# Linking retirement age to life expectancy does not lessen the demographic implications of unequal lifespans

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## Abstract

People live longer and spend more time in retirement than in previous years. This phenomenon jeopardizes the stability of pension systems. Recent reforms aim to alleviate the burden of increasing longevity by linking retirement ages to changes in life expectancy. However, the demographic implications of such linkages are still unknown.

In this study we analyse the case of Denmark where the retirement age is linked to changes in life expectancy targeting a period of constant pension payments for 14.5 years. Using high-quality data from the Danish population registers, we explore trends in life expectancy and lifespan inequality after retirement by sex and by socio-economic groups (SES) during the period 1985-2016. Our results indicate that the linkage rule place retirees in a demographic setting where higher uncertainty about the length of life prevails. This pattern is magnified for males from lower SES. We also show that, given the low interest rates prevailing in Denmark, the costs of pensions are highly sensitive to changes in mortality.

Increased longevity and unequal lifespans are at the heart of imbalanced pension systems, affecting individuals, societies and financial institutions. This study serves as a reference of the possible implications that might arise not only in Denmark but also in countries experiencing similar pension reforms.

**Keywords:** Danish longevity, socio-economic status, lifespan inequality, retirement age

# 1. Background

Retirement ages are traditionally based on a fixed chronological age such that individuals eligible to retire from working have lived the same number of years (e.g. 65 years). Such schemes exhibit a fundamental pitfall: they do not consider the dynamics of mortality over time. There is a growing body of evidence that provides support of this deficiency. First of all, life expectancy at birth has increased over time (Oeppen and Vaupel, 2002). This measure has gone up mostly because the risk of dying at young ages has declined (Burger et al., 2012). As a consequence, a high fraction of individuals from recent birth cohorts survive to retirement ages. Second, the risk of dying during post-retirement ages has trended downwards over time (Vaupel and Lundstrom, 1994). Recent studies have also put forward evidence that old-age mortality in a number of developed countries is being postponed at a speed of about 3 years per 10-year generation (Zuo et al., 2018). In other words, the risk of dying at age 68 years today is equivalent to the risk of dying at age 65 ten years ago. These regularities imply that, under a fixed retirement age scheme, individuals from most recent cohorts spend a greater number of years in retirement in comparison to those from previous cohorts. Increased longevity exacerbates inter-cohort inequality and has several implications to the national economic outcomes (Sanderson and Scherbov, 2010, 2013, 2017).

In order to ensure sustainability in their pension systems, many OECD countries such as Denmark, Finland, Italy, the Netherlands, Portugal and the Slovak Republic have passed reforms to link retirement ages to changes in life expectancy (OECD, 2017). This means that increases in retirement ages will be closely associated to the rise of life expectancy. Particularly in Denmark, the current statutory retirement age (often denoted to as normal retirement age) is 65 years but according to the legislation adopted in 2007 (Ministry for Economic Affairs and the Interior, 2017, 2018), it will gradually go up towards the age of 68 over the period 2019-2030, targeting a retirement age were remaining life expectancy is 14.5 years (OECD, 2015). Thus, it is expected that in the long run, retirees receive an old-age pension during an average period of 14.5 years. This scheme is based on a prospective age (Sanderson and Scherbov, 2013), which depends on the future years to live rather than on the years already lived and it has pointed out to be effective in lessening the increasing pattern over time in the average length of life (Antolin 2007; Sanderson and Scherbov, 2014).

***A different demographic panorama after retirement***

Increasing retirement ages (in this case, by linking them to life expectancy) does not modify national mortality regimes. Age-specific mortality schedules remain the same for the total population at a specific point in time. However, the demographic setting in which individuals retire changes because their retirement is now conditioned upon surviving to an older age, where the distribution of lifespans has a different shape (Baudisch et. al, 2011; Wrycza et. al, 2015). For example, probabilities of surviving to the current retirement age (65 years) and to the new one might be distinct. Pensions also begin to be paid at an age positioned further to the right of the distribution of lifespans. Given that death rates are higher at older ages (Rau et al. 2008), the probability of surviving to the whole set of payments (for an average period of 14.5 years according to the 2007 Danish reform) is also affected. With modifications to the retirement age, events associated to it occur later in life and in a different demographic panorama. Since not all individuals live the same amount of years, diverse demographic scenarios might also appear among sub-populations leading to disadvantageous settings for some of them. For example, it has been shown that inequality in life expectancy regarding education attainment has increased in Denmark (Brønnum-Hansen and Baadsgaard, 2008). Hence, the analysis of the different demographic settings after retirement is necessary to better understand the implications of linking retirement age to life expectancy.

### *Unequal lifespans*

Life expectancy does not capture the spread of the distribution of lifespans. Thus, a look at the variation is necessary to fully describe differences among mortality schedules (Alvarez et. al, 2019). The variation of lifespans can be interpreted as inequality in the length of life (henceforward referred to as lifespan inequality). This inequality is the most fundamental of all inequalities to which humans are exposed (Tuljapurkar, 2001) since every other type of inequality is conditional upon being alive (Van Raalte et al, 2018). The strong relationship over time between life expectancy and lifespan inequality has been previously documented (Vaupel et. al, 2011; Colchero et. al, 2016) such that every time that life expectancy at birth decreases, lifespan inequality goes down. However, two populations can exhibit very similar life expectancies and completely different levels of lifespan inequality. As an example of this situation, in Figure 1 we display the distribution of lifespans after age 65 for females in Denmark, Korea and United States for the years 2016, 2008 and 2015 respectively (based on data retrieved from the Human Mortality Database, 2019). The three populations show almost identical remaining life expectancies at age 65 (20.72 for Denmark and Korea and 20.76 for United States). Nonetheless, noticeable differences in the distribution of lifespans are translated into different outcomes of lifespan inequality measures here depicted by life disparity, $e^{\dagger}(65)$, and lifetable entropy $H(65)$ (see Aburto et. al, 2019) for a further description of these measures of lifespan inequality). This means that the length of life after age 65 is more variable in Denmark than in Korea but less variable than in the United States. With this brief example of national populations, we show that life expectancy analyses alone are insufficient since they do not reflect the complete demographic setting of the population.

***Figure 1 about here***

The 2007 pension reform in Denmark aims for constant life expectancies at retirement over time at levels of 14.5 years. Still, it is unknown how unequal lifespans are after retirement and if the levels of inequality will also remain constant over time. The overall aim of this article is to provide a thorough analysis of the inequality in the length of life after retirement by using the Danish pension system to illustrate the consequences. As shown in Figure 1, different levels of lifespan inequality can arise from the same values of life expectancy meaning that inequality after retirement can fluctuate even with constant life expectancies of 14.5 years. Further, some sub-populations denoted by a social gradient might not enjoy life expectancies of 14.5 years at retirement (Cairns et al., 2019). How unequal lifespans are among these sub-populations is less than clear cut. Thus, investigating the levels of lifespan inequality after retirement and how they evolve over time is fundamental to foresee the implications of changing retirement age not only in Denmark, but also in other countries experiencing similar pension reforms (OECD, 2015, 2018).

### *Implications of unequal lifespans after retirement for individuals and societies*

The uncertainty about the length of life complicates planning for actors involved in pension systems: individuals, societies, governments, and financial institutions in charge of the management of pension funds (Whitehouse, 2007). At individual level, retirement requires careful planning. Individuals need to plan the number of years they will spend on it and determine their savings and consumption paths for post-retirement years accordingly. High lifespan inequality after retirement means great uncertainty about the number of years an individual will spend on it. This hinders effective planning (Van Raalte et. al, 2011; Aronsson and Blomquist, 2018) and discourage the participation of individuals on the pension scheme. Sub-populations experiencing high uncertainty about their survival will value future pension benefits less than groups with low uncertainty because of a lower present value of their future payouts

(Edwards and Tuljapurkar, 2005; Haberman et al., 2011)

At a societal level, differences in lifespan inequality between socio-economic groups (SES) are translated into an overlooked dimension of social inequality in health and survival since more advantaged groups can plan their post-retirement years more effectively, whereas less-advantaged groups face greater uncertainty about their survival (Van Raalte et al., 2018). In Denmark lifespan inequality has stagnated among people from the lowest income quartile whereas increasing equality is observed among individuals belonging to the highest quartiles (Brønnum-Hansen, 2017). Similar results have been found in other countries where analyses of lifespan inequality by a social dimension have been conducted. For example, in Finland by occupational class (Van Raalte et al., 2014), and by educational level in Spain (Permanyer et al., 2018) and in the United States (Sasson, 2016). Altogether these studies conclude that those in social disadvantage experience higher lifespan variation at all levels of life expectancy.

Nonetheless, it is worth noting that these studies have measured lifespan inequality either from the perspective of a new-born (Brønnum-Hansen, 2017) or from the viewpoint of young adults (i.e. conditioning upon survival to age 25 in Sasson (2016), to age 30 in Van Raalte et al. (2018) and to age 35 in Permanyer et al. (2018)). Individuals face different amount of uncertainty throughout their lives. This depends on the factors or events ahead that could potentially kill them and on how such factors are distributed across the remaining lifespan. For example, a new-born is exposed to certain diseases that a person in their adolescence is not. Likewise, mid-life years are strongly affected by external mortality such as road accidents (Remund et al., 2018), while cardiovascular diseases and neoplasms are the main causes of death among the elderly (Roth et al., 2018). Indeed, the number of deaths attributed to these factors varies at each age and across countries. Currently in Denmark, infant mortality is at its lowest levels, whereas most of the deaths in this country occur around age 87 (Human Mortality Database, 2019). This results into different levels of lifespan inequality across the age-span such that the uncertainty about the survival of a new born is different to the one experienced by a young adult or a person in retirement ages.

It has also been shown that trends over time in lifespan inequality statistics depend on the age to which the chosen measure of inequality is conditioned (Engelman et al., 2010). For instance, inequality in lifespans decreases over time if the complete distribution is considered. Trends are nearly flat when conditioning upon survival to age 50 and they slightly go up when starting the analysis at age 75 years. These divergent trends are closely related to the existence of a threshold age in which mortality improvements below such age decrease inequality but reductions in the risk of dying above it, increase variation (Zhang and Vaupel, 2009; Aburto et. al, 2019). Retirement ages are located close to such threshold ages. Further, in developed countries, reductions in the risk of dying have been more pronounced at younger ages, whereas mortality improvements at older ages have been done to a lesser extend (Burger et al., 2012; Rau et al., 2008) so the patterns over time in lifespan inequality after retirement are unclear.

***Implications of unequal lifespans after retirement for entities***

The indexation rule implemented in the 2007 Danish reform (OECD, 2015; Ministry for Economic Affairs and the Interior, 2017, 2018) implies that the average length of pension payments will be constant for 14.5 years. However, this rule does not imply that lifespan inequality will also be constant (see Figure 1). Greater inequality in lifespans has detrimental implications on the cost of pensions. For instance, Haberman et al. (2011) show that, in a context of low interest rates, high lifespan inequality (measured by a variant of the lifetable entropy) indicates that the cost of annuities is more propense to respond to a change in the force of mortality than at a lower level of entropy. Thus, institutions managing pension funds require to be aware of lifespan inequality statistics when pricing annuities and to protect themselves against unexpected fluctuations in mortality. Lifespan inequality emerges as source of longevity risk complementing traditional analysis focused solely on the mean length of life (Cocco and Gomes, 2012; Slipsager, 2018).

This study examines the demographic implications of linking retirement ages to national life expectancies. Specifically, we analyse whether constant life expectancies after retirement imply constant lifespan inequality. Given the evidence of previous studies (Sasson, 2016; Brønnum-Hansen, 2017; VanRaalte et al., 2018; Permanyer et al., 2018) we foresee that high disparities in mortality by socio-economic groups (SES) also prevail after retirement. To test this, we use high-quality data from Danish registers for the period 1985 – 2016 and analyse trends in life expectancy and lifespan inequality by sex and by SES at the current retirement age (65 years) and at the age in which remaining life expectancy is 14.5 years. Our analyses allow us to determine the disparities between the demographic scenario in which individuals currently retire and a setting where retirement age is linked to life expectancy. Finally, we discuss how a change in the demographic scenario at retirement with constant life expectancies affects the actors involved in the pension system, specifically individuals retiring, societies and financial entities involved in the management of pension funds. To our knowledge, this is the first study examining lifespan inequalities after retirement by socio-economic groups. This study serves as a reference of the possible implications after retirement that might arise in other countries experiencing similar pension reforms to Denmark (OECD, 2015, 2018).

# 2. Material and methods

We use the longitudinal register databases covering the entire Danish population for the period 1985 to 2016. The advantage of using such high-quality dataset is that we are able to identify each individual across the entire population in areas such as financial income, wealth, date of birth and death. We use the newly developed affluence measure by Cairns et. al (2019) based on the individuals' income and wealth to subdivide the population into five socio-economic status (SES) groups at each age and each point in time. People in the lowest quantile are those with the lowest SES whereas those in the top quantile are the ones from highest SES. The affluence measure is a significant improvement compared to previous studies using education (Sasson, 2016; Permanyer et al., 2018) or the individuals last observed income (Brønnum-Hansen, 2017) since the affluence measure is able to maintain equally sized groups across time and allow individuals to move between groups as they age. Similar to Cairns et al. (2019), we restrict the age dimension to individuals above the age of 50 with a lockdown at age 67, indicating that individuals are maintained in the same socioeconomic group during the post-retirement years.

