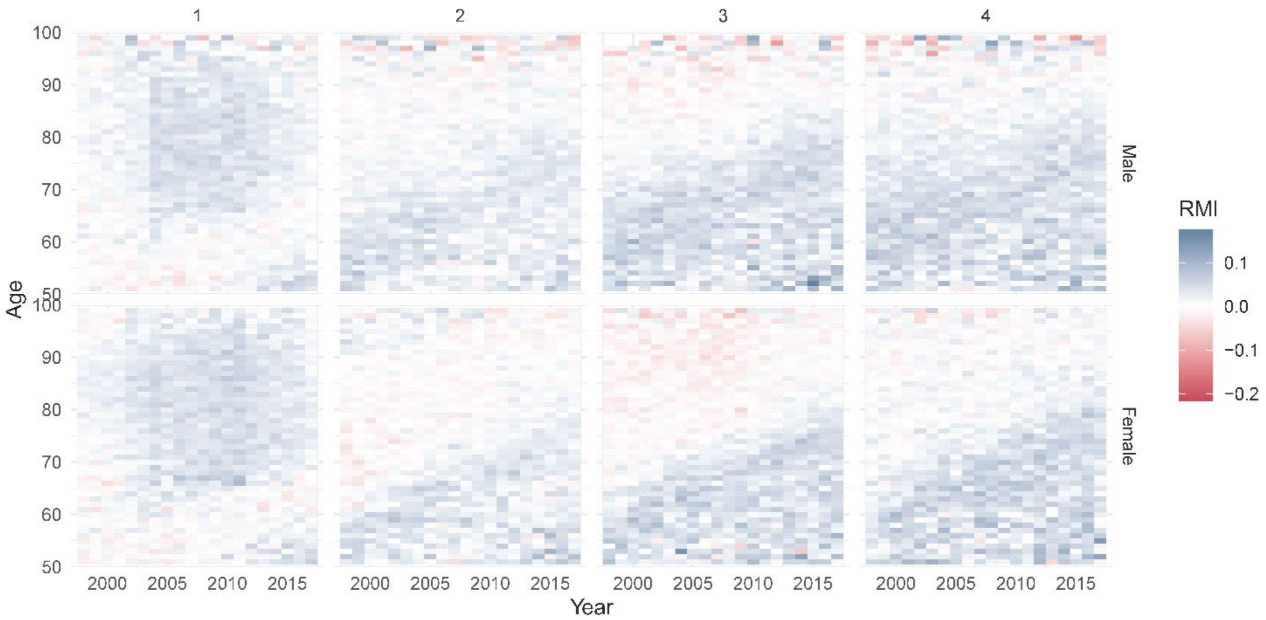
Life expectancy increased for all income groups and for both sexes over the course of the study period. For males, the progress in life expectancy has been slower for the lowest group, leading to increasing inequalities over time. Between 1988 and 2018, life expectancy increased by 3.4 years for the first (lowest) income quartile, 4.9 years for the second, 6.3 years for the third, and 7.0 years fourth (highest) income quartile. For females, life expectancy increases have been slower for the second- and third-income group, which increased by 3.2 and 2.3 years, respectively, and roughly equal between the first and fourth groups, which increased by 4.8 and 4.5 years, respectively. Inequalities decreased between some groups and increased between others.

Figure 1. Life expectancy at age 50 by sex and socioeconomic status (income quartile) in Denmark. Years 1988-2018



To better understand these developments, we look at the ASRMI, i.e., how fast mortality has been changing by age for each income group and both sexes. Figure 2 shows a clear cohort effect for the second to the fourth income groups, which is particularly strong for females, and worsening mortality for the cohorts born before the Second World War. A similar cohort effect is observed for males, but for older generations, while a mortality decline for younger generations was observed at most ages.

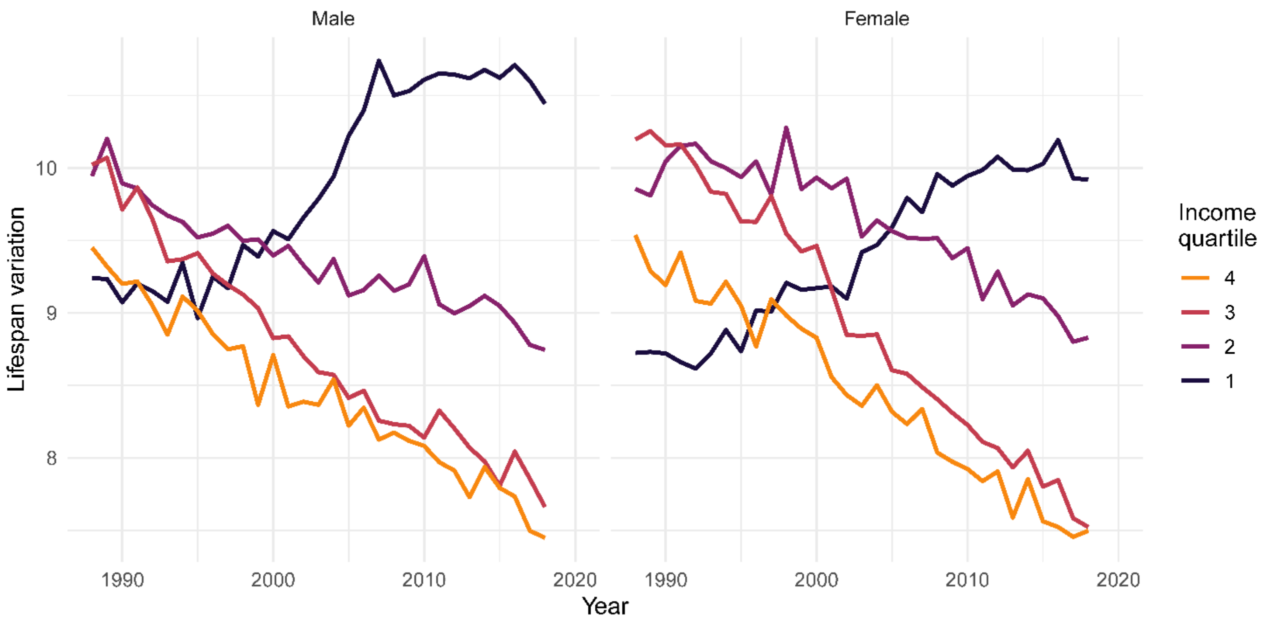
Figure 2: Age-specific Rates of Mortality Improvements (ASRMI) by sex and income quartile. Years 1998-2018



A surprising result is the absence of this cohort effect for individuals from the first income quartile (lowest). Mortality decreased between ages 70 and 95 since the early 2000s for this group. However, a new cohort effect appears for this group; individuals born in the 1950s had worse mortality than the previous and following cohorts in the first income quartile (Figure 2).

The mortality progress at older ages for the lowest income groups can be offset by mortality worsening at younger ages, both slowing down the progress in life expectancy and increasing lifespan inequality (Figure 3). Indeed, there was an increase in lifespan inequalities for the first income quartile (lowest SES) group, while the other groups had a sustained decrease in lifespan inequalities over time. There is increased uncertainty for individuals in the former group regarding the time of death and the probability to reach old ages, including retirement age.

Figure 3. Lifespan variation measured through e-dagger by sex and income quartile in Denmark. Years 1988-2018



As illustrated in Figure 4, there was a postponement of mortality, i.e., a shift of the lifespan distribution towards older ages, for both sexes and all income groups, with the exception of the second and third income groups for women. The levels of the modal age at death have been converging among the three lowest SES groups, suggesting more similar longevity. This information is used in the Mode model to forecast mortality.

Figure 4. Modal age at death by sex and income quartile in Denmark. Years 1988-2018

These results suggest that the difference in life expectancy, as also shown in Figure 2, is mostly driven by differences in mortality at younger ages. Mortality at older ages is less different between groups, expect among individuals from the highest SES group, who also have a clear advantage at older ages.

