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Differences in mortality before retirement: The role of living arrangements and marital status in Denmark

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Abstract

BACKGROUND

To make the pension system robust to population ageing, Denmark will increase the statutory retirement age in tandem with national life expectancy. By universally increasing this age, this pension indexation policy might amplify known inequalities in mortality, such as those between people in different living arrangements.

OBJECTIVE

We aim to quantify inequalities in mortality before retirement age by living arrangement over time.

METHODS

We estimate the probability of dying between ages 50 and 65 for several cohorts of Danes living in different household types and with differing numbers of children, controlling for their socioeconomic status. To give a more complete picture, we also calculate lifespan variability, equivalent age, and average yearly rate of mortality improvement for each sub-group.

RESULTS

In Denmark, considerable mortality inequalities exist depending on living arrangements and they are becoming larger. Across all the dimensions of mortality we examine, single and childless men, and to a lesser extent single and childless women, cumulate a clear disadvantage.

CONCLUSIONS

Relying on the national average to set the statutory retirement age risks further disadvantaging these subpopulations. While early retirement schemes exist in Denmark, they mostly impact people based on their occupation. We highlight that other characteristics are strongly tied with mortality and should be considered too.

CONTRIBUTION

This paper falls within a project developed and directed by Jim Vaupel from 2019 until his death. He believed that the Danish pension indexation policy risked unfairly damaging specific groups. The results of this, as well as other papers, show that it might indeed be the case.

Introduction

The ageing of European populations has jeopardised the financial sustainability of pension systems across the continent (Doyle et al. 2009; Ediev 2014). In order to address this concern, governments have strived to lengthen the working lives of their citizens, often by increasing the legal age of retirement (Directorate-General for Employment 2021; Liu 2021). Specifically, Denmark has been gradually increasing the statutory age at retirement (from this point forward retirement age) with the objective to index (i.e. link) it to the national life expectancy, so that an average individual would be expected to live 14.5 years after retirement (Neergaard Larsen 2015).

While this reform makes the pension system more financially sustainable, it also risks making it more unbalanced. By considering a measure of average mortality, pension indexation does not account for the inequalities in mortality that exists within the Danish population. Several studies have focused on social inequalities in average and variation in length of life in Denmark, finding that those inequalities have been increasing over time (Brønnum-Hansen and Baadsgaard 2012; Brønnum-Hansen et al. 2021). Uniformly raising retirement age means that all individuals from a cohort are expected to survive longer to reach retirement age. This might disproportionately increase the risk of death before retirement for certain sub-groups of the population. For example, Strozza *et al.* (2022) have found remarkable inequalities – increasing over time – in survival to retirement age or shortly thereafter among socioeconomic groups in Denmark. Similarly, Alvarez *et al.* (2021) have found that indexing retirement age to national life expectancy increases uncertainty and socioeconomic inequalities in length of retirement. These studies suggest that such pension reforms risk disadvantaging already underprivileged groups in terms of access to retirement. It is so even in a country such as Denmark, which has a flexible pension system, allowing for “early exit” from the labour market under certain conditions. However, those studies focus on socioeconomic characteristics, not considering other features that are associated with mortality.

In this paper, we will focus specifically on the impact of mortality differentials linked to living arrangements and co-resident children on the probability of reaching retirement, by examining how the probability of dying before reaching the retirement age having survived to age 50, or of dying shortly after having reached retirement age, differs according to marital status and living arrangements combined, as well as number of children in the Danish population.

Relationship status

Living arrangements (together with relationship status) have been shown to be strongly linked with mortality, with married individuals typically enjoying longer lives than other groups (Rendall et al. 2011; Poulain, Dal, and Herm 2016; Zueras, Rutigliano, and Trias-Llimós 2020), an association also reflected in health levels (Lawrence et al. 2019; E. M. Grundy and Tomassini 2010; Umberson et al. 2006). Moreover, the distribution of living arrangements has considerably evolved across time (Fokkema and Liefbroer 2008) with an ever-higher share of Europeans living alone, a condition linked with the highest levels of mortality (Reher and Requena 2018; Esteve et al. 2020). While both relationship status (e.g. being married, divorced, in a registered partnership or widowed) and living arrangements (e.g. living alone, living with a small child, living with a partner) have been used in this strand of research, the recent literature has suggested the need to account for both (Zueras, Rutigliano, and Trias-Llimós 2020).