In order to obtain continuous estimates of the underlying mortality hazard and compute different longevity measures based on it, we used the observed death rates to simulate a high number of lifetimes. We sample 100,000 lifetimes for every SES and every year from an exponential distribution with piece-wise constant rate (Willekens, 2009). The results obtained from the simulation are equivalent to the ones obtained by calculating lifetables directly from the observed death rates. However, with this procedure we are able to determine the exact age *r* at which remaining life expectancy is 14.5 years, (i.e. $e(r) = 14.5$). Such age *r* is calculated for the total population portraying the target retirement age proposed in the new Danish pension system (OECD, 2015; Ministry for Economic Affairs and the Interior, 2017, 2018). Similarly, $r_{ses}^{sex}$ is the hypothetical retirement age of each sub-population based on their own mortality profile such that $sex = female, male$ and $ses = 1, 2, \dots, 5$ denotes the socio-economic status, where 1 is the lowest and 5 is the highest respectively. Survival probabilities were also computed at different ages. For example, ${}_{r-50}p_{50} = \frac{l(r)}{l(50)}$ denotes the probability of surviving from age 50 to age r such that $r \geq 50$

and $l(50)$ and $l(r)$ are the number of survivors to ages 50 and r respectively.

Next, we estimated remaining life expectancy after different retirement ages. For example, remaining life expectancy at age *r* is denoted as:

$$e(r) = \frac{\int_r^\infty l(x)dx}{l(r)}, \tag{1}$$

such that $x \geq r$. A pension is defined as a series of payments made at equal intervals payable for the whole life starting at retirement age. At age *r*, the cost of a pension is represented as a life annuity (Bowers et. al, 1997):

$$a(r) = \frac{\int_r^\infty l(x)e^{-\delta x}dx}{l(r)}, \tag{2}$$

where $\delta$ denotes the interest rate at which the pension is evaluated. Thus, $a(r)$ is equivalent to $e(r)$ whenever $\delta=0$.

In this study, the lifetable entropy (Lesser, 1955; Keyfitz, 1968, 1977), denoted to as $H(r)$, is the preferred measure of lifespan inequality because of two main reasons. First, this indicator is dimensionless since it does not depend on the level of mortality (Wrycza et al., 2015). This property is particularly important in our study because we compare the shape of the distribution of lifespans after age *r*, which changes overtime. Second, an absolute measure of inequality such as life disparity (Brønnum-Hansen, 2017) or the standard deviation could lead to different results since they hinge on the onset age of calculation, which varies according to age *r*. Goldman and Lord (1986) and Vaupel (1986) proved that $H(r)$ can be expressed as:

$$H(r) = \frac{\int_r^\infty d(x)e(x)dx}{e(r)} = \frac{e^\dagger(r)}{e(r)}, \tag{3}$$

where $e^\dagger(r) = \int_r^\infty d(x)e(x)dx$ denotes the number of years lost due to death (Vaupel and Canudas-Romo, 2003), which is calculated as an average of the distribution of remaining life expectancies, $e(x)$, weighted by the distribution of lifespans $d(x)$. Haberman et. al (2010) applied the concept of lifetable entropy to the cost of an annuity such that at given $\delta$, $H(r,\delta)$ represents the sensitivity of the cost of a life annuity contract due to changes in death rates*:*

$$H(r,\delta) = \frac{\int_r^\infty d(x)a(x)e^{-\delta x}dx}{a(r)}. \tag{4}$$

It can also be shown that in the case of $\delta=0$, $H(r,\delta = 0) = H(r)$. We calculated $H(r)$ and $H(r,\delta)$ by SES and sex and for different interest rates δ to determine *(i)* how unequal lifespans are after retirement in each sub-population and *(ii)* how such inequalities affect the cost of pensions. We computed such measures at age *r* and at the current retirement age (i.e. 65 years).

# 3. Results

The distributions of lifespans after age 65 by SES, by sex and for selected years during the period 1985-2016 are shown in Figure 2. Despite the high overlapping between distributions pertaining to the highest and lowest SES quintiles (84% for females and 78% for males in 2015) we can observe noticeable differences among them. Distributions for high SES are, in all cases, shifted to the right and their tail is much longer than for low SES. This indicates that a great number of individuals form high SES outlive those pertaining to lower SES. Likewise, distributions for males are shorter than their female counterpart. The white lines denote the target retirement age $r$ calculated for the total population (same for females and males). Indeed, $r$ increases over time (from 67.16 in 1985 to 71.32 in 2015; see panels A and B of Figure 3 and Table A1 in the Appendix for more details) and the distribution of lifespans after such age varies. Intuitively, the discrepancies among distributions of lifespans result into different values of remaining life expectancies and lifespan inequalities among sexes and across SES. Such disclosed inequalities are examined in the following paragraphs.

***Figure 2 about here***

Panels A and B of Figure 3 show trends over time in the ages at which remaining life expectancy is 14.5 years for the total population ($r$, in grey) and for each of the SES quantiles ($r_{ses}^{sex}$, in different colours) for females and males respectively. From 1985 to 1995, the age $r$ stagnates around 67 years. This corresponds to the stagnation period in which inter-war cohorts suffer from deterioration in mortality mainly associated to an increase in smoking attributable mortality (Lindahl-Jacobsen et al., 2016 a, b). From 1995 onward, $r$ went up and reached values of 71 years in 2016. This indicates that a person aged 71 years in 2016 enjoyed the same remaining life expectancy (14.5 years in this case) as a person aged 67 years in 1995.

***Figure 3 about here***

Inequalities appear when focusing on sub-populations characterized by SES (see panels A and B of Figure 3). As a regularity, individuals from higher SES quantiles enjoy longer lives than those from lower SES. Such differences prevail overtime since distances between hypothetical retirement ages remain somewhat similar for most of the SES groups. However, the lowest SES group is an exception to this. Females and males pertaining to lowest SES depict a steady increase in $r$ during the whole period of observation resulting on a narrowed gap between $r_1^{females}$ and $r_2^{females}$. This provides evidence that *(i)* the stagnation period in life expectancy (Cairns et al. 2019) is driven by upper SES and that *(ii)* females from the lowest two SES (comprising 40% of the total female population) would enjoy similar lifespans after retirement age $r$. From panels A and B of Figure 3 it is also clear that females outlive males for all SES.

As mentioned in the introduction, it is fundamental that individuals exhibit similar chances of surviving to retirement to ensure a continuous political support from beneficiaries of the pension system (Sanderson and Scherbov, 2017). In this sense, we observe that the probability of surviving from age 50 to the target retirement age (${}_{r-50}p_{50}$, see panels A and B of Figure 4) for the total population has remained constant over time around values of 0.80 with moderate increases in recent years. This is a crucial aspect that determines the number of individuals being eligible to receive public pensions every year. A high probability indicates that a great number of people make it to the retirement age but also that they survive to the full period in which they contribute by taxes and by payments to their pension funds. By looking at differences by SES groups we observe that females from all SES (panel A of Figure 4) and males from the fourth and fifth SES quantiles (panel B of Figure 4) exhibit either higher or equal values of ${}_{r-50}p_{50}$ than the population. Males from the lowest two SES quantiles experience lower values of ${}_{r-50}p_{50}$ in comparison to the rest of the population. Despite the upward trend depicted by males in the first SES quantile, their ${}_{r-50}p_{50}$ was still 10% lower than ${}_{r-50}p_{50}$ for the total population during 2016.

Panels C and D of Figure 4 display the probability that an individual survives 14.5 years more after their retirement age $r$, ${}_{14.5}p_r$. In other words, we calculate the probability that a person remains alive to receive pension payments for 14.5 years. For the total population, ${}_{14.5}p_r$ is roughly 0.50 (or 50%) and remains remarkably constant over time. This indicates that at the population level, there is a balance between current and previous generations (Institute and Faculty of Actuaries, 2017) since Danish pensioners would have similar chances to receive pension payments for 14.5 years regardless on when they reach retirement age $r$. This finding also implies that pension fund managers have 50% of chances of ceasing pension payments within the next 14.5 years due to the death of the pensioner. It is also worth noting that ${}_{r-50}p_{50}$ is 30% higher than ${}_{14.5}p_r$ entailing that it is 30% more likely that a person survives to retirement than to receive pension payments for 14.5 years. Patterns ${}_{14.5}p_r$ across SES are very much alike to the ones depicted by ${}_{r-50}p_{50}$ such that the probability of remaining alive 14.5 years after retirement is much higher for the top SES groups than for the low ones. As in all longevity measures shown here, females exhibit higher values of ${}_{14.5}p_r$ than males.

***Figure 4 about here***

In Figure 5 we show differences between remaining life expectancies calculated at the current retirement age 65 (panels A and B, see Table A2 for more details) and at the target retirement age *r* (panels C and D, see Table A3 for more details). It is clear that as of 1995, $e(65)$ has increased over time (with an average annual increase of 1%), indicating that if the current retirement age (65 years) remains unchanged, individuals from most recent generations would spend more time in retirement than those form previous generations. The 2007 Danish pension reform (Ministry for Economic Affairs and the Interior, 2017, 2018) aims to account for changes in longevity such that life expectancy after retirement remains roughly constant. By looking at panels C and D of Figure 5 it seems that this objective would have been accomplished if the 2007 pension scheme was implemented prior to 1985 since at the population level the increasing pattern of $e(65)$ is offset by the constant pattern of $e(r) = 14.5$ years.

The female advantage and the inequalities across SES reported above also hold for life expectancies after retirement. Individuals pertaining to higher SES outlive those from lower SES. For example, $e(65)$ is 17 years for females from the highest SES quantile. This means that they are expected to spend 2.5 years more in retirement than what is expected for the total population (14.5 years). Conversely, males from the lowest SES would spend 3 years less in retirement than the total population. Males from the highest SES would attain similar remaining life expectancies at retirement. Therefore, the pension reform in Denmark stays short in reducing disparities encountered among sexes and across SES.

***Figure 5 about here***

Figure 6 depicts trends in lifespan inequality portrayed by the lifetable entropy calculated at the current and target retirement ages ($H(65)$ and $H(r)$ respectively, see Tables A4 and A5 for more details). At the population level, we observe that $H(65)$ and $H(r)$ remained constant during the period 1985-2000.

Thereafter, both measures declined towards values of 0.39 and 0.46 for $H(65)$ and $H(r)$ respectively. The downward trend of $H(65)$ is more pronounced than for $H(r)$ (the annual average decline was about 1.06% and 0.50% respectively for both measures from 2000 onwards). Further, levels of $H(65)$ are in all cases much lower than $H(r)$, entailing that inequality of lifespans is greater after age $r$ than after the current retirement age 65. Lifespan inequality can be translated as measure of uncertainty about their length of life. Thus, our results indicate that individuals experience more uncertainty after age $r$ than after age 65.

***Figure 6 about here***

Similar to what is observed in life expectancy trends, upper SES experience low levels of lifespan inequality compared to lower SES groups. Females and males from the two highest SES quantiles consistently show lower lifespan inequality than the population average. Conversely, men from the lowest three SES quantiles display lifespan inequality values higher than the ones calculated at the aggregate level. These trends demonstrate that socio-economic inequality after retirement not only prevails on life expectancy but also on lifespan inequality such that males from the lowest SES are in consistent disadvantage in comparison with other members of the population. Altogether our findings indicate that linking retirement age to life expectancy increase the uncertainty about individuals' length of life after retirement.

In order to measure the cost of the inherent inequality in lifespans after retirement, we compute values for the life annuities $a(65)$, $a(r)$ and their associated entropies $H(65, \delta)$ and $H(r, \delta)$ over time, by SES and assuming different interest rates $\delta = 1\%, 2\%, 5\%$ (results are shown in Figures A1 to A12 in the Appendix). First of all, we observe that the higher the interest rate, the lower the annuity price. The distances between SES also become smaller as $\delta$ increases. At $\delta = 5\%$, not only the pattern of $a(65)$ is constant over time and almost identical for all SES but also values for $a(65)$ and $a(r)$ are very much alike.

Similar to the trends in $a(65)$ and $a(r)$, values for $H(65, \delta)$ and $H(r, \delta)$ diminish whenever $\delta$ increases. This pattern entails that in high interest regimes, the cost of a pension becomes less susceptible to changes in mortality. Conversely, in low interest environments, longevity risk becomes more relevant in the management of pension plans. Indeed, the maximum value of entropy in the cost of an annuity is attained when $\delta = 0\%$ such that $H(65, \delta)$ equals the lifetable entropy $H(65)$ and $H(r, \delta) = H(r)$. This regularity is in line with previous findings of Haberman and colleagues (2011). Finally, it is worth noting that in the scenario of high interest rates, the gap between SES in $H(65, \delta)$ and $H(r, \delta)$ reduces to a lesser extent than the SES gap in $a(65)$ and $a(r)$.

# 4. Discussion

Increased longevity seems to be a feature of modern populations doing the best (Oeppen and Vaupel, 2002). This phenomenon posits challenges among which is the redefinition of national pension schemes. In this study we examine the case of Denmark, which in 2007 passed a reform that modifies the retirement age such that it will be linked to the age at which remaining life expectancy is 14.5 years (Ministry for Economic Affairs and the Interior, 2017, 2018). It is expected that this indexation rule controls for changes in longevity over time, alleviates the pressure on public finances and allows for a more egalitarian demographic regime after retirement (OECD, 2015).

In this study, we analyse retrospective (${}_{r-50}p_{50}$) and prospective (${}_{14.5}p_r$ and $e(r)$) measures of longevity to obtain a full overview of the demographic implications of linking retirement age with life expectancy (see Kjærgaard and Canudas-Romo, 2018 for further reading). We show that these measures remain at similar levels over time. The increasing trend of life expectancy at age 65 (current retirement age) is offset by the 2007 pension reform since individuals would spend similar average number of years on retirement. Still, demographic inequalities appear across all SES quantiles. Such disparities are magnified when comparing patterns among sexes. Males are in clear disadvantage with respect to their female counterparts at all levels of SES. Particularly, men from the lowest two SES quantiles under-perform in all longevity outcomes.