4.1.2 Comparing mortality, longevity, and survival to and after retirement in Denmark and Sweden

Tables 1 and 2 contextualise the trends in mortality, longevity, and survival to and after retirement that were observed in 4.1 section for Denmark with that of Sweden. In Table 1 we compare social inequalities in mortality and longevity in the two countries. In terms of remaining life expectancy at age 50, Denmark shows greater social inequalities than Sweden. For both countries, these inequalities are greater among men and increased from 1991 to 2017. On the other hand, social inequalities among women remained stable in Denmark, but they were still higher than that of Sweden, where they increased over this time period. When looking at lifespan inequality for women in Sweden, we observe the same increasing trend as the women in the lowest income group in Denmark (previously described). However, men in the lowest income group in Sweden present a small decrease in lifespan inequality, contrary to the same group in Denmark. Regarding the modal age at death, a coherent increase is observed among men and women in both countries. The stronger increase in the modal age of death of the lowest income group that was described presented in the previous section for Denmark is also observed in Sweden.

Table 1. Comparing life expectancy, lifespan inequality, and modal age at death in Denmark and Sweden by sex and income quartile. Years 1991 and 2017

Income quartile	Male				Female			
	Denmark		Sweden		Denmark		Sweden	
	1991	2017	1991	2017	1991	2017	1991	2017
	Life expectancy at age 50							
1	22.41	26.10	24.51	27.75	26.67	31.65	30.94	32.74
2	25.14	29.81	26.50	30.80	30.05	32.80	30.93	32.98
3	26.75	32.14	27.73	32.77	31.13	33.93	32.05	34.14
4	28.36	34.58	29.16	34.04	32.21	36.71	32.78	35.95
	Lifespan inequality at age 50							
1	9.20	10.60	9.81	9.36	8.66	9.93	8.33	8.72
2	9.86	8.78	9.09	7.60	10.15	8.80	8.85	7.73
3	9.86	7.86	8.76	6.93	10.16	7.58	9.15	7.16
4	9.22	7.50	8.39	6.78	9.42	7.46	8.54	6.68
	Modal age at death							
1	75.00	83.80	79.10	85.30	81.50	88.10	84.90	89.20
2	76.80	84.60	79.90	85.50	87.40	87.40	86.00	87.80
3	78.90	85.50	80.70	86.40	87.00	86.90	86.70	87.60
4	81.70	88.50	82.50	87.70	87.60	90.20	87.30	89.20

Table 2 displays measures of survival to and after retirement. Generally, Sweden has higher survival to pension age for all the income groups. Still, social inequalities in survival to retirement in Denmark and Sweden increased from 1991 to 2017. The only exception is for Swedish men, for whom it remained constant over the 26-year study period. Among men, in 1991, the magnitude of the social inequalities was comparable in the two countries (with Swedish residents having an advantage of around 0.3 percentage points for all income groups). Among women, both in Denmark and Sweden, the magnitude of social inequalities was lower in Sweden in 1991, but became comparable in 2017, even though survival to pension are is higher for women in Sweden across all income groups. However, while inequalities in length of life to be spent in retirement has increased in both Denmark and Sweden among men, this is not the case among women. In Denmark, social inequalities reduced from 1991 to 2017 and remained stable at a low level in Sweden.

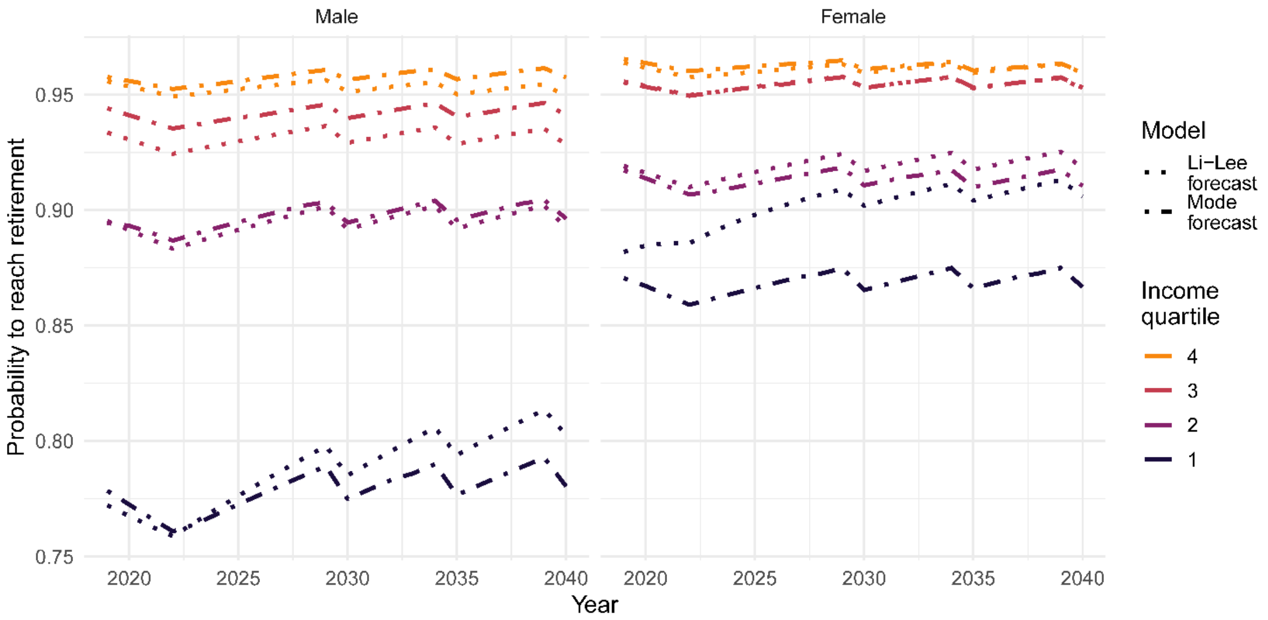
Table 2. Comparing survival to and after retirement in Denmark and Sweden by sex and income quartile. Years 1991 and 2017

Income quartile	Male				Female			
	Denmark		Sweden		Denmark		Sweden	
	1991	2017	1991	2017	1991	2017	1991	2017
	Probability to reach retirement							
1	0.25	0.22	0.22	0.16	0.14	0.12	0.09	0.10
2	0.20	0.10	0.15	0.07	0.14	0.07	0.09	0.06
3	0.16	0.06	0.12	0.04	0.12	0.04	0.08	0.03
4	0.12	0.04	0.09	0.03	0.10	0.03	0.07	0.03
	Life expectancy at retirement							
1	12.11	15.88	14.07	16.37	14.71	19.70	18.20	20.42
2	14.13	17.09	14.68	17.41	18.39	19.58	18.21	19.38
3	15.12	18.57	15.27	18.84	19.12	20.08	19.12	19.96
4	16.05	20.69	16.21	19.92	19.64	22.64	19.44	21.63