Despite the abundant literature on the subject, there remains a debate about the mechanisms leading to the clear mortality differentials uncovered. The two main competing explanations are those of protection of marriage and selection into marriage. The first argues that marriage offers advantages such as financial stability and economies of scale, emotional support or institutional recognition (Frisch and Simonsen 2013) and that a live-in partner is more likely to monitor the health habits of an individual and to encourage them to contact health professionals (Lau and Kirby 2009). The second points out that individuals getting married and/or living with someone are probably different from individuals who do not. These differences can be tied to physical health, SES, or even personality traits (Requena and Reher 2021). From the moment these traits influence positively both entry into marriage or partnership and survival, they could explain the mortality differentials between various groups. Recent studies found that these two mechanisms coexist, although selection effects may be particularly important at younger ages, while protection effects gain a greater role later in life (Requena and Reher 2021; Franke and Kulu 2018).

While findings consistently point to the greater mortality of single people and individuals living alone and to the higher survival of married individuals and those living with a partner (Rendall et al. 2011; Robards et al. 2012; Frisch and Simonsen 2013; Kilpi et al. 2015), the role of other characteristics have also been examined. Gender seems to be an important moderator of this relationship, with men benefiting more from marriage than women, although not all analyses find such differences, which may also depend on the national context (Kandler et al. 2007; Scafato et al. 2008; Rendall et al. 2011; Zueras, Rutigliano, and Trias-Llimós 2020). Differences according to living arrangements also seem to wane with age, as also happens with other mortality differences, such as those linked with SES. A number of theories have been proposed to explain these results, from the increased prevalence of extremely bad health among older individuals (Hoffmann 2011) to the effect of selection on intrinsic or extrinsic (e.g. education) factors in a heterogeneous population (Vaupel and Yashin 1985; Dupre 2007). At the same time, the literature focuses on differences in mortality at mature ages, so that less is known about the relationship between relationship status and mortality during younger adulthood (Koskinen et al. 2007; Poulain, Dal, and Herm 2016; Zueras, Rutigliano, and Trias-Llimós 2020). Another important aspect to consider are marital disruptions, such as divorce or widowhood. Divorced and widowed individuals consistently show higher probability of dying compared to their married counterparts and marital disruptions are typically followed by periods of increased mortality (Berntsen and Kravdal 2012; Leopold 2018; Lucas 2005). However, these spells can be more or less lengthy and the higher mortality of divorced and widowed people could be endogenously linked with selection as well as with a range of causal mechanisms (e.g. unhealthy behaviours, stress, loss of resources) (Sbarra, Law, and Portley 2011).

Number of children

A great deal of research has also looked into the relationship between parity and mortality, typically highlighting a U- or J-shaped association between the two, with the lowest mortality for individuals having had 2 or 3 children (Konishi, Ng, and Watanabe 2018; Jaffe et al. 2009). This literature has highlighted both physiological and social mechanisms behind this association. For women especially, bearing a child can have a taxing effect on the body, increasing the likelihood of some diseases at older ages (Friedlander 1996; Jaffe, Eisenbach, and Manor 2010), but not others (e.g. breastfeeding may decrease the probability of developing breast cancer (González-Jiménez et al. 2014)). Another strand of literature has focused more on the social consequences of having a child. The presence of children in the household and the responsibility of caring for them may modify behaviours, decreasing risky ones and encouraging healthy ones. Moreover, taking part in children-related activities may increase social contact, which has been shown to be positively linked with mortality (Holt-Lunstad et al. 2015; Shor and Roelfs 2015). Parents are also likely to receive support from their adult children during old age, with consequences both on health and social contact (Nazio 2021; Modig et al. 2017; Seeman and Berkman 1988). At the same time, children may burden parents beyond the purely physiological consequences of procreation. Raising a child may lead to stress, considerable economic costs and less time for self-care (E. Grundy and Read 2015), although the characteristics of the children themselves also seem to be associated with parents' health and wellbeing (E. Grundy and Murphy 2018; Kohler, Behrman, and Skytthe 2005; Galbarczyk et al. 2019; Thomas and Thomeer 2019). Considering the effect of number of children on survival to retirement age would contribute to the discussion on the costs and benefits of parenthood (Gal, Medgyesi, and Vanhuysse 2020; Liefbroer 2005).