The ultimate dimension of inequality in longevity is captured in our analysis of lifespan inequality trends. We put forward evidence that constant life expectancies after retirement do not imply constant variation of lifespans. Indeed, in both scenarios (retirement at age 65 and at age *r*), lifespan inequality decreases over time. However, we show that *H*(65) is much lower, declines more rapidly and to a larger extend than *H*(r). This indicates that the new pension scheme sets retirees into a demographic scenario where the lifespans are more unequal.

Inequalities in lifespans after retirement arise from different sources: trends overtime, across SES groups and due to the age-dispersion of the distribution of lifespans. Such inequalities affect the components of the Danish pension system: *(i)* the universal old-age public pension conceived under a defined benefit scheme, *(ii)* labour market pensions, which are mostly defined contribution schemes, and *(iii)* individual pension savings (OECD, 2015, 2018). However, each component is affected differently by these inequalities. Thus, we must analyse the implications of unequal lifespans from the perspective of the different actors involved in the pension system: individuals retiring, pension funds, risk managers and national governments.

***Demographic balance over time and across socio-economic groups***

A balance between the needs of current and future generations without placing an unfair burden on either is the backbone of any egalitarian pension scheme (Institute and Faculty of Actuaries, 2017). The stability of macroeconomic indicators and the adequate management of finances play an important role on promoting such intergenerational balance (Hassler and Lindbeck, 2002; Queisser and Whitehouse, 2006; Alonso-Garcia, 2018). Still, as shown here, increasing life expectancies and unequal lifespans are at the root of imbalanced pension systems (Institute and Faculty of Actuaries, 2017) as all other inequalities are conditional on being alive (Van Raalte, 2018).

In this study we show that an *intergenerational* demographic balance is promoted in the Danish pension reform since similar probabilities of reaching retirement and surviving to the end of it would prevail over time. However, not all individuals in the population enjoy similar longevity outcomes, disclosing nuances embedded in the composition of the population. These patterns reveal a disruption on the *intragenerational* demographic balance since pensioners from low SES are at great disadvantage in comparison with those from high SES.

The general acceptance of a public pension system relies (among other factors) on the likelihood that all groups within a society survive to retirement age (Sanderson and Scherbov, 2017). Such approval is essential in any democratic system, but it is unlikely to be reinforced by the parts of the population which, because of low survival, only receive limited benefits from the system. With a retirement age linked to the increase in total life expectancy, the probability of surviving to retirement is curtailed for individuals from low SES. As shown in this study, only around 70% of the Danish males in the lowest SES quantile would have survived to the prospective retirement age and just 33% of them would have receive pensions for 14.5 years if the new Danish pension system where fully implemented in 2016. Thus, it is likely that males from lower SES will struggle more to cope with changes in retirement ages. Effective health policies can contribute to reduce disparities in longevity among SES (Van Raalte et al., 2011, Brønnum-Hansen, 2017).

Interest rates are an important factor determining the extent of the gap in pension costs between SES. We show that differences in the value of life annuities between SES diminish in a context of high interest rates. Specifically, under the scenario of constant interest rates of 5%, the value of an annuity $a(65)$ is very similar for all SES. Indeed, under this scenario, $a(65)$ and $a(r)$ are very much alike, indicating that differences in mortality after retirement are of less importance under a setting of high interest rates. Many developed countries have been experiencing extremely low interest rates after the financial crisis which have lowered the returns from risk free investments (OECD, 2019). This is also the case of Denmark. This country has experienced remarkably low interest rates during recent years (Pedersen 2015; Feveile and Pedersen, 2019). Hence, as interest rates go down, the inequality of lifespans becomes more relevant on annuity pricing. Such disparities are reflected into equal differences in cost of pensions for the different SES. Under a context of low interest rates, social inequalities in mortality are still prevalent after retirement.

***Implications of unequal lifespans on individual planning***

Individuals require to envisage the number of years they expect to spend in retirement in order to plan the financial conditions in which they will experience it. In this regard, lifespan inequality can be seen as a measure that summarises the uncertainty about the number of years a person will remain in retirement. While it is true that individuals are mostly unaware of lifespan inequality statistics, they experience the survival chances of friends and relatives affecting their perceptions of survival expectations (Van Raalte et al., 2018). High uncertainty about the length of life makes the future more blurred hindering individuals' planning (Aronsson and Blomquist, 2018). Without careful planning, important financial decisions about retirement can be taken lightly resulting into insufficient individual savings to maintain the consumption path during post-retirement years. A demographic setting like the one drawn in our analysis, where high lifespan inequality prevails among retirement, might be an important trigger of ineffective financial planning among individuals. This affects directly the third pillar of the Danish pension system, which is mainly constituted by voluntary pensions and individual savings (OECD, 2015).

Along the same lines, economic studies have also shown that, since individuals tend to be risk averse, they would forego additional years of life expectancy to reduce uncertainty about their length of life (Edwards, 2013). Thus, a retirement scheme with high lifespan inequality can push them to anticipate their retirement to ages where uncertainty is lower. In other words, individuals might prefer to retire at the moment where benefits associated to retirement are more certain (Aronsson and Blomquist, 2018). Under this perspective, a setting in which lower lifespan inequality prevails after retirement is preferred for individuals.

***Implications of unequal lifespans for institutions involved in the management of pensions***

Longevity risk is associated with the risk that future mortality and life expectancy outcomes turn out different than expected (Blake et al. 2011). Specifically, pension funds, national government and insurance companies providing defined benefit pension plans face the risk that the present value of their annuity payments will result higher than expected, as they will have to pay out a periodic sum of income that will last for an uncertain lifespan (Antolin, 2007). The measurement of longevity risk on pension plans hinges on differences between scenarios of the future development of life expectancy (Koissi, 2006; Cocco and Gomes, 2011; Slipsager, 2018). In this sense, one might think that longevity risk is eradicated on a pension system where life expectancies after retirement are held constant over time. However, this is not the case since as we show here, the inequality of lifespans is a neglected source of longevity risk.

Similar to the results of Haberman et al. (2011), in this study we show that in a context of low interest rates, the higher the value of entropy, the greater are the effects of longevity risk on the present value of annuity payments. In this sense, Danish pensions are highly susceptible to fluctuations in longevity for two main reasons. First, as mentioned above, interest rates in Denmark have been at their lowest levels in recent years (Pedersen 2015; Feveile and Pedersen, 2019), which makes the cost of pensions very susceptible to changes in mortality. Second, we show that the entropy is higher when pension payments start to be paid at an older age (i.e. target retirement age) than when the onset is at age 65. This implies that there is a greater exposition to longevity risk under the scheme stablished on the 2007 pension reform. Further, the retirement age $r$ is located next to a threshold age in which mortality improvements after such age increase the entropy (Aburto et. al, 2019). Thus, any improvement in mortality after retirement will impact the variability of lifespans increasing the uncertainty.

Not only the under estimation of life expectancy is a source of longevity risk but also the inequality of lifespans is. This dimension of longevity risk has not specifically considered in any of the previous studies analysing the implications of linking retirement age with life expectancy (Sanderson and Scherbov, 2010, 2013, 2017; Ministry for Economic Affairs and the Interior, 2017, 2018). Therefore, it is fundamental for insurance companies, pension funds and governments providing defined benefit pension plans to be are aware of this source of uncertainty that arises from the linkage of retirement age to life expectancy and adjust their risk assessments and liabilities accordingly. An improper measurement of it might jeopardize the financial stability of entities involved in the pension system.

# 5. Conclusion

Increased longevity and unequal lifespans are at the heart of imbalanced pension systems. In this study we show that linking retirement age with life expectancy partially alleviates these imbalances since constant life expectancies do not imply lower inequality in lifespans. Here we explore the implications of unequal lifespans under the perspective of actors involved in the Danish pension system. Nevertheless, these issues are not restricted to Denmark. In a similar fashion, other countries such as Finland, Italy, the Netherlands, Portugal and the Slovak Republic will also modify retirement ages by linking them to life expectancy (OECD, 2017, 2018). Demographic imbalances after retirement will invariably arise in such countries. Retirement ages should therefore be defined as a trade-off between constant life expectancies and low lifespan inequality.

## 6. Figures

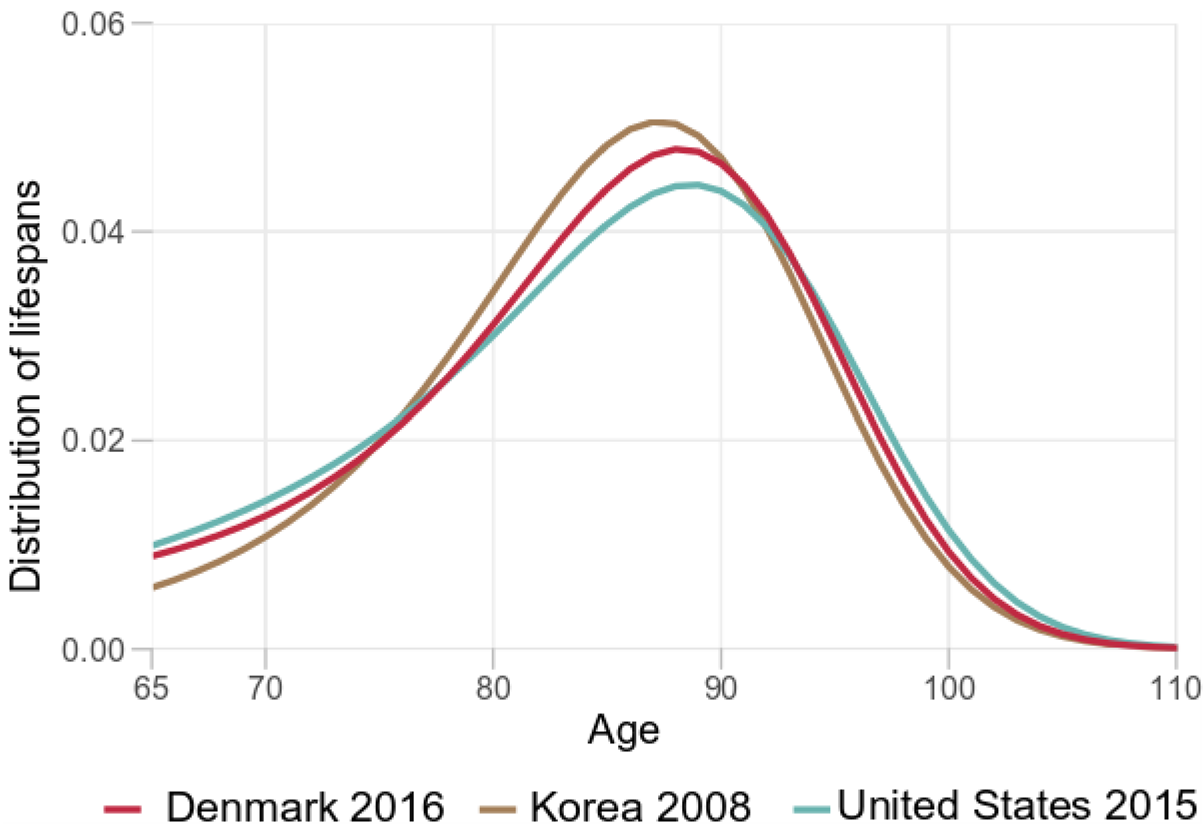


**Figure 1** Distribution of lifespans after age 65 in Denmark, Korea and the United States. Females, various years.

*Notes:* Values for remaining life expectancy at age 65, $\boldsymbol{e(65)}$ are 20.72 for Denmark and Korea and 20.76 for the United States. Life disparity $\boldsymbol{e^{\dagger}(65)}$ values are 7.78 for Denmark, 7.40 for Korea and 8.20 for the United States respectively. Lifetable entropy $\boldsymbol{H(65)}$ outcomes are 0.38 for Denmark, 0.35 for Korea and 0.40 for the United States respectively.
*Source:* Own calculations using data from the Human Mortality Database (2019).


**Figure 2**. Distribution of lifespans after age 65 by SES for selected years. Both sexes.

*Notes:* The numbers on the bottom right represent the percentage of overlapping between both distributions. The white lines depict the target retirement age calculated for the total population. This age is same for females and for males.
*Source:* Own calculations using data from the Danish registers.