4.2 Future survival to and after retirement in Denmark

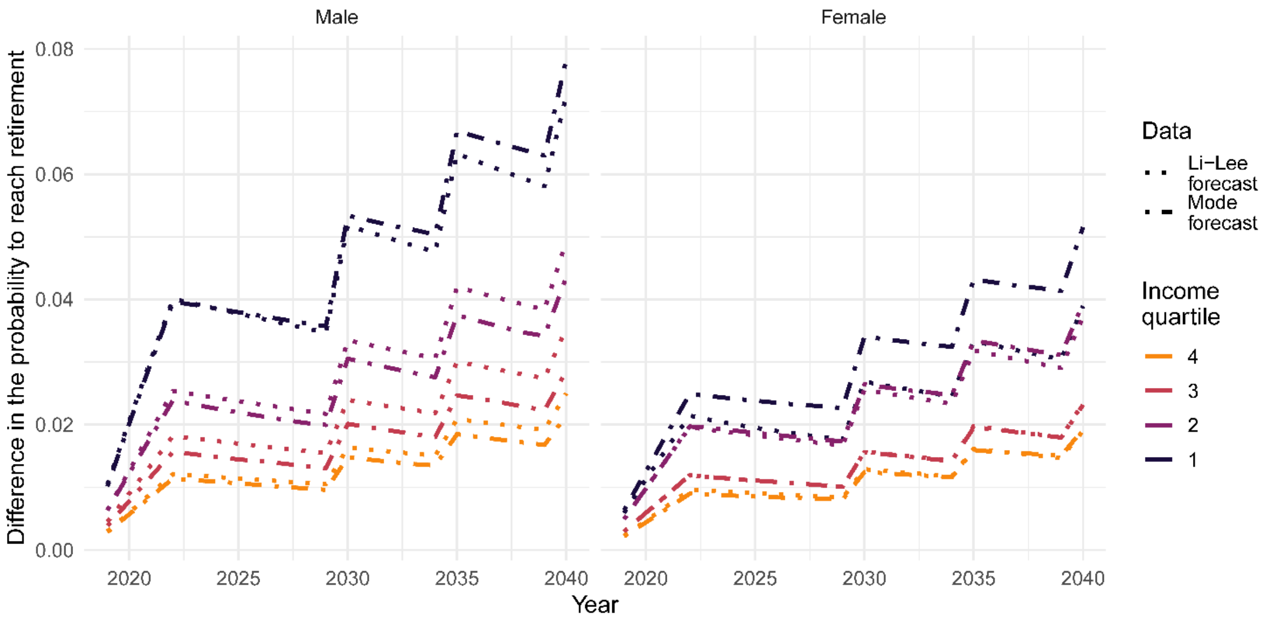
How do these mortality differences translate into access to retirement and time spent in retirement? How does the indexation of the statutory pension age to life expectancy affect the different income groups? Figure 5 shows the probability of reaching retirement, under the indexation scheme, forecast with the LL and Mode models. Both models forecast little difference in terms of access to retirement over time for the three highest income groups. However, the LL model forecasts an increase in access to retirement for the lowest income group, while the Mode model predicts little change.

Figure 5. Probability of surviving to retirement by sex and income quartile. Two models are used to forecast mortality: Li-Lee and Mode. Years 2019-2040



However, both models forecast a similar difference in terms of access to retirement, whether the statutory retirement age is indexed or not. Figure 6 shows the difference in the probability of reaching retirement if the statutory retirement age remains at age 65, and if it is indexed. Indexing the statutory retirement age with life expectancy disproportionally affects the lowest income group in terms of access to retirement. By 2040, the difference for the lowest income group will be around three times higher than that of the highest income group, with both models.

Figure 6. Differences in the probability of surviving to retirement by sex and income quartile between two scenarios: no-indexation and indexation of pension age. Two models are used to forecast mortality: Li-Lee and Mode. Years 2019-2040



By indexing the statutory retirement age, one of the goals of the Danish government is to reduce the time spent in retirement. The goal is to reach a life expectancy in retirement of 14.5 years. Figure 7 shows the life expectancy at retirement forecasts (e_R), with the indexation of the statutory retirement age. The LL model forecasts a decrease in e_R over time for all income groups. However, the Mode model forecasts a constant e_R over time.

Figure 7. Life expectancy at retirement by sex and income quartile. Two models are used to forecast mortality: Li-Lee and Mode. Years 2019-2040

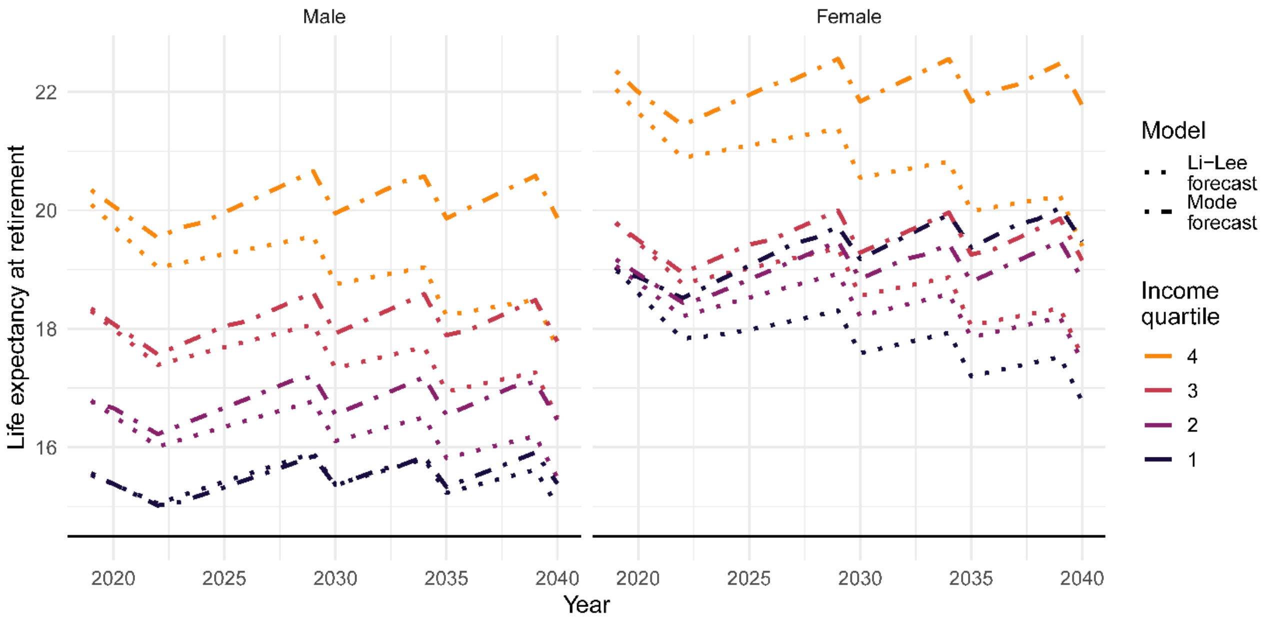
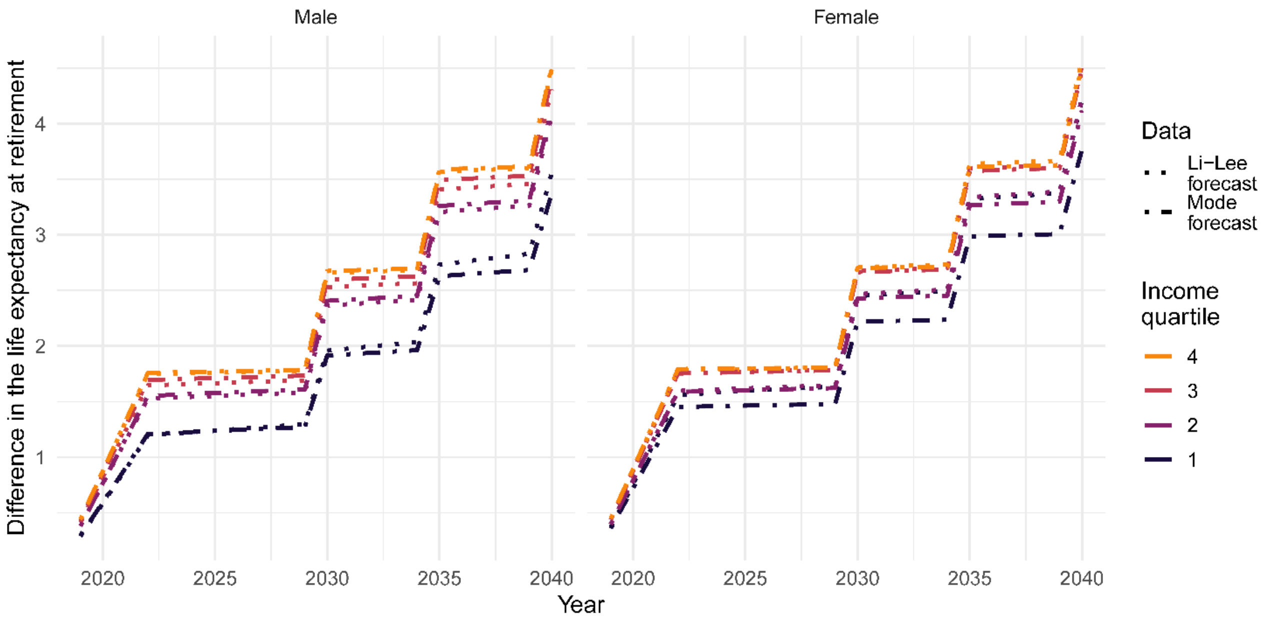


Figure 8 shows the number of years in retirement lost by indexing the statutory retirement age. It shows the difference in life expectancy between age 65 (retirement age without indexation) and eR (life expectancy at retirement with indexation). Both forecast models provide similar results: indexing statutory retirement age has a greater impact on the highest socioeconomic group. Indexing the statutory retirement age will reduce the number of years spent at retirement by around 4.5 years for the highest SES group and by 3.5 years for the lowest SES group for males by 2040, and by 4.5 and 4 years for females, on average with both models.