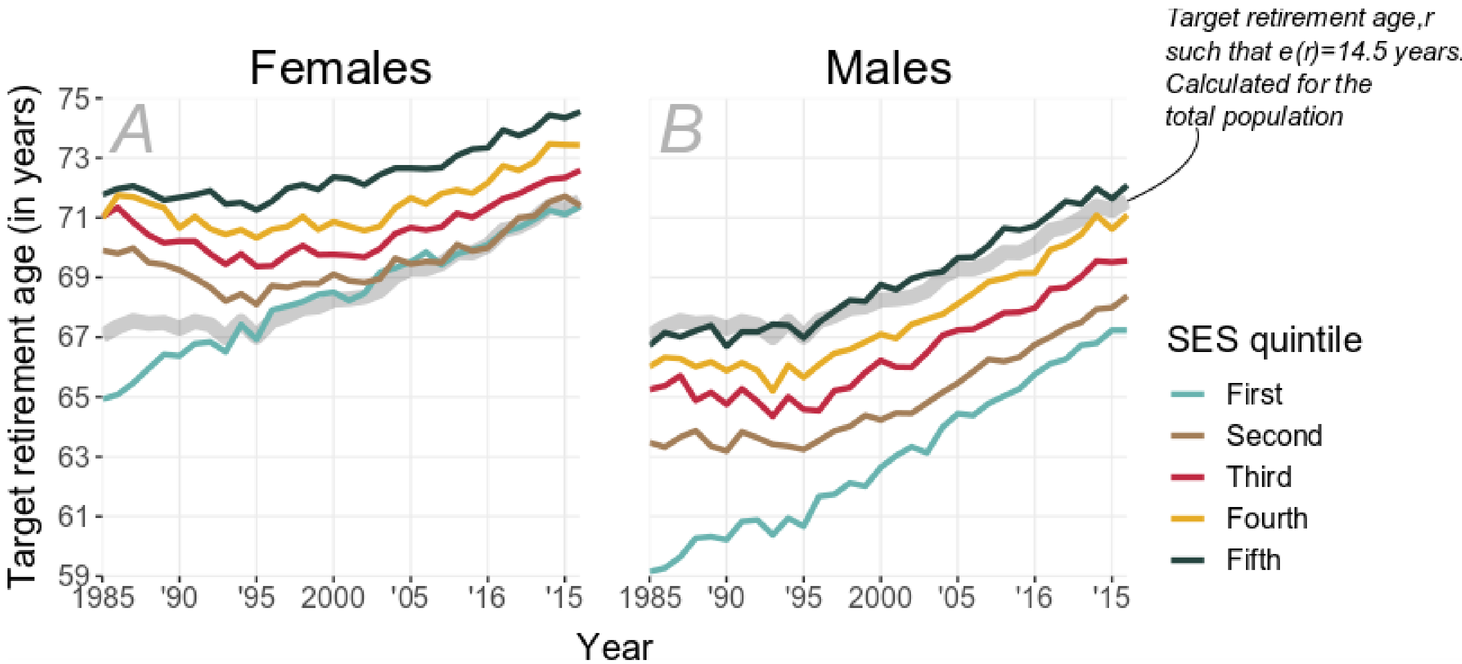


**Figure 3.** Target retirement age calculated for the total population (in grey) and hypothetical retirement ages for each of the SES quintiles.

*Notes:* Each of the coloured line represents a specific SES quantile. The lowest quintile is denoted by the legend "First" and the highest quintile is denoted by "Fifth". The complete set values can be found in Table A1 in the Appendix.
*Source:* Own calculations using data from the Danish registers.


**Figure 4.** Probability of surviving from age 50 to age *r* (panels A and B) and from age *r* to *r + 14.5* years (panels C and D) by SES. Both sexes, 1985-2016.

*Notes:* Each of the coloured line represents a specific SES quantile. The lowest quintile is denoted by the legend “First” and the highest quintile is denoted by “Fifth”.
*Source:* Own calculations using data from the Danish registers.

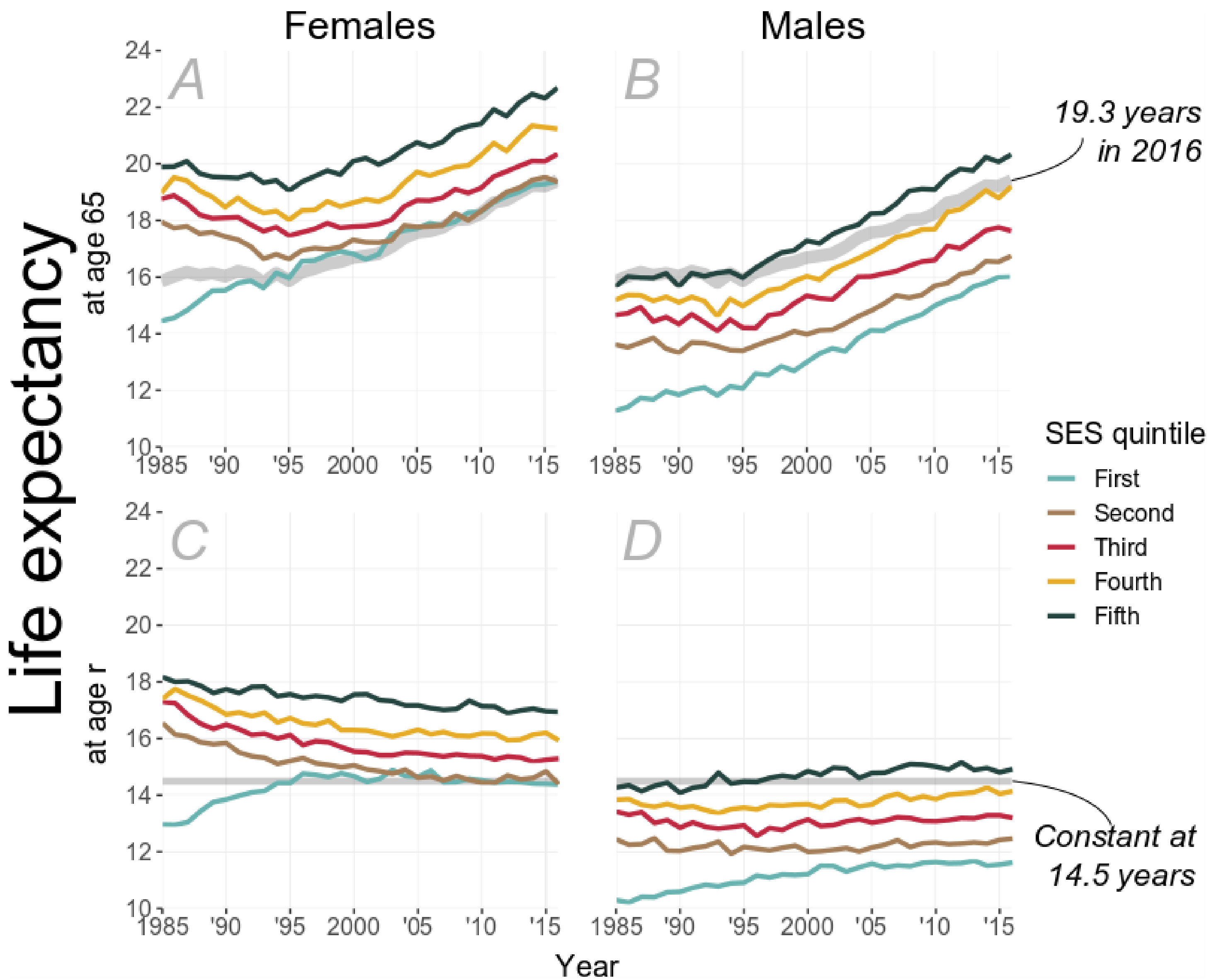


**Figure 5.** Remaining life expectancy calculated at age 65 (panels A and B) and at the target retirement age *r* (panels C and D) by SES. Both sexes, 1985-2016.

*Notes:* Each of the coloured line represents a specific SES quantile. The lowest quintile is denoted by the legend "First" and the highest quintile is denoted by "Fifth". The complete set values can be found in Tables A2 and A3 in the Appendix.
*Source:* Own calculations using data from the Danish registers.


**Figure 6.** Lifetable entropy calculated at age 65 (panels A and B) and at the target retirement age *r* (panels C and D) by SES. Both sexes, 1985-2016.

*Notes:* Each of the coloured line represents a specific SES quantile. The lowest quintile is denoted by the legend "First" and the highest quintile is denoted by "Fifth". The complete set values can be found in Tables A4 and A5 in the Appendix.
*Source:* Own calculations using data from the Danish registers.

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# Appendix

| | Target retirement age (in years) | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Total population | | Females | | | | | Males | | | | |
| Year | Value | Change (%) | *First* | *Second* | *Third* | *Fourth* | *Fifth* | *First* | *Second* | *Third* | *Fourth* | *Fifth* |
| 1985 | 67.16 | | 64.95 | 69.97 | 71.02 | 71.08 | 71.71 | 61.78 | 64.06 | 65.27 | 66.10 | 66.78 |
| 1986 | 67.36 | 0.30 | 65.14 | 69.80 | 71.29 | 71.81 | 71.89 | 61.90 | 64.00 | 65.44 | 66.36 | 67.22 |
| 1987 | 67.53 | 0.25 | 65.42 | 69.94 | 70.95 | 71.68 | 72.02 | 62.18 | 64.19 | 65.67 | 66.39 | 67.04 |
| 1988 | 67.55 | 0.03 | 66.03 | 69.50 | 70.38 | 71.55 | 71.82 | 62.22 | 64.28 | 64.95 | 66.05 | 67.17 |
| 1989 | 67.56 | 0.01 | 66.52 | 69.44 | 70.24 | 71.38 | 71.62 | 62.46 | 63.98 | 65.01 | 66.14 | 67.44 |
| 1990 | 67.28 | -0.41 | 66.39 | 69.20 | 70.28 | 70.70 | 71.68 | 62.33 | 63.84 | 64.86 | 65.81 | 66.77 |
| 1991 | 67.47 | 0.28 | 66.78 | 68.88 | 70.17 | 71.05 | 71.88 | 62.46 | 64.20 | 65.17 | 66.06 | 67.18 |
| 1992 | 67.45 | -0.03 | 66.77 | 68.60 | 69.76 | 70.66 | 71.91 | 62.62 | 64.14 | 64.93 | 65.99 | 67.21 |
| 1993 | 67.01 | -0.65 | 66.45 | 68.17 | 69.50 | 70.38 | 71.45 | 62.32 | 64.07 | 64.55 | 65.31 | 67.38 |
| 1994 | 67.38 | 0.55 | 67.30 | 68.56 | 69.80 | 70.58 | 71.54 | 62.69 | 63.97 | 64.98 | 66.12 | 67.37 |
| 1995 | 66.99 | -0.58 | 66.89 | 68.09 | 69.43 | 70.30 | 71.21 | 62.59 | 63.92 | 64.72 | 65.71 | 67.03 |
| 1996 | 67.61 | 0.93 | 67.89 | 68.64 | 69.33 | 70.57 | 71.57 | 63.10 | 64.05 | 64.74 | 66.05 | 67.57 |
| 1997 | 67.71 | 0.15 | 68.01 | 68.62 | 69.78 | 70.64 | 71.97 | 63.00 | 64.27 | 65.17 | 66.49 | 67.89 |
| 1998 | 68.06 | 0.52 | 68.20 | 68.82 | 70.13 | 71.03 | 72.09 | 63.34 | 64.43 | 65.34 | 66.60 | 68.26 |
| 1999 | 68.05 | -0.01 | 68.45 | 68.84 | 69.76 | 70.56 | 71.90 | 63.12 | 64.61 | 65.73 | 66.88 | 68.19 |
| 2000 | 68.37 | 0.47 | 68.48 | 69.02 | 69.74 | 70.81 | 72.39 | 63.52 | 64.45 | 66.21 | 67.14 | 68.64 |
| 2001 | 68.24 | -0.19 | 68.30 | 68.93 | 69.81 | 70.68 | 72.20 | 63.77 | 64.62 | 66.01 | 66.98 | 68.54 |
| 2002 | 68.37 | 0.19 | 68.43 | 68.85 | 69.71 | 70.53 | 72.07 | 64.01 | 64.65 | 65.89 | 67.44 | 69.00 |
| 2003 | 68.65 | 0.41 | 69.20 | 69.00 | 69.88 | 70.74 | 72.50 | 63.88 | 64.91 | 66.52 | 67.58 | 69.12 |
| 2004 | 69.09 | 0.64 | 69.34 | 69.72 | 70.48 | 71.36 | 72.56 | 64.27 | 65.14 | 67.11 | 67.84 | 69.26 |
| 2005 | 69.26 | 0.25 | 69.46 | 69.37 | 70.64 | 71.61 | 72.75 | 64.65 | 65.50 | 67.11 | 68.15 | 69.67 |
| 2006 | 69.30 | 0.06 | 69.90 | 69.56 | 70.65 | 71.46 | 72.63 | 64.57 | 65.86 | 67.21 | 68.56 | 69.74 |
| 2007 | 69.52 | 0.32 | 69.51 | 69.58 | 70.66 | 71.77 | 72.68 | 64.78 | 66.21 | 67.57 | 68.86 | 70.07 |
| 2008 | 69.83 | 0.45 | 69.84 | 70.15 | 71.12 | 71.89 | 73.09 | 65.09 | 66.14 | 67.85 | 68.97 | 70.62 |
| 2009 | 69.88 | 0.07 | 70.00 | 69.93 | 70.98 | 71.82 | 73.26 | 65.29 | 66.37 | 67.85 | 69.26 | 70.68 |
| 2010 | 70.04 | 0.23 | 70.12 | 69.95 | 71.23 | 72.15 | 73.33 | 65.76 | 66.73 | 67.88 | 69.17 | 70.73 |
| 2011 | 70.52 | 0.69 | 70.52 | 70.42 | 71.64 | 72.69 | 73.82 | 66.05 | 67.04 | 68.71 | 69.89 | 71.07 |
| 2012 | 70.70 | 0.26 | 70.62 | 71.07 | 71.78 | 72.60 | 73.65 | 66.26 | 67.31 | 68.57 | 69.99 | 71.59 |
| 2013 | 70.90 | 0.28 | 70.99 | 70.99 | 72.07 | 72.89 | 73.97 | 66.59 | 67.47 | 69.01 | 70.38 | 71.45 |
| 2014 | 71.43 | 0.75 | 71.30 | 71.52 | 72.33 | 73.46 | 74.44 | 66.82 | 67.89 | 69.59 | 71.00 | 71.99 |
| 2015 | 71.32 | -0.15 | 71.11 | 71.69 | 72.30 | 73.47 | 74.33 | 67.24 | 67.99 | 69.54 | 70.60 | 71.69 |
| 2016 | 71.51 | 0.27 | 71.38 | 71.41 | 72.58 | 73.44 | 74.56 | 67.30 | 68.49 | 69.57 | 71.06 | 72.12 |