Figure 8. Difference in life expectancy at retirement by sex and income quartile between two scenarios: no-indexation and indexation of pension age. Two models are used to forecast mortality: Li-Lee and Mode. Years 2019-2040



5. Discussion

With aging populations threatening the sustainability of pension systems, Denmark, Sweden, and other European countries have instigated a system whereby statutory pension age is linked to life expectancy (indexation policy). For instance, in Denmark, with approval from parliament, pension age is set to rise in steps to age 70 in 2040. This is done to account for the improvements in mortality of those aging populations. However, the calculations to evaluate improvements in mortality, i.e., increases in life expectancy, are done at the population level, and do not account for inequalities within the Danish population. The basis for this paper was twofold: to quantify mortality developments by SES in Denmark and Sweden, and to forecast how these mortality developments, and consequent changes in statutory pension age, will impact social inequalities in survival to and after retirement in Denmark.

Mortality developments by SES in Denmark and Sweden (objective 1)

Lower socioeconomic groups have lower life expectancies and more lifespan inequalities than those of higher socioeconomic groups (van Raalte et al., 2018). Over the past decades, social inequalities in mortality have been widening in Denmark, Sweden, as well as in other European countries (Brønnum-Hansen & Baadsgaard, 2012; Huisman et al., 2004; Mackenbach, 2017; Mackenbach et al., 2003). Pension indexation policies, like the ones implemented in Denmark and Sweden, do not account these inequalities, even though both schemes are generally flexible and allow for early-exits. The primary risk of this type of pension policy that the already existing inequalities in mortality at retirement could be magnified by an increase in statutory pension age (Alvarez et al., 2021; Strozza et al., 2022). Here we investigated mortality and longevity developments in Denmark and Sweden to quantify the social inequalities in mortality in two Nordic countries. Overall, we observed an increase in life expectancy at age 50 in Denmark and Sweden for all income groups and both sexes, in line with research that concludes that life expectancies in countries with the longest lifespans are increasing. However, men in the lowest SES groups were found to have experienced increased inequalities in mortality over the study period. This is consistent with research that finds widening inequalities in mortality by SES in the Nordic region (Brønnum-Hansen et al., 2021; Brønnum-Hansen & Baadsgaard, 2012; Mackenbach, 2012; Strozza et al., 2022). This signals that improvements in mortality are not homogeneous within the population and therefore suggests for a deeper investigation of the source of such inequalities.

For this reason, we looked at the ASRMI to determine how fast mortality has been changing over time by age for the different socioeconomic groups. While clear cohort effects were observed for some income groups, the absence of a cohort effect for individuals from the lowest income quartile was noteworthy, particularly with regards to worsening mortality for the cohorts born after the Second World War. It has been shown that females born between 1915 and 1945 had particularly high mortality, due to a high smoking prevalence of women in these cohorts (Lindahl-Jacobsen et al., 2006, 2016). Similarly, Aburto et al. (2018) find that since 1960, Danish improvement in life expectancy and lifespan inequality was halted by smoking-related mortality in the cohorts born between 1919 and 1939. Kallestrup-Lamb et al. (2020) find very similar results to ours in their analysis on cause-specific mortality by socioeconomic groups in Denmark. They find that a long period of stagnation in mortality was observed among Danish women between 1985 and 1995 in the mid-socioeconomic groups, caused by an increase in mortality from cancer and other causes. On the other hand, they also find that mortality among the lowest socioeconomic group improved due to a reduction in cardiovascular and cerebrovascular disease mortality. Additionally, given that smoking-related mortality and other health-risk behaviours tend to have more of an impact on mortality among individuals of lower SES, one potential explanation could be a selection effect. Individuals who survived to higher ages are selected individuals that tend to be less frail or healthier. A new cohort effect appears for individuals from the first income quartile (lowest). Individuals born in the 1950s had worse mortality than the previous and following cohorts in the first income quartile. It is possible that this new cohort effect is due to an increase in smoking prevalence for individuals of the lowest SES group in these cohorts, but other factors could also explain this trend (Osler et al., 2001).

Additional information is provided by the analysis of lifespan inequality across socioeconomic groups, as the information on the variability of ages at death is crucial for effective policy planning (Alvarez et al., 2021). Generally, as life expectancy increases, lifespan inequality decreases (Aburto et al., 2020). However, in our analysis we find that lifespan inequality increases for the lowest socioeconomic groups in Denmark and Sweden. This result is in line with previous research that finds that the Nordic countries do not postpone early deaths (Brønnum-Hansen et al., 2021).

Life expectancy and lifespan variation provide little information on longevity extension, which is best measured by the modal age at death. The modal age at death captures the most common lifespan and indicates the timing of death. We observe an overall increase in modal age at death among men in Denmark and Sweden, with those in the lowest socioeconomic group experiencing a greater improvement that the others. Among women, in both countries, the lowest socioeconomic group experienced the biggest improvement, surpassing the two mid-socioeconomic groups in terms of longevity. This result is again a consequence of the development of the ASRMI previously discussed. The modal age at death is indeed an indicator that is solely influenced by mortality reduction at older ages (Canudas-Romo, 2008, 2010; Horiuchi et al., 2013).

The mortality and longevity trends discussed are key for the assessment and interpretation of future mortality in Denmark in the light of the indexation policy.

Impact of the indexation policy on mortality inequalities at retirement (objective 2)

Looking at how social inequalities in mortality will look in the future allows for better policy planning as well as for an evaluation of the indexation policy in place in Denmark. For this purpose, we forecast mortality with two different methods: a coherent extension of the current model employed in Denmark (LL), and the Mode model developed by Bergeron-Boucher et al. (2022). We use those models to forecast the probability of surviving to retirement and remaining life expectancy in retirement. In the indexation scenario, both models predict that the probability of surviving to pension age will not change over time for the three highest income groups. However, the LL forecasts a higher probability to survive to retirement for the lowest income group, while the Mode model predicts little change also for those. This result is mainly due to the assumption behind both models. The LL model forecasts a faster mortality decrease (ASRMI) at younger ages than the Mode model, resulting in a faster decline in lifespan inequalities and an increased probability to reach retirement. The Mode model, due to its rotation, forecasts a gradual slowdown in the ASRMI at younger ages (Bergeron-Boucher et al., 2022). In terms of time spent in retirement, the LL model forecasts a decrease in remaining life expectancy at retirement while the Mode model forecast no changes until 2040. These differences can also be explained by the different forecast assumption regarding the ASRMI. With the LL model, the ASRMI at older ages are assumed to remain constant. As the ASRMI are usually lower at older ages, the model forecasts a gradual slowdown in life expectancy as more and more people reach older ages. With the LL model, the statutory retirement age increases faster than life expectancy, resulting in a decrease in remaining life expectancy at retirement. However, the Mode model forecasts an acceleration in the ASRMI at older ages. The life expectancy is forecast to increase at a more similar pace to the statutory retirement age, leading to a constant remaining life expectancy at retirement.

These results are based on two forecasts using distinct assumptions regarding the pace of decline in mortality by age. Which model is the most accurate is a difficult question and has been shown to depend on the population and period of interest. For Denmark, there was an accelerated decline in mortality in recent years, mainly due to a cohort effect. Coherent models using other countries as the reference (which generally produce higher, but constant ASRMI) or models using changing ASRMI over time have been shown to produce more accurate forecasts for Denmark (Bergeron-Boucher et al., 2020, 2022; Bergeron-Boucher & Kjærgaard, 2022; Bohk-Ewald & Rau, 2017). However, there is always uncertainty regarding the future, and which of the two models is the most likely remains an open question.

Nevertheless, while the forecast probability to reach retirement and the numbers of years in retirement vary between forecast models, both models agree that indexing the statutory retirement age will reduce inequalities in terms of years lived in retirement, but will fail to reduce inequalities in terms of access to retirement. This result is obtained by comparing the forecast in the two scenarios: one in which there is no indexation (pension age is constant at age 65) and one in which the indexation policy is in place. As the probability of surviving to age 65 (no indexation) would improve more among the low socioeconomic group, in absolute terms, the cost of indexation in terms of survival to retirement will be higher for the lowest SES. One of the goals of the Danish pension system is to redistribute funds from high-income to low-income individuals. It is unlikely that the indexation of the pension system fully meets this goal. Low-income individuals contributing to pension funds are less likely to see the return of their investment than individuals from high-income groups, and increasing retirement age will slow down or stop the convergence between income-groups, compared with having a retirement age of 65. However, indexation will most likely reduce, or at least stop, the currently increasing number of years spent in retirement expected if there would be no indexation of pension age, especially for the high-income groups, and further reduce the gap in terms of time spent in retirement between income-groups.

6. Acknowledgements

CS, MPBB, and JC received funding from the ROCKWOOL Foundation, through the research project “Challenges to Implementation of Indexation of the Pension Age in Denmark” and MPBB and JC received funding from the European Research Council (ERC) under the European Union’s Horizon 2020 research and innovation programme (Grant agreement No. 884328 – Unequal Lifespans). SD received funding through the Swedish Research Council for Health, Working life, and Welfare (FORTE), grant number 2016-07115 and 2016-07105. CS, MPBB, and JC are grateful to James W. Vaupel for his inspiration on our work, and wish to thank their colleagues at the Interdisciplinary Centre on Population Dynamics (CPop) for the feedback they gave on this paper.

7. References

Aburto, J. M., Villavicencio, F., Basellini, U., Kjærgaard, S., & Vaupel, J. W. (2020). Dynamics of life expectancy and life span equality. *Proceedings of the National Academy of Sciences*, *117*(10), 5250–5259. https://doi.org/10.1073/pnas.1915884117

Aburto, J. M., Wensink, M., van Raalte, A., & Lindahl-Jacobsen, R. (2018). Potential gains in life expectancy by reducing inequality of lifespans in Denmark: An international comparison and cause-of-death analysis. *BMC Public Health*, *18*(1). https://doi.org/10.1186/s12889-018-5730-0

Alvarez, J.-A., Kallestrup-Lamb, M., & Kjærgaard, S. (2021). Linking retirement age to life expectancy does not lessen the demographic implications of unequal lifespans. *Insurance: Mathematics and Economics*, *99*, 363–375. https://doi.org/10.1016/j.insmatheco.2021.04.010

Bergeron-Boucher, M.-P., Canudas-Romo, V., Oeppen, J. E., & Vaupel, J. W. (2017). Coherent forecasts of mortality with compositional data analysis. *Demographic Research*, *37*(17), 527–566. https://doi.org/10.4054/DemRes.2017.37.17

Bergeron-Boucher, M.-P., Kjæ rgaard, S., Pascariu, M. D., Aburto, J. M., Alvarez, J.-A., Basellini, U., Rizzi, S., & Vaupel, J. W. (2020). Alternative Forecasts of Danish Life Expectancy. In S. Mazzuco & N. Keilman (Eds.), *Developments in Demographic Forecasting* (pp. 131–151). Springer International Publishing. https://doi.org/10.1007/978-3-030-42472-5_7

Bergeron-Boucher, M.-P., & Kjærgaard, S. (2022). Mortality forecasting at age 65 and above: An age-specific evaluation of the Lee-Carter model. *Scandinavian Actuarial Journal*, *2022*(1), 64–79. https://doi.org/10.1080/03461238.2021.1928542

Bergeron-Boucher, M.-P., Vázquez-Castillo, P., & Missov, T. (2022). *A modal age at death approach to forecasting mortality* [Preprint]. SocArXiv. https://doi.org/10.31235/osf.io/5zr2k

Berkman, L. F., Kawachi, I., & Glymour, M. M. (Eds.). (2014). *Social epidemiology* (Second edition). Oxford University Press.

Bohk-Ewald, C., Ebeling, M., & Rau, R. (2017). Lifespan Disparity as an Additional Indicator for Evaluating Mortality Forecasts. *Demography*, *54*(4), 1559–1577. https://doi.org/10.1007/s13524-017-0584-0

Bohk-Ewald, C., & Rau, R. (2017). Probabilistic mortality forecasting with varying age-specific survival improvements. *Genus*, *73*(1), 1. https://doi.org/10.1186/s41118-016-0017-8

Brønnum-Hansen, H., & Baadsgaard, M. (2012). Widening social inequality in life expectancy in Denmark. A register-based study on social composition and mortality trends for the Danish population. *BMC Public Health*, *12*(1), 994. https://doi.org/10.1186/1471-2458-12-994

Brønnum-Hansen, H., Eriksen, M. L., Andersen-Ranberg, K., & Jeune, B. (2017). Persistent social inequality in life expectancy and disability-free life expectancy: Outlook for a differential pension age in Denmark? *Scandinavian Journal of Public Health*, *45*(4), 459–462. https://doi.org/10.1177/1403494816683591

Brønnum-Hansen, H., Foverskov, E., & Andersen, I. (2020). Occupational inequality in health expectancy in Denmark. *Scandinavian Journal of Public Health*, *48*(3), 338–345. https://doi.org/10.1177/1403494819882138

Brønnum-Hansen, H., Östergren, O., Tarkiainen, L., Hermansen, Å., Martikainen, P., van der Wel, K. A., & Lundberg, O. (2021). Changes in life expectancy and lifespan variability by income quartiles in four Nordic countries: A study based on nationwide register data. *BMJ Open*, *11*(6), e048192. https://doi.org/10.1136/bmjopen-2020-048192

Burger, O., Baudisch, A., & Vaupel, J. W. (2012). Human mortality improvement in evolutionary context. *Proceedings of the National Academy of Sciences*, *109*(44), 18210–18214. https://doi.org/10.1073/pnas.1215627109

Canudas-Romo, V. (2008). The modal age at death and the shifting mortality hypothesis. *Demographic Research*, *19*, 1179–1204. https://doi.org/10.4054/DemRes.2008.19.30

Canudas-Romo, V. (2010). Three measures of longevity: Time trends and record values. *Demography*, *47*(2), 299–312. https://doi.org/10.1353/dem.0.0098

Clouston, S. A. P., Rubin, M. S., Phelan, J. C., & Link, B. G. (2016). A Social History of Disease: Contextualizing the Rise and Fall of Social Inequalities in Cause-Specific Mortality. *Demography*, *53*(5), 1631–1656. https://doi.org/10.1007/s13524-016-0495-5

DREAM. (2013). *Danmarks fremtidige befolkning—Befolkningsfremskrivning 2013* (DREAM Rapport). DREAM. http://dreammodel.dk/publikationer/2013/juli/danmarks-fremtidige-befolkning-befolkningsfremskrivning-2013/

Eurostat. (2021). *Glossary:Equivalised disposable income*. https://ec.europa.eu/eurostat/statistics-explained/index.php?title=Glossary:Equivalised_disposable_income

Horiuchi, S., Ouellette, N., Cheung, K. S. L., & Robine, J.-M. (2013). Modal age at death: Lifespan indicator in the era of longevity extension. *Vienna Yearbook of Population Research*, *11*, 37–69. https://doi.org/10.1553/populationyearbook2013s37

Huisman, M., Kunst, A. E., Andersen, O., Bopp, M., Borgan, J.-K., Borrell, C., Costa, G., Deboosere, P., Desplanques, G., Donkin, A., Gadeyne, S., Minder, C., Regidor, E., Spadea, T., Valkonen, T., & Mackenbach, J. P. (2004). Socioeconomic inequalities in mortality among elderly people in 11 European populations. *Journal of Epidemiology & Community Health*, *58*(6), 468–475. https://doi.org/10.1136/jech.2003.010496

Kallestrup-Lamb, M., Kjærgaard, S., & Rosenskjold, C. P. T. (2020). Insight into stagnating adult life expectancy: Analyzing cause of death patterns across socioeconomic groups. *Health Economics*, *29*(12), 1728–1743. https://doi.org/10.1002/hec.4166

Lee, R. D., & Carter, L. R. (1992). Modeling and Forecasting U. S. Mortality. *Journal of the American Statistical Association*, *87*(419), 659–671. https://doi.org/10.2307/2290201

Li, N., & Lee, R. (2005). Coherent Mortality Forecasts for a Group of Populations: An Extension of the Lee-Carter Method. *Demography*, *42*(3), 575–594.