**Table A1.** Target retirement ages for the total population and by SES quantile. Both sexes, 1985-2016.

| | Remaining life expectancy at age 65 | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Total population | | Females | | | | | Males | | | | | |
| Year | Value | Change (%) | *First* | *Second* | *Third* | *Fourth* | *Fifth* | *First* | *Second* | *Third* | *Fourth* | *Fifth* |
| 1985 | 15.9 | | 14.5 | 18.0 | 18.8 | 19.0 | 19.9 | 11.3 | 13.6 | 14.7 | 15.2 | 15.7 |
| 1986 | 16.0 | 1.1 | 14.6 | 17.7 | 18.9 | 19.5 | 19.9 | 11.4 | 13.5 | 14.7 | 15.4 | 16.0 |
| 1987 | 16.2 | 0.9 | 14.8 | 17.8 | 18.6 | 19.4 | 20.1 | 11.7 | 13.7 | 14.9 | 15.4 | 16.0 |
| 1988 | 16.1 | -0.7 | 15.2 | 17.5 | 18.2 | 19.1 | 19.7 | 11.7 | 13.9 | 14.4 | 15.2 | 16.0 |
| 1989 | 16.1 | 0.4 | 15.5 | 17.6 | 18.1 | 18.8 | 19.5 | 12.0 | 13.5 | 14.6 | 15.3 | 16.1 |
| 1990 | 16.0 | -0.7 | 15.5 | 17.4 | 18.1 | 18.5 | 19.5 | 11.8 | 13.3 | 14.3 | 15.1 | 15.7 |
| 1991 | 16.2 | 1.1 | 15.8 | 17.3 | 18.1 | 18.8 | 19.5 | 12.0 | 13.7 | 14.7 | 15.3 | 16.1 |
| 1992 | 16.1 | -0.6 | 15.9 | 17.1 | 17.9 | 18.5 | 19.6 | 12.1 | 13.7 | 14.4 | 15.2 | 16.0 |
| 1993 | 15.8 | -1.9 | 15.6 | 16.7 | 17.6 | 18.3 | 19.3 | 11.8 | 13.6 | 14.1 | 14.6 | 16.2 |
| 1994 | 16.1 | 2.2 | 16.2 | 16.8 | 17.8 | 18.3 | 19.4 | 12.1 | 13.4 | 14.5 | 15.2 | 16.2 |
| 1995 | 15.9 | -1.7 | 16.0 | 16.6 | 17.5 | 18.0 | 19.1 | 12.1 | 13.4 | 14.2 | 15.0 | 16.0 |
| 1996 | 16.2 | 2.0 | 16.6 | 16.9 | 17.6 | 18.4 | 19.4 | 12.6 | 13.6 | 14.2 | 15.3 | 16.3 |
| 1997 | 16.3 | 0.7 | 16.6 | 17.0 | 17.7 | 18.4 | 19.6 | 12.5 | 13.8 | 14.7 | 15.5 | 16.6 |
| 1998 | 16.5 | 1.0 | 16.8 | 17.0 | 17.9 | 18.7 | 19.8 | 12.9 | 13.9 | 14.7 | 15.6 | 16.9 |
| 1999 | 16.5 | 0.5 | 16.9 | 17.1 | 17.7 | 18.5 | 19.6 | 12.7 | 14.1 | 15.1 | 15.9 | 16.9 |
| 2000 | 16.7 | 0.9 | 16.8 | 17.3 | 17.8 | 18.6 | 20.1 | 13.0 | 14.0 | 15.3 | 16.0 | 17.3 |
| 2001 | 16.8 | 0.4 | 16.6 | 17.2 | 17.8 | 18.8 | 20.2 | 13.3 | 14.1 | 15.3 | 15.9 | 17.2 |
| 2002 | 16.8 | 0.5 | 16.8 | 17.2 | 17.9 | 18.7 | 20.0 | 13.5 | 14.1 | 15.2 | 16.3 | 17.5 |
| 2003 | 17.1 | 1.4 | 17.5 | 17.3 | 18.0 | 18.9 | 20.2 | 13.4 | 14.4 | 15.6 | 16.5 | 17.7 |
| 2004 | 17.4 | 1.9 | 17.7 | 17.8 | 18.5 | 19.3 | 20.5 | 13.8 | 14.6 | 16.0 | 16.7 | 17.8 |
| 2005 | 17.6 | 1.1 | 17.7 | 17.8 | 18.7 | 19.7 | 20.8 | 14.1 | 14.8 | 16.0 | 16.9 | 18.2 |
| 2006 | 17.6 | 0.3 | 17.9 | 17.8 | 18.7 | 19.6 | 20.6 | 14.1 | 15.1 | 16.1 | 17.1 | 18.3 |
| 2007 | 17.8 | 0.7 | 17.8 | 17.8 | 18.8 | 19.7 | 20.8 | 14.4 | 15.4 | 16.2 | 17.4 | 18.6 |
| 2008 | 18.0 | 1.5 | 18.0 | 18.3 | 19.1 | 19.9 | 21.2 | 14.5 | 15.3 | 16.4 | 17.5 | 19.0 |
| 2009 | 18.1 | 0.2 | 18.3 | 18.0 | 19.0 | 19.9 | 21.3 | 14.7 | 15.4 | 16.6 | 17.7 | 19.1 |
| 2010 | 18.2 | 1.1 | 18.3 | 18.3 | 19.1 | 20.3 | 21.4 | 15.0 | 15.7 | 16.6 | 17.7 | 19.1 |
| 2011 | 18.6 | 2.1 | 18.6 | 18.7 | 19.6 | 20.7 | 21.9 | 15.2 | 15.8 | 17.1 | 18.3 | 19.5 |
| 2012 | 18.7 | 0.5 | 18.9 | 19.0 | 19.7 | 20.5 | 21.7 | 15.3 | 16.1 | 17.0 | 18.4 | 19.8 |
| 2013 | 19.0 | 1.4 | 19.0 | 19.2 | 19.9 | 20.9 | 22.2 | 15.7 | 16.2 | 17.3 | 18.7 | 19.8 |
| 2014 | 19.2 | 1.3 | 19.3 | 19.4 | 20.1 | 21.4 | 22.5 | 15.8 | 16.6 | 17.7 | 19.1 | 20.2 |
| 2015 | 19.2 | -0.1 | 19.3 | 19.5 | 20.1 | 21.3 | 22.3 | 16.0 | 16.5 | 17.8 | 18.8 | 20.1 |
| 2016 | 19.4 | 1.0 | 19.4 | 19.4 | 20.4 | 21.2 | 22.7 | 16.0 | 16.8 | 17.6 | 19.2 | 20.3 |

**Table A2.** Remaining life expectancy at age 65 for the total population and by SES quantiles. Both sexes, 1985-2016.

| Remaining life expectancy at the target retirement age (in years) | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Females | | | | | Males | | | | |
| Year | *First* | *Second* | *Third* | *Fourth* | *Fifth* | *First* | *Second* | *Third* | *Fourth* | *Fifth* |
| 1985 | 12.9 | 16.5 | 17.2 | 17.4 | 18.0 | 10.2 | 12.4 | 13.4 | 13.8 | 14.3 |
| 1986 | 13.0 | 16.1 | 17.2 | 17.8 | 17.9 | 10.2 | 12.2 | 13.4 | 13.9 | 14.4 |
| 1987 | 13.0 | 16.1 | 16.9 | 17.5 | 18.0 | 10.4 | 12.3 | 13.4 | 13.7 | 14.2 |
| 1988 | 13.4 | 15.8 | 16.4 | 17.3 | 17.8 | 10.4 | 12.4 | 13.0 | 13.6 | 14.2 |
| 1989 | 13.8 | 15.8 | 16.3 | 17.1 | 17.6 | 10.5 | 12.0 | 13.0 | 13.6 | 14.4 |
| 1990 | 13.9 | 15.8 | 16.5 | 16.9 | 17.8 | 10.6 | 12.0 | 12.9 | 13.5 | 14.2 |
| 1991 | 14.0 | 15.5 | 16.3 | 17.0 | 17.7 | 10.7 | 12.2 | 13.0 | 13.6 | 14.3 |
| 1992 | 14.0 | 15.3 | 16.1 | 16.8 | 17.8 | 10.8 | 12.1 | 12.9 | 13.5 | 14.3 |
| 1993 | 14.1 | 15.3 | 16.2 | 16.8 | 17.8 | 10.8 | 12.4 | 12.8 | 13.4 | 14.8 |
| 1994 | 14.5 | 15.3 | 16.1 | 16.7 | 17.6 | 11.0 | 12.1 | 12.9 | 13.6 | 14.5 |
| 1995 | 14.4 | 15.2 | 16.1 | 16.7 | 17.6 | 11.0 | 12.2 | 12.9 | 13.6 | 14.5 |
| 1996 | 14.7 | 15.2 | 15.7 | 16.5 | 17.5 | 11.1 | 12.1 | 12.6 | 13.5 | 14.5 |
| 1997 | 14.7 | 15.1 | 15.9 | 16.5 | 17.5 | 11.1 | 12.1 | 12.8 | 13.7 | 14.6 |
| 1998 | 14.6 | 15.0 | 15.8 | 16.6 | 17.4 | 11.2 | 12.1 | 12.7 | 13.6 | 14.6 |
| 1999 | 14.8 | 15.0 | 15.7 | 16.3 | 17.3 | 11.1 | 12.2 | 12.9 | 13.7 | 14.6 |
| 2000 | 14.6 | 14.9 | 15.4 | 16.2 | 17.5 | 11.2 | 11.9 | 13.1 | 13.6 | 14.7 |
| 2001 | 14.5 | 15.0 | 15.6 | 16.3 | 17.5 | 11.5 | 12.0 | 12.9 | 13.6 | 14.7 |
| 2002 | 14.5 | 14.8 | 15.4 | 16.1 | 17.3 | 11.5 | 12.1 | 12.8 | 13.8 | 15.0 |
| 2003 | 14.9 | 14.7 | 15.3 | 16.0 | 17.3 | 11.2 | 12.1 | 13.1 | 13.7 | 14.9 |
| 2004 | 14.7 | 14.9 | 15.5 | 16.2 | 17.1 | 11.4 | 12.0 | 13.1 | 13.6 | 14.6 |
| 2005 | 14.6 | 14.6 | 15.5 | 16.3 | 17.2 | 11.6 | 12.2 | 13.0 | 13.7 | 14.8 |
| 2006 | 14.9 | 14.7 | 15.5 | 16.1 | 17.1 | 11.4 | 12.3 | 13.1 | 14.0 | 14.8 |
| 2007 | 14.5 | 14.6 | 15.3 | 16.2 | 17.0 | 11.4 | 12.4 | 13.2 | 14.0 | 14.9 |
| 2008 | 14.5 | 14.7 | 15.4 | 16.1 | 17.1 | 11.5 | 12.2 | 13.2 | 13.9 | 15.1 |
| 2009 | 14.6 | 14.5 | 15.3 | 16.0 | 17.3 | 11.6 | 12.3 | 13.1 | 14.0 | 15.1 |
| 2010 | 14.6 | 14.4 | 15.3 | 16.2 | 17.2 | 11.6 | 12.3 | 13.1 | 13.9 | 15.1 |
| 2011 | 14.5 | 14.4 | 15.3 | 16.2 | 17.1 | 11.6 | 12.4 | 13.2 | 14.0 | 14.9 |
| 2012 | 14.4 | 14.8 | 15.4 | 16.0 | 16.8 | 11.6 | 12.3 | 13.1 | 14.0 | 15.2 |
| 2013 | 14.6 | 14.6 | 15.4 | 16.1 | 17.0 | 11.7 | 12.4 | 13.2 | 14.1 | 14.9 |
| 2014 | 14.4 | 14.6 | 15.2 | 16.1 | 17.0 | 11.5 | 12.2 | 13.3 | 14.2 | 14.9 |
| 2015 | 14.4 | 14.8 | 15.2 | 16.2 | 16.9 | 11.6 | 12.4 | 13.3 | 14.0 | 14.8 |
| 2016 | 14.4 | 14.4 | 15.3 | 16.0 | 17.0 | 11.7 | 12.5 | 13.2 | 14.2 | 15.0 |

**Table A3.** Remaining life expectancy at the target retirement age *r* by SES quantiles. Both sexes, 1985-2016.

| | Lifetable entropy at age 65 | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | **Total population** | | **Females** | | | | | **Males** | | | | |
| **Year** | **Value** | **Change (%)** | ***First*** | ***Second*** | ***Third*** | ***Fourth*** | ***Fifth*** | ***First*** | ***Second*** | ***Third*** | ***Fourth*** | ***Fifth*** |
| 1985 | 0.48 | | 0.47 | 0.41 | 0.42 | 0.40 | 0.38 | 0.59 | 0.56 | 0.53 | 0.52 | 0.48 |
| 1986 | 0.49 | 0.97 | 0.47 | 0.44 | 0.43 | 0.40 | 0.38 | 0.59 | 0.56 | 0.53 | 0.51 | 0.50 |
| 1987 | 0.48 | -0.93 | 0.47 | 0.44 | 0.43 | 0.40 | 0.37 | 0.58 | 0.56 | 0.53 | 0.51 | 0.47 |
| 1988 | 0.49 | 0.55 | 0.46 | 0.44 | 0.43 | 0.41 | 0.40 | 0.59 | 0.55 | 0.53 | 0.50 | 0.47 |
| 1989 | 0.48 | -1.11 | 0.45 | 0.43 | 0.44 | 0.42 | 0.38 | 0.57 | 0.56 | 0.54 | 0.52 | 0.47 |
| 1990 | 0.48 | 0.55 | 0.45 | 0.45 | 0.43 | 0.42 | 0.38 | 0.60 | 0.55 | 0.52 | 0.50 | 0.48 |
| 1991 | 0.49 | 0.54 | 0.45 | 0.45 | 0.45 | 0.42 | 0.40 | 0.59 | 0.54 | 0.52 | 0.50 | 0.46 |
| 1992 | 0.48 | -1.11 | 0.45 | 0.46 | 0.44 | 0.42 | 0.38 | 0.58 | 0.54 | 0.51 | 0.50 | 0.46 |
| 1993 | 0.49 | 1.47 | 0.45 | 0.47 | 0.44 | 0.43 | 0.38 | 0.59 | 0.54 | 0.52 | 0.50 | 0.46 |
| 1994 | 0.49 | -0.08 | 0.45 | 0.47 | 0.44 | 0.43 | 0.39 | 0.59 | 0.54 | 0.50 | 0.50 | 0.46 |
| 1995 | 0.49 | -0.35 | 0.46 | 0.46 | 0.44 | 0.44 | 0.39 | 0.58 | 0.54 | 0.52 | 0.49 | 0.47 |
| 1996 | 0.48 | -1.28 | 0.46 | 0.46 | 0.44 | 0.43 | 0.39 | 0.57 | 0.55 | 0.51 | 0.48 | 0.46 |
| 1997 | 0.48 | -0.02 | 0.45 | 0.46 | 0.44 | 0.43 | 0.40 | 0.58 | 0.53 | 0.50 | 0.47 | 0.45 |
| 1998 | 0.48 | 0.53 | 0.46 | 0.48 | 0.46 | 0.42 | 0.40 | 0.56 | 0.53 | 0.50 | 0.49 | 0.45 |
| 1999 | 0.47 | -1.91 | 0.47 | 0.46 | 0.44 | 0.42 | 0.39 | 0.58 | 0.52 | 0.48 | 0.47 | 0.42 |
| 2000 | 0.47 | -0.73 | 0.45 | 0.45 | 0.45 | 0.43 | 0.38 | 0.56 | 0.53 | 0.48 | 0.46 | 0.44 |
| 2001 | 0.47 | -0.46 | 0.46 | 0.45 | 0.44 | 0.41 | 0.37 | 0.55 | 0.51 | 0.48 | 0.47 | 0.43 |
| 2002 | 0.46 | -1.72 | 0.46 | 0.45 | 0.43 | 0.41 | 0.38 | 0.54 | 0.52 | 0.49 | 0.45 | 0.41 |
| 2003 | 0.45 | -1.42 | 0.43 | 0.45 | 0.43 | 0.40 | 0.37 | 0.54 | 0.50 | 0.46 | 0.45 | 0.41 |
| 2004 | 0.45 | -1.34 | 0.44 | 0.43 | 0.42 | 0.40 | 0.37 | 0.53 | 0.50 | 0.45 | 0.43 | 0.41 |
| 2005 | 0.44 | -0.57 | 0.43 | 0.44 | 0.42 | 0.38 | 0.36 | 0.51 | 0.51 | 0.47 | 0.42 | 0.40 |
| 2006 | 0.44 | -0.70 | 0.43 | 0.44 | 0.41 | 0.39 | 0.36 | 0.51 | 0.49 | 0.46 | 0.42 | 0.40 |
| 2007 | 0.43 | -1.66 | 0.43 | 0.43 | 0.41 | 0.38 | 0.36 | 0.52 | 0.50 | 0.46 | 0.42 | 0.38 |
| 2008 | 0.43 | -0.64 | 0.43 | 0.43 | 0.40 | 0.38 | 0.34 | 0.52 | 0.48 | 0.46 | 0.40 | 0.38 |
| 2009 | 0.43 | -1.16 | 0.43 | 0.43 | 0.41 | 0.37 | 0.34 | 0.51 | 0.48 | 0.44 | 0.43 | 0.37 |
| 2010 | 0.42 | -0.76 | 0.42 | 0.41 | 0.41 | 0.37 | 0.34 | 0.50 | 0.48 | 0.45 | 0.41 | 0.37 |
| 2011 | 0.42 | -1.60 | 0.41 | 0.41 | 0.39 | 0.35 | 0.33 | 0.49 | 0.48 | 0.43 | 0.40 | 0.37 |
| 2012 | 0.41 | -0.49 | 0.41 | 0.40 | 0.39 | 0.37 | 0.34 | 0.49 | 0.46 | 0.44 | 0.39 | 0.36 |
| 2013 | 0.40 | -2.70 | 0.41 | 0.40 | 0.38 | 0.35 | 0.32 | 0.48 | 0.46 | 0.43 | 0.38 | 0.35 |
| 2014 | 0.40 | -0.97 | 0.41 | 0.40 | 0.38 | 0.35 | 0.32 | 0.47 | 0.45 | 0.42 | 0.38 | 0.35 |
| 2015 | 0.40 | -0.35 | 0.40 | 0.39 | 0.37 | 0.34 | 0.32 | 0.45 | 0.45 | 0.41 | 0.39 | 0.35 |
| 2016 | 0.39 | -0.83 | 0.40 | 0.39 | 0.37 | 0.35 | 0.31 | 0.47 | 0.45 | 0.42 | 0.37 | 0.35 |

**Table A4.** Lifetable entropy calculated at age 65 for the total population and by SES quantile. Both sexes, 1985-2016.

| | Lifetable entropy calculated at the target retirement age *r* | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | **Total population** | | **Females** | | | | | **Males** | | | | |
| **Year** | **Value** | **Change (%)** | ***First*** | ***Second*** | ***Third*** | ***Fourth*** | ***Fifth*** | ***First*** | ***Second*** | ***Third*** | ***Fourth*** | ***Fifth*** |
| 1985 | 0.51 | | 0.50 | 0.43 | 0.44 | 0.42 | 0.41 | 0.60 | 0.58 | 0.55 | 0.55 | 0.51 |
| 1986 | 0.51 | 1.17 | 0.51 | 0.46 | 0.45 | 0.42 | 0.40 | 0.62 | 0.57 | 0.55 | 0.54 | 0.54 |
| 1987 | 0.51 | -0.32 | 0.50 | 0.46 | 0.45 | 0.42 | 0.40 | 0.61 | 0.58 | 0.56 | 0.54 | 0.51 |
| 1988 | 0.51 | -0.29 | 0.49 | 0.46 | 0.45 | 0.43 | 0.42 | 0.62 | 0.57 | 0.55 | 0.53 | 0.49 |
| 1989 | 0.51 | -0.35 | 0.48 | 0.46 | 0.46 | 0.43 | 0.41 | 0.61 | 0.59 | 0.57 | 0.55 | 0.50 |
| 1990 | 0.51 | 0.43 | 0.48 | 0.47 | 0.45 | 0.44 | 0.40 | 0.63 | 0.58 | 0.55 | 0.52 | 0.50 |
| 1991 | 0.51 | 0.98 | 0.48 | 0.48 | 0.47 | 0.45 | 0.42 | 0.61 | 0.57 | 0.56 | 0.53 | 0.50 |
| 1992 | 0.51 | -1.30 | 0.48 | 0.48 | 0.46 | 0.43 | 0.40 | 0.60 | 0.57 | 0.54 | 0.53 | 0.49 |
| 1993 | 0.51 | 0.22 | 0.48 | 0.49 | 0.47 | 0.44 | 0.40 | 0.61 | 0.56 | 0.55 | 0.52 | 0.48 |
| 1994 | 0.51 | 0.71 | 0.48 | 0.49 | 0.46 | 0.45 | 0.41 | 0.61 | 0.57 | 0.53 | 0.53 | 0.49 |
| 1995 | 0.51 | -0.66 | 0.49 | 0.49 | 0.46 | 0.45 | 0.41 | 0.60 | 0.56 | 0.55 | 0.51 | 0.50 |
| 1996 | 0.51 | -0.45 | 0.49 | 0.48 | 0.46 | 0.45 | 0.41 | 0.60 | 0.58 | 0.55 | 0.51 | 0.49 |
| 1997 | 0.51 | 0.34 | 0.48 | 0.49 | 0.46 | 0.45 | 0.42 | 0.60 | 0.57 | 0.54 | 0.50 | 0.48 |
| 1998 | 0.51 | 1.13 | 0.49 | 0.50 | 0.48 | 0.45 | 0.43 | 0.59 | 0.57 | 0.54 | 0.52 | 0.49 |
| 1999 | 0.50 | -1.77 | 0.50 | 0.49 | 0.47 | 0.45 | 0.42 | 0.60 | 0.56 | 0.53 | 0.51 | 0.46 |
| 2000 | 0.50 | -0.13 | 0.48 | 0.49 | 0.48 | 0.46 | 0.41 | 0.59 | 0.57 | 0.52 | 0.50 | 0.49 |
| 2001 | 0.50 | 0.14 | 0.49 | 0.49 | 0.47 | 0.45 | 0.41 | 0.58 | 0.56 | 0.53 | 0.51 | 0.47 |
| 2002 | 0.50 | -1.44 | 0.49 | 0.48 | 0.47 | 0.44 | 0.41 | 0.58 | 0.56 | 0.53 | 0.50 | 0.45 |
| 2003 | 0.50 | -0.24 | 0.47 | 0.49 | 0.47 | 0.45 | 0.41 | 0.58 | 0.55 | 0.51 | 0.50 | 0.46 |
| 2004 | 0.49 | -0.16 | 0.49 | 0.48 | 0.47 | 0.44 | 0.42 | 0.57 | 0.55 | 0.50 | 0.49 | 0.47 |
| 2005 | 0.49 | -0.51 | 0.48 | 0.50 | 0.46 | 0.43 | 0.40 | 0.55 | 0.55 | 0.52 | 0.48 | 0.46 |
| 2006 | 0.49 | 0.08 | 0.47 | 0.49 | 0.46 | 0.44 | 0.41 | 0.57 | 0.55 | 0.51 | 0.48 | 0.46 |
| 2007 | 0.49 | -0.90 | 0.49 | 0.49 | 0.46 | 0.43 | 0.41 | 0.58 | 0.56 | 0.51 | 0.47 | 0.44 |
| 2008 | 0.48 | -0.79 | 0.48 | 0.48 | 0.45 | 0.44 | 0.40 | 0.58 | 0.53 | 0.51 | 0.46 | 0.44 |
| 2009 | 0.48 | -0.26 | 0.49 | 0.48 | 0.46 | 0.42 | 0.40 | 0.57 | 0.53 | 0.50 | 0.50 | 0.44 |
| 2010 | 0.48 | -0.25 | 0.48 | 0.48 | 0.46 | 0.43 | 0.39 | 0.57 | 0.54 | 0.50 | 0.47 | 0.43 |
| 2011 | 0.48 | -0.47 | 0.48 | 0.48 | 0.45 | 0.41 | 0.40 | 0.56 | 0.53 | 0.50 | 0.47 | 0.45 |
| 2012 | 0.48 | -0.84 | 0.48 | 0.47 | 0.45 | 0.43 | 0.40 | 0.57 | 0.53 | 0.50 | 0.46 | 0.43 |
| 2013 | 0.47 | -1.42 | 0.48 | 0.47 | 0.44 | 0.42 | 0.38 | 0.56 | 0.52 | 0.49 | 0.45 | 0.42 |
| 2014 | 0.47 | -0.12 | 0.48 | 0.47 | 0.45 | 0.42 | 0.38 | 0.55 | 0.52 | 0.48 | 0.45 | 0.43 |
| 2015 | 0.47 | -0.67 | 0.47 | 0.45 | 0.44 | 0.41 | 0.39 | 0.52 | 0.51 | 0.48 | 0.46 | 0.43 |
| 2016 | 0.46 | -0.61 | 0.47 | 0.46 | 0.43 | 0.42 | 0.38 | 0.55 | 0.51 | 0.48 | 0.44 | 0.42 |

**Table A5.** Lifetable entropy calculated at the target retirement age for the total population and by SES quantile. Both sexes, 1985-2016.