Li, N., Lee, R., & Gerland, P. (2013). Extending the Lee-Carter method to model the rotation of age patterns of mortality-decline for long-term projection. *Demography*, *50*(6), 2037–2051. https://doi.org/10.1007/s13524-013-0232-2

Lindahl-Jacobsen, R., Keiding, N., & Lynge, E. (2006). Causes of death behind low life expectancy of Danish women. *Scandinavian Journal of Public Health*, *34*(4), 432–436. https://doi.org/10.1080/14034940500489842

Lindahl-Jacobsen, R., Rau, R., Jeune, B., Canudas-Romo, V., Lenart, A., Christensen, K., & Vaupel, J. W. (2016). Rise, stagnation, and rise of Danish women's life expectancy. *Proceedings of the National Academy of Sciences*, *113*(15), 4015–4020. https://doi.org/10.1073/pnas.1602783113

Mackenbach, J. P. (2012). The persistence of health inequalities in modern welfare states: The explanation of a paradox. *Social Science & Medicine*, *75*(4), 761–769. https://doi.org/10.1016/j.socscimed.2012.02.031

Mackenbach, J. P. (2017). Persistence of social inequalities in modern welfare states: Explanation of a paradox. *Scandinavian Journal of Public Health*, *45*(2), 113–120. https://doi.org/10.1177/1403494816683878

Mackenbach, J. P., Bopp, M., Deboosere, P., Kovacs, K., Leinsalu, M., Martikainen, P., Menvielle, G., Regidor, E., & de Gelder, R. (2017). Determinants of the magnitude of socioeconomic inequalities in mortality: A study of 17 European countries. *Health & Place*, *47*, 44–53. https://doi.org/10.1016/j.healthplace.2017.07.005

Mackenbach, J. P., Bos, V., Andersen, O., Cardano, M., Costa, G., Harding, S., Reid, A., Hemström, Ö., Valkonen, T., & Kunst, A. E. (2003). Widening socioeconomic inequalities in mortality in six Western European countries. *International Journal of Epidemiology*, *32*(5), 830–837. https://doi.org/10.1093/ije/dyg209

Oeppen, J. (2008, July 9). *Coherent forecasting of multiple-decrement life tables: A test using Japanese cause of death data*. European Population Conference, Barcelona. https://dugi-doc.udg.edu/handle/10256/742

Osler, M., Heitmann, B. L., Gerdes, L. U., Jørgensen, L. M., & Schroll, M. (2001). Dietary patterns and mortality in Danish men and women: A prospective observational study. *British Journal of Nutrition*, *85*(2), 219–225. https://doi.org/10.1079/BJN2000240

Ouellette, N., & Bourbeau, R. (2011). Changes in the age-at-death distribution in four low mortality countries: A nonparametric approach. *Demographic Research*, *25*(19), 595–628. https://doi.org/10.4054/DemRes.2011.25.19

Pensions Myndigheten. (2023, January 26). *The Swedish Pension System*. The Swedish Pension System. https://www.pensionsmyndigheten.se/other-languages/english-engelska/english-engelska/pension-system-in-sweden

Rau, R., Soroko, E., Jasilionis, D., & Vaupel, J. W. (2008). Continued Reductions in Mortality at Advanced Ages. *Population and Development Review*, *34*(4), 747–768. https://doi.org/10.1111/j.1728-4457.2008.00249.x

Sanderson, W. C., & Scherbov, S. (2010). Remeasuring Aging. *Science*, *329*(5997), 1287–1288. https://doi.org/10.1126/science.1193647

Sanderson, W. C., & Scherbov, S. (2015). An Easily Understood and Intergenerationally Equitable Normal Pension Age. In *The Future of Welfare in a Global Europe* (1st Edition, pp. 193–220). Routledge. https://doi.org/10.4324/9781315239446-12

Statistiska centralbyrån. (2018). *Sveriges framtida befolkning 2018–2070* (BE51 - Demografiska rapporter). Statistiska centralbyrån. https://www.scb.se/hitta-statistik/statistik-efter-amne/befolkning/befolkningsframskrivningar/befolkningsframskrivningar/pong/publikationer/sveriges-framtida-befolkning-20182070/

Strozza, C., Vigezzi, S., Callaway, J., Kashnitsky, I., Aleksandrovs, A., & Vaupel, J. W. (2022). *Socioeconomic inequalities in survival to retirement age: A register-based analysis* [Preprint]. Open Science Framework. https://doi.org/10.31219/osf.io/8wbdv

van Raalte, A. A., & Caswell, H. (2013). Perturbation Analysis of Indices of Lifespan Variability. *Demography*, 27. https://doi.org/10.1007/s13524-013-0223-3

van Raalte, A. A., Sasson, I., & Martikainen, P. (2018). The case for monitoring life-span inequality. *Science*, *362*(6418), 1002–1004. https://doi.org/10.1126/science.aau5811

Vaupel, J. W., & Canudas-Romo, V. (2003). Decomposing change in life expectancy: A bouquet of formulas in honor of Nathan Keyfitz's 90th birthday. *Demography*, *40*(2), 201–216. https://doi.org/10.1353/dem.2003.0018

Vaupel, J. W., Villavicencio, F., & Bergeron-Boucher, M.-P. (2021). Demographic perspectives on the rise of longevity. *Proceedings of the National Academy of Sciences*, *118*(9), e2019536118. https://doi.org/10.1073/pnas.2019536118

Vaupel, J. W., Zhang, Z., & van Raalte, A. A. (2011). Life expectancy and disparity: An international comparison of life table data. *BMJ Open*, *1*(1), e000128–e000128. https://doi.org/10.1136/bmjopen-2011-000128

Whitta-Jacobsen, H. J., Neergaard, J., Mortensen, L., Vanglo, D., & Andersen, L. (2022, May 4). Fremtidssikring af et stærkt pensionssystem. *Det Samfundsvidenskabelige Fakultetet*. https://samf.ku.dk/presse/kronikker-og-debat/2022/fremtidssikring-af-et-staerkt-pensionssystem/

Forecasting inequalities in survival to and after retirement by socioeconomic status in Denmark and Sweden

Cosmo Strozza[1], Marie-Pier Bergeron Boucher[1], Julia Callaway[1], Sven Drefhal[2]

[1]Interdisciplinary Centre on Population Dynamics, University of Southern Denmark, Odense, Denmark

[2]Department of Sociology, Stockholm University, Stockholm, Sweden

Supplementary Figures

Figure S1. Life expectancy at age 50 by sex and socioeconomic status (income quartile) in Denmark. Two models are used to forecast mortality: Li-Lee and Mode. Years 1988-2040