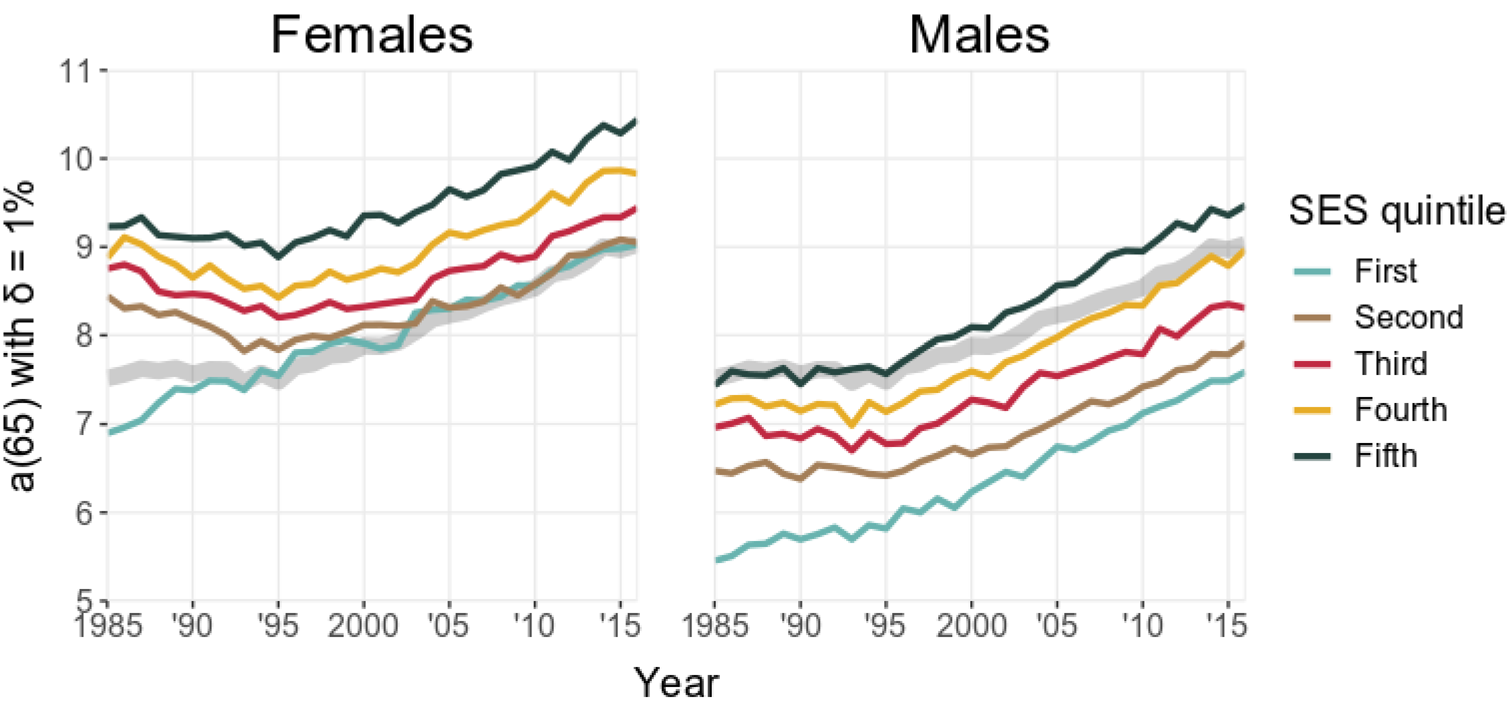


**Figure A1.** Value of life annuities by SES calculated at age 65, assuming a constant interest rate of 1%. Both sexes, 1985-2016.

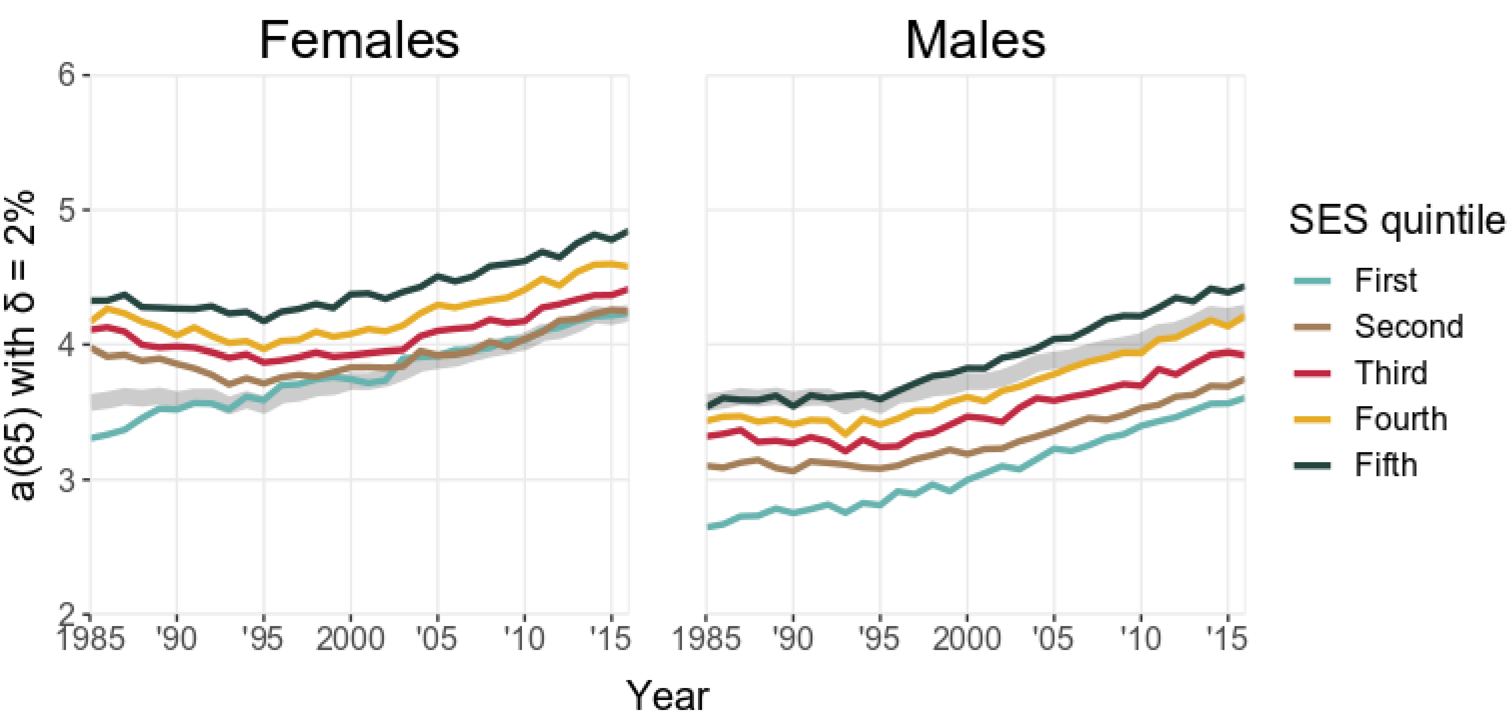


**Figure A2.** Value of life annuities by SES calculated at age 65, assuming a constant interest rate of 2%. Both sexes, 1985-2016.

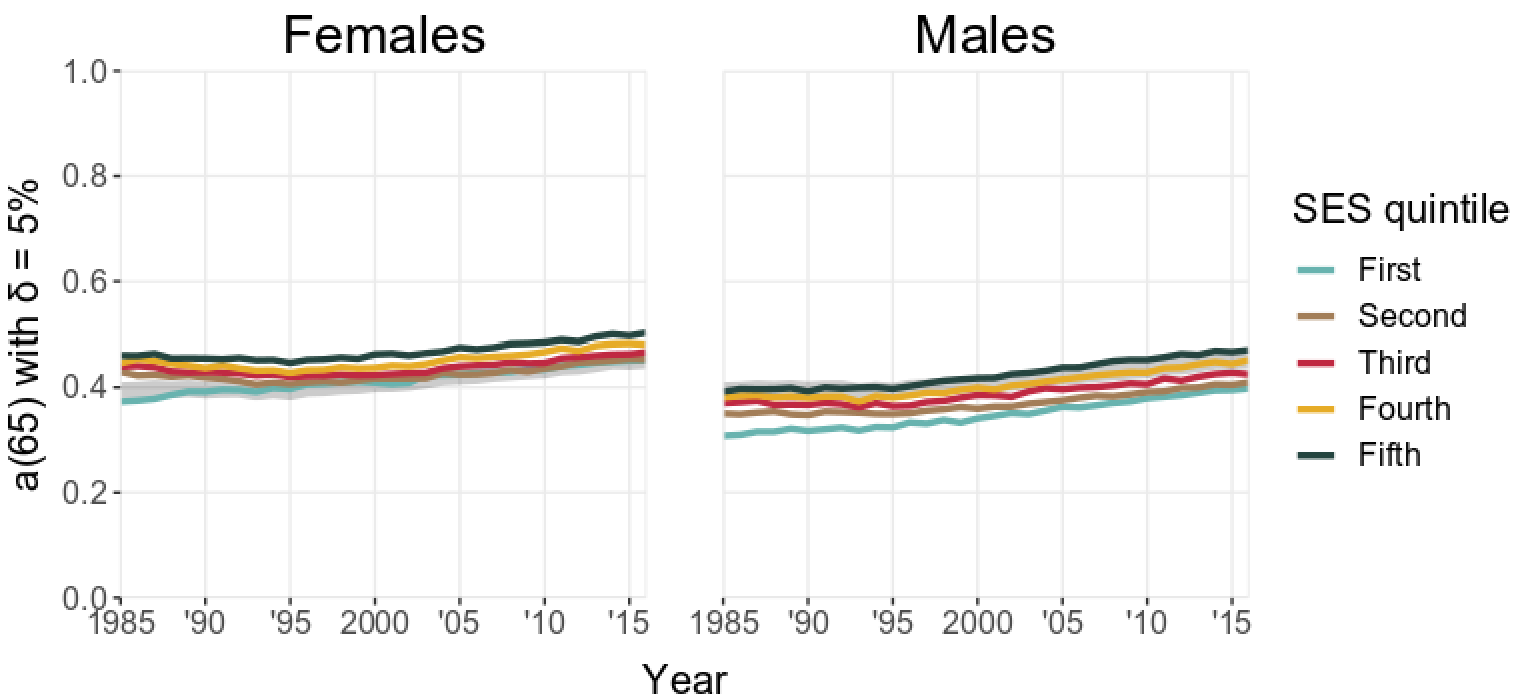


**Figure A3.** Value of life annuities by SES calculated at age 65, assuming a constant interest rate of 5%. Both sexes, 1985-2016.


**Figure A4** Value of life annuities by SES calculated at the target retirement age, assuming a constant interest rate of 1%. Both sexes, 1985-2016.

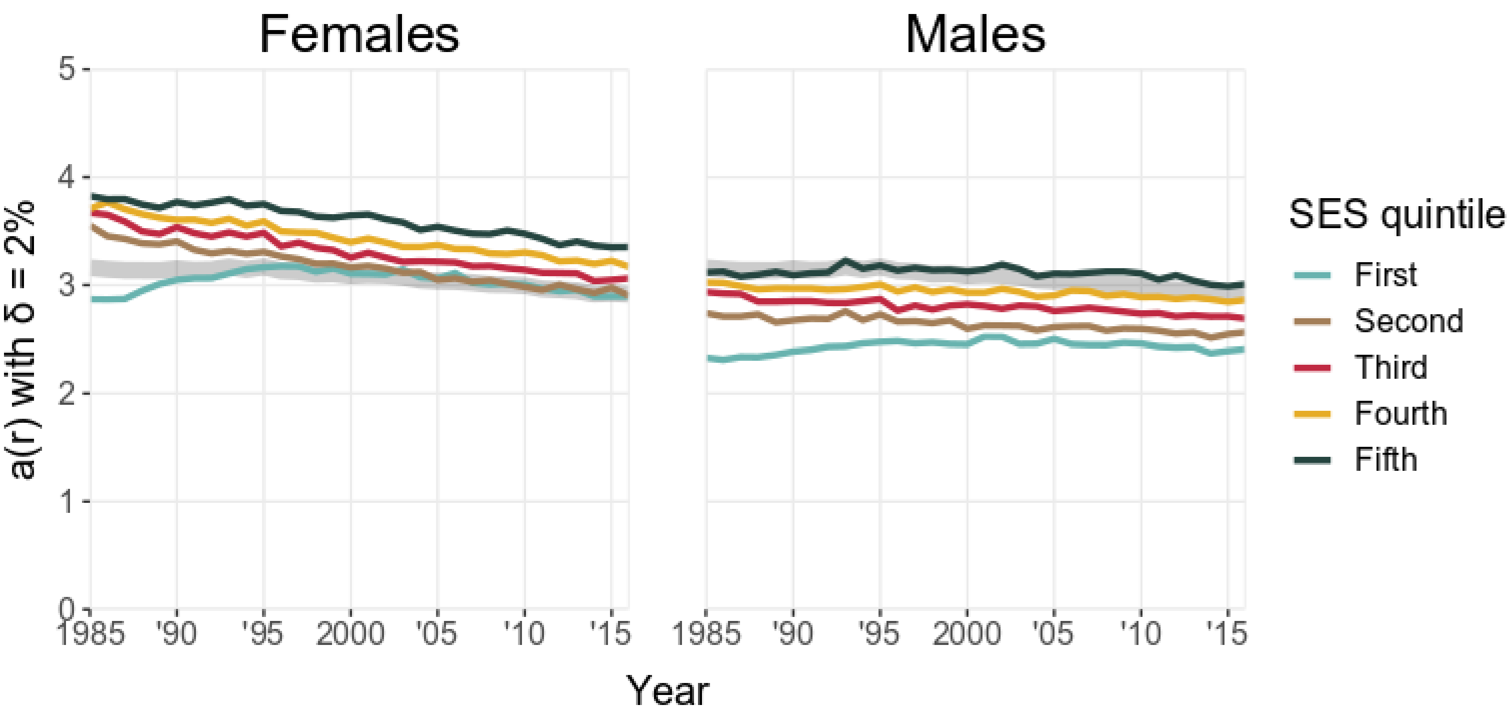


**Figure A5.** Value of life annuities by SES calculated at the target retirement age, assuming a constant interest rate of 2%. Both sexes, 1985-2016.