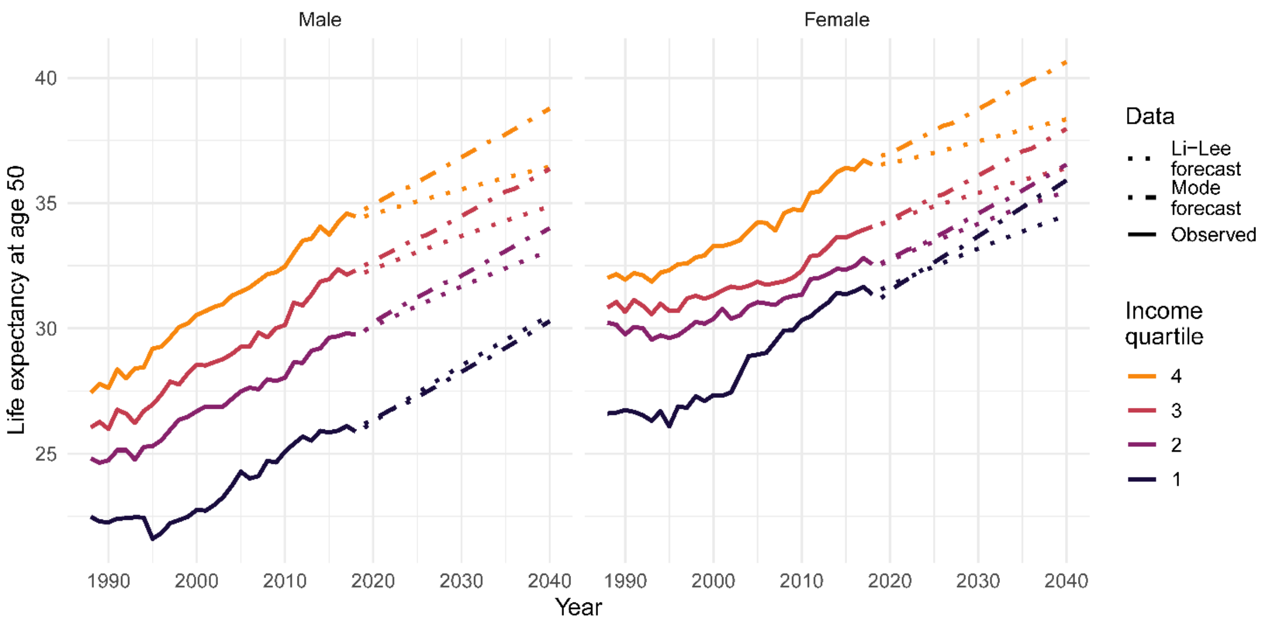


Figure S2. Lifespan variation measured through e-dagger by sex and income quartile in Denmark. Two models are used to forecast mortality: Li-Lee and Mode. Years 1988-2040

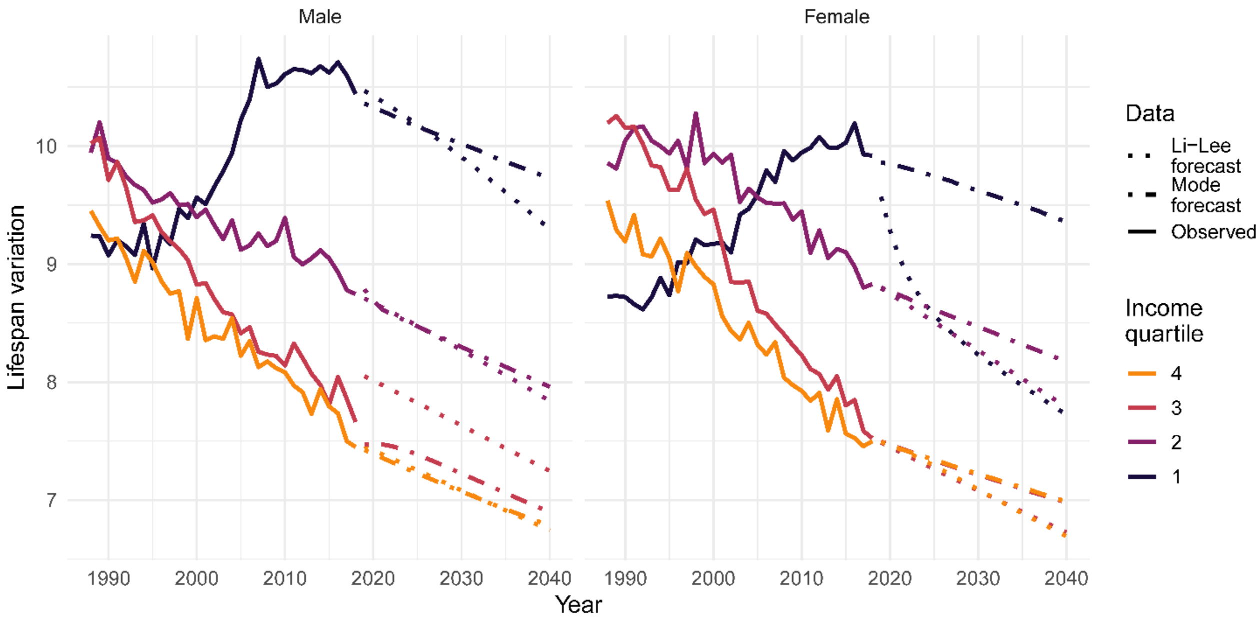


Figure S3. Modal age at death by sex and income quartile in Denmark. Two models are used to forecast mortality: Li-Lee and Mode. Years 1988-2040

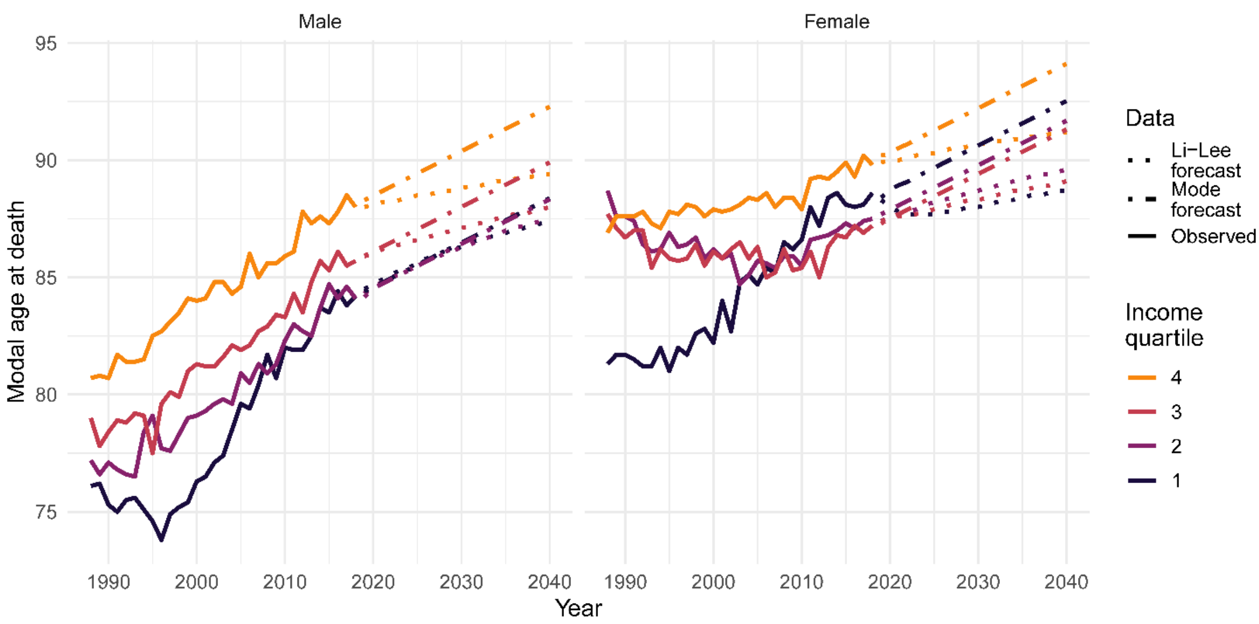


Figure S4. Probability of surviving to age 65 by sex and income quartile. Two models are used to forecast mortality: Li-Lee and Mode. Years 1988-2040

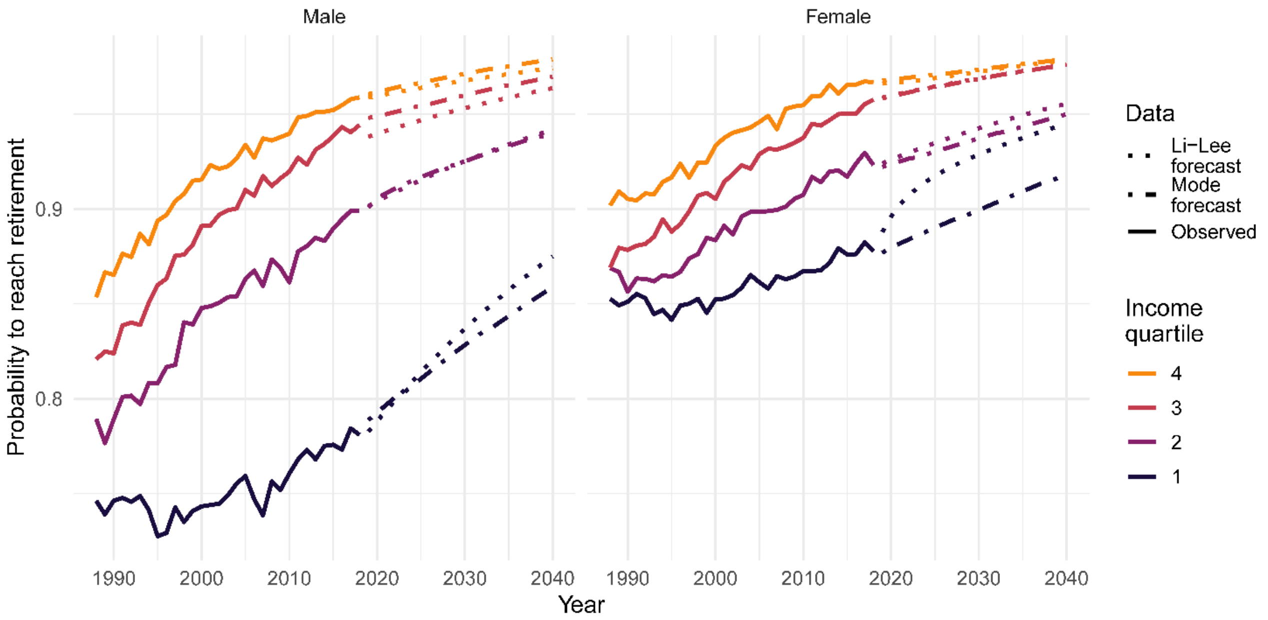


Figure S5. Probability of surviving to retirement by sex and income quartile. Two models are used to forecast mortality: Li-Lee and Mode. Years 1988-2040

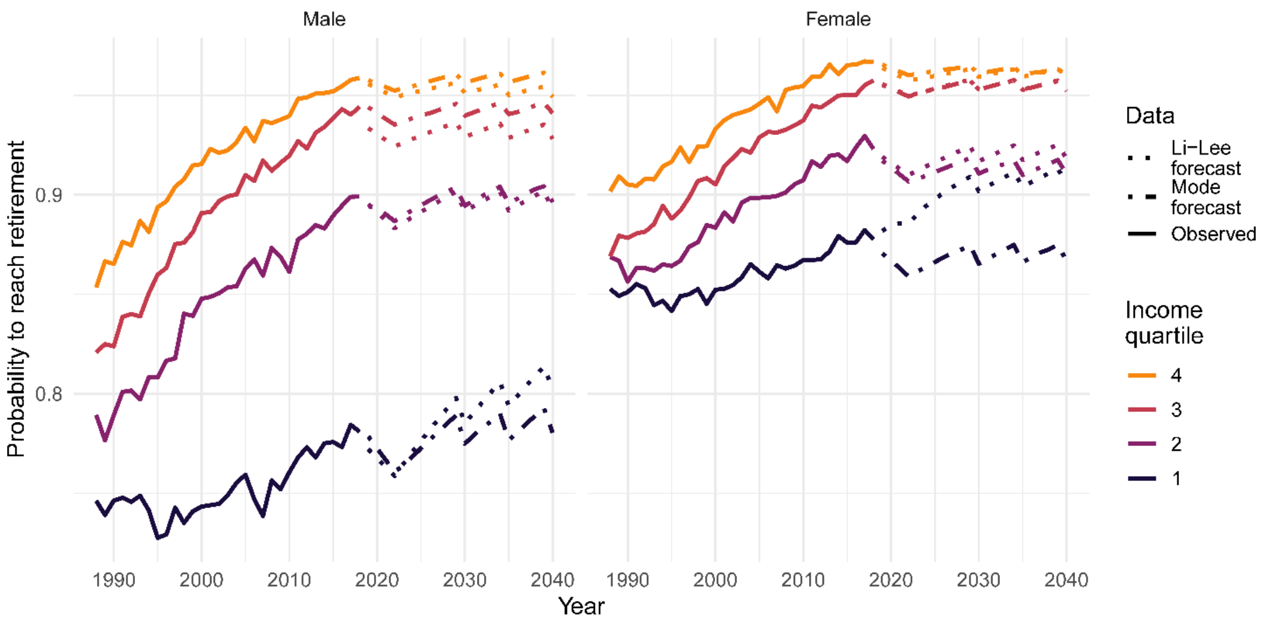


Figure S6. Life expectancy at age 65 by sex and income quartile. Two models are used to forecast mortality: Li-Lee and Mode. Years 1988-2040

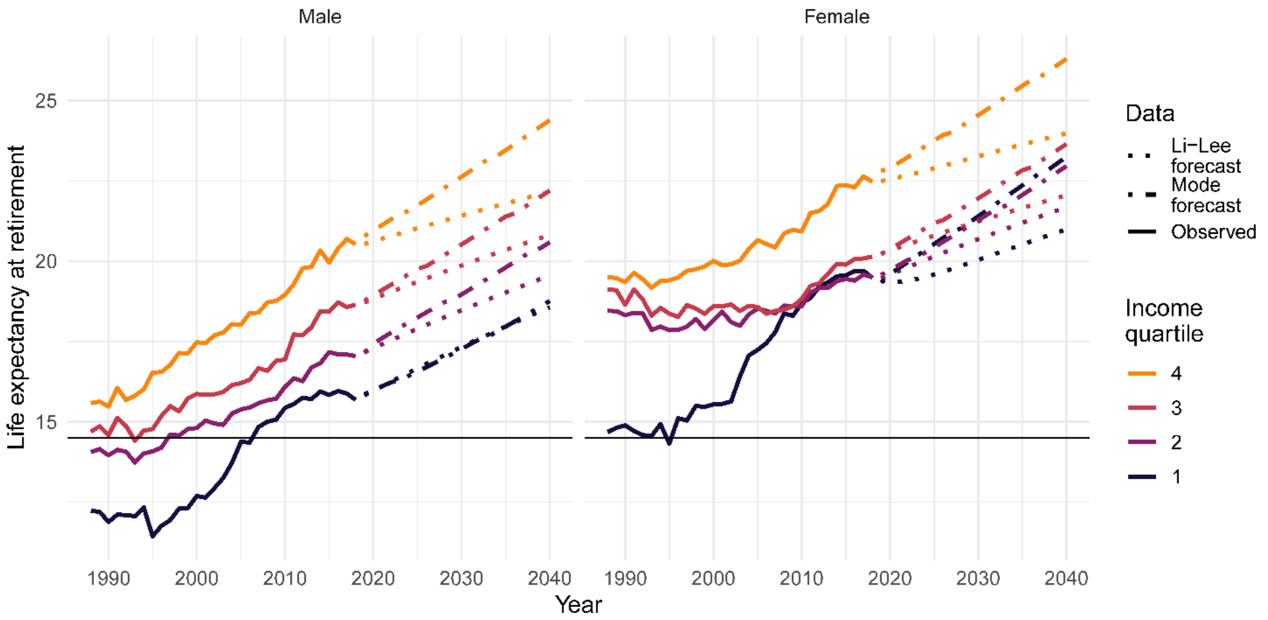


Figure S7. Life expectancy at age retirement by sex and income quartile. Two models are used to forecast mortality: Li-Lee and Mode.