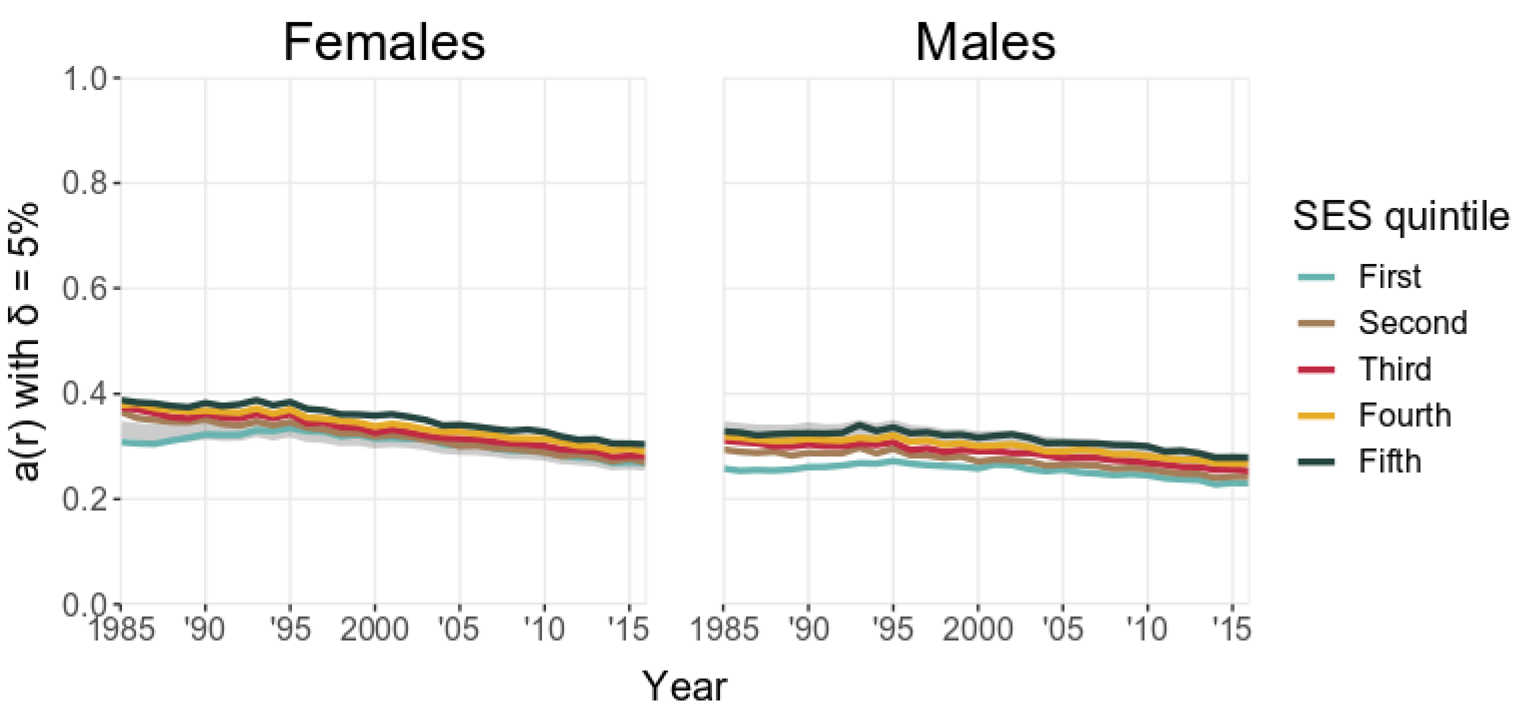


**Figure A6.** Value of life annuities by SES calculated at the target retirement age, assuming a constant interest rate of 5%. Both sexes, 1985-2016.


**Figure A7.** Entropy of life annuities by SES calculated at age 65, assuming a constant interest rate of 1%. Both sexes, 1985-2016.

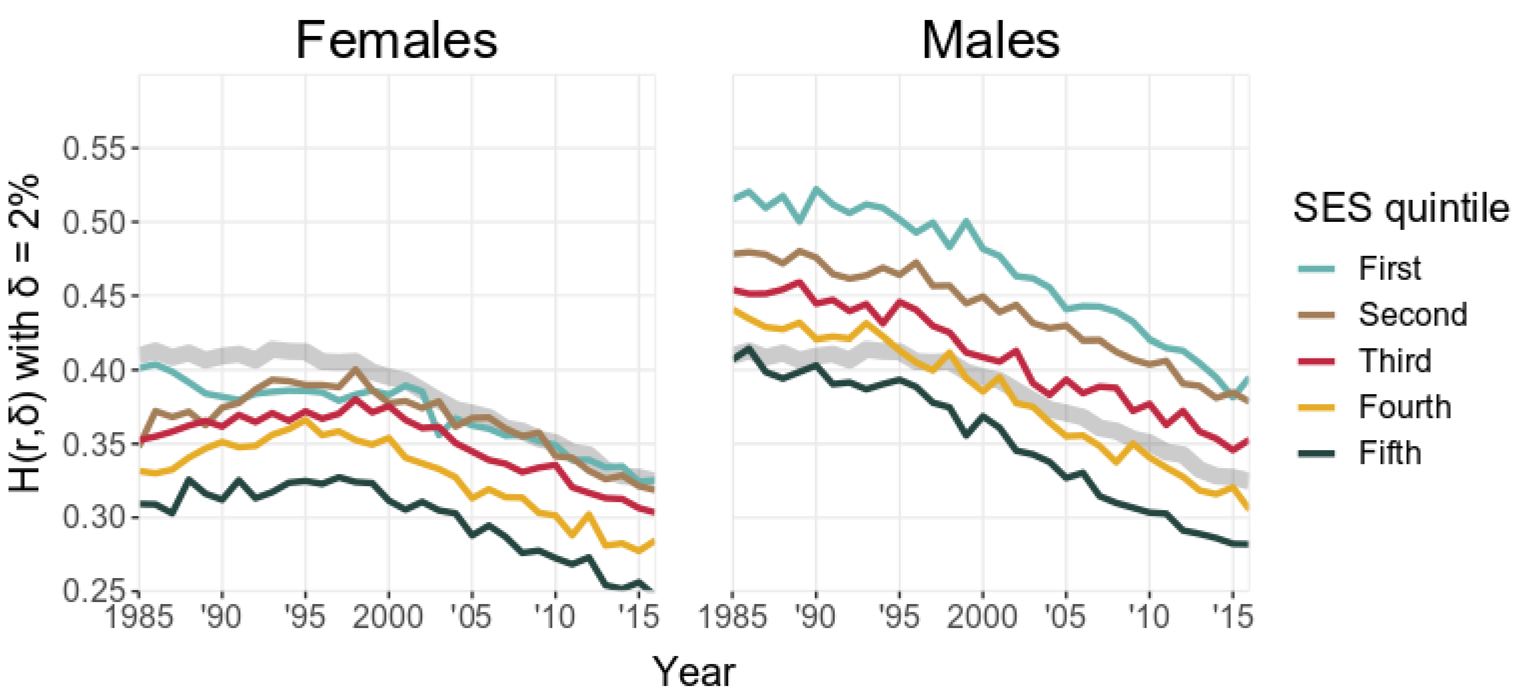


**Figure A8.** Entropy of life annuities by SES calculated at age 65, assuming a constant interest rate of 2%. Both sexes, 1985-2016.


**Figure A9.** Entropy of life annuities by SES calculated at age 65, assuming a constant interest rate of 5%. Both sexes, 1985-2016.

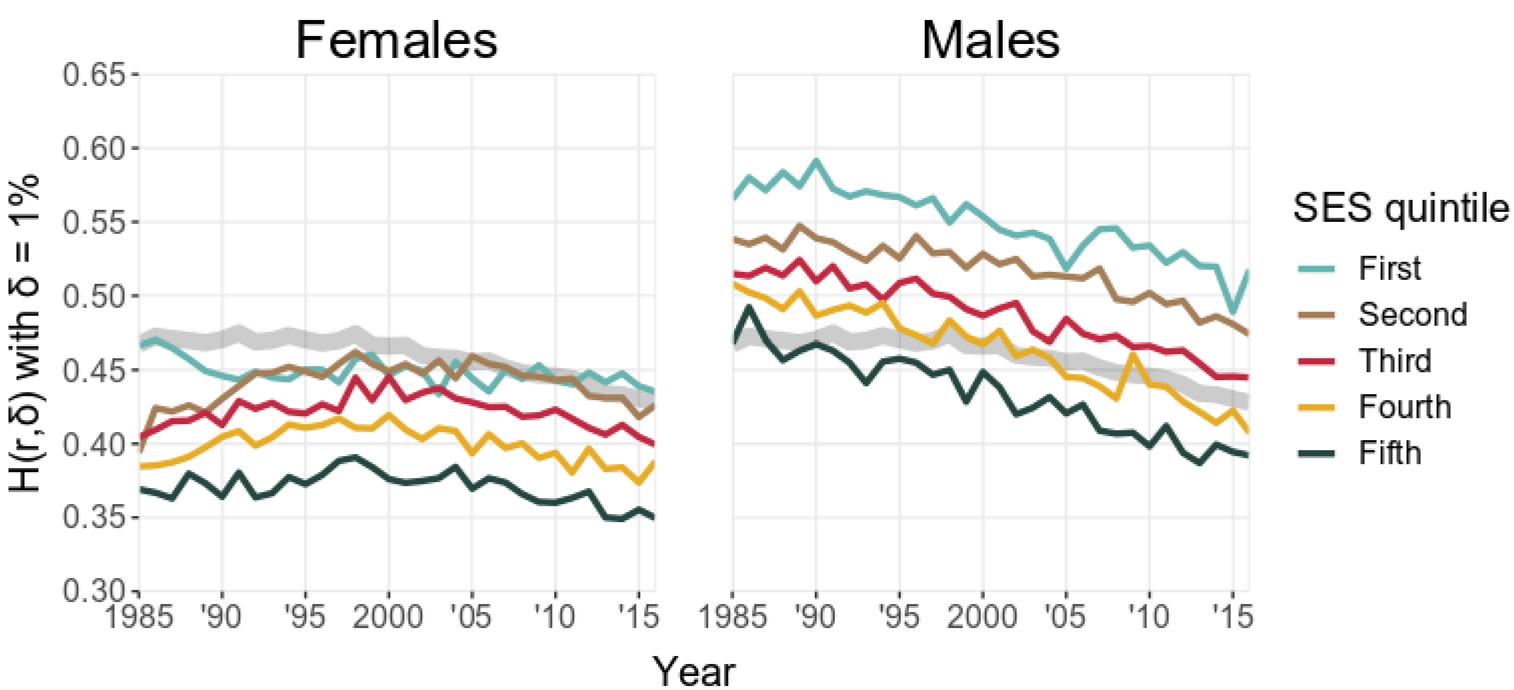


**Figure A10.** Entropy of life annuities by SES calculated at the target retirement age, assuming a constant interest rate of 1%. Both sexes, 1985-2016.


**Figure A11.** Entropy of life annuities by SES calculated at the target retirement age, assuming a constant interest rate of 2%. Both sexes, 1985-2016.

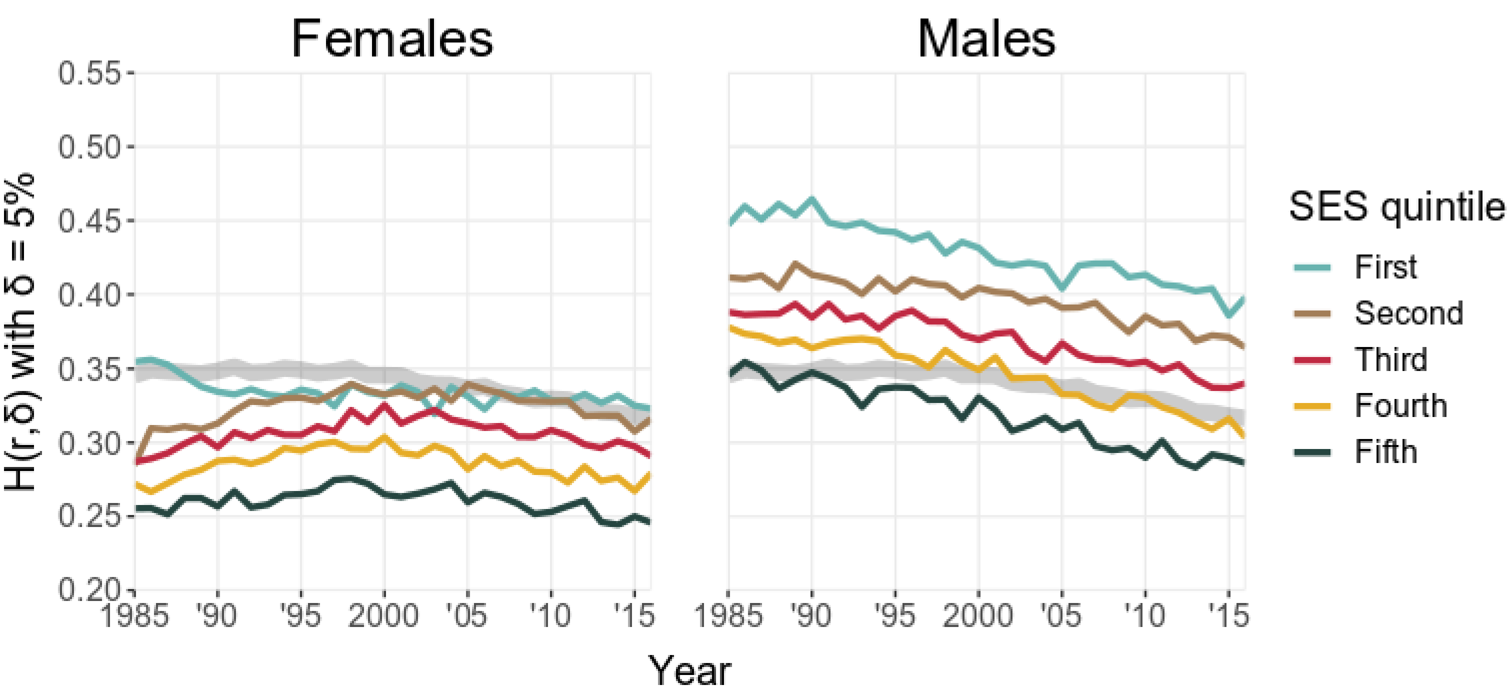


**Figure A12.** Entropy of life annuities by SES calculated at the target retirement age, assuming a constant interest rate of 5%. Both sexes, 1985-2016.