As is the case for the association between relationship status and mortality, the relationship between parity and mortality may also derive from selection processes. Individuals with impaired health are less likely to enter a relationship, which often precedes having a child, and may be not or less able to have a child. Parity is also strongly tied with socioeconomic characteristics. Typically, having a large number of children is linked to lower income and education (Hartnett and Gemmill 2020; Huber, Bookstein, and Fieder 2010), although this relationship has been recently changing in the Nordic countries (Jalovaara et al. 2019; Jalovaara and Miettinen 2013). At the same time, individuals, especially men, with lower SES are more likely to be childless, given the selection into entering a stable partnership (Wiik and Dommermuth 2014). For parity, as for relationship status and living arrangements, the association with mortality is likely to be shaped both by protection and selection effects (Barclay and Kolk 2019).

Limitations of previous literature and our contributions

While the literature on the mortality differentials linked to living arrangements and parity is abundant, it has some limitations. Firstly, papers can lack a concrete policy application with regards to the inequalities they uncover, whereas our analysis is explicitly focused on the impact of these differentials on the probability of dying before retirement or shortly after. Previous literature has also focused solely on differences between groups. However, studies focusing on different characteristics (e.g. SES) have shown that within-group inequality in mortality can move independently of and might actually be larger than between-group inequality (Permanyer et al. 2018; van Raalte et al. 2011; Sasson 2016; Smits and Monden 2009). In this paper, we will consider how mortality differs between individuals within each group through measures of lifespan variation, which have been used extensively in the literature (Permanyer and Scholl 2019; Aburto and Beltrán-Sánchez 2019; van Raalte et al. 2011; Wilmoth and Horiuchi 1999). Lifespan variation is tied with uncertainty about the timing of one's own death, which can affect individual behaviours with concrete economic consequences, such as saving for future retirement (Tuljapurkar 2011; Edwards 2013). Finally, analyses are often limited to a period perspective because of the unavailability of longitudinal data. This makes it difficult to obtain a panorama of the overall progression of inequalities across specific cohorts. Moreover, using surveys based on samples can make it more difficult to obtain reliable estimates, especially when intersecting different characteristics. By using population-wide longitudinal data we analyse mortality differentials in a cohort perspective and by combining different characteristics. This is particularly important when considering policies that are cohort-based and that can target specific groups, like those influencing standard and special pension systems.

Methods and data

We use data from the Danish registries. These provide yearly information on, among other variables, socioeconomic, marital, and co-residence status for all individuals residing in Denmark, updated yearly since 1986, for a total of about 3.3 million individuals and 35.7 million person-years of observation. We divide the Danish population into meaningful sub-groups defined according to sex, living arrangements, and SES. For each sub-population, we extract the exposure and the number of deaths to construct sex-specific lifetables. In such a setting, we do not make any assumption on each subpopulation's mortality pattern. From these, we compute the probability of dying between ages 50 and 65, which was the standard retirement age throughout most of our observation period. In the same way, we calculate the probability of dying between ages 65 and 70 i.e. reaching retirement, but not having time to enjoy it. As a sensitivity analysis, we also estimated the probability of dying between ages 65 and 75 and ages 65 and 80. This did not substantially alter our results.

We use a variable capturing both marital status and cohabitation (as suggested by Zueras, Rutigliano, and Trias-Llimós (2020)) to distinguish individuals living in four household types: single people living alone (from this point forward referred as single), married individuals living with their spouse (from this point forward referred as married), individuals cohabiting with a partner (from this point forward referred as cohabiting), and individuals in complex households (i.e. a residual category constructed by Statistics Denmark in its registries, comprising different families living at the same address). Given the definition used in the registries, complex households can also be constituted of parents and children aged 25 or over (we use the term as defined by Statistics Denmark, which is slightly different from the definition used in censuses (see definition by Insee[1])). On the other hand, children under the age of 18 are not counted, so a single person could be living with one or more minor children. We compute a modal household type for each individual (i.e. the most observed household type for each individual during the observation period. From now on simply household type). This means that we do not consider transitions between households. However, household trajectories are fairly stable. For 70% of individuals between ages 50 and 65, the modal household type corresponds to the first and last household types recorded, which increases to 86% for ages 65 to 70. To further investigate the association between household structure and survival to retirement age, we retrieve the number of children living in the household when the individual was aged 40. This is taken as a proxy for number of children ever born. Individuals were divided into those with no children, one, and two or more.

We include three measures of SES: education, income, and occupation. As detailed in Strozza et al. (2022), we calculate average or modal values, respectively for continuous and categorical SES indicators, observed in the five years before age 50 (or 65 when considering post-retirement survival). Education is measured in terms of length of education (in months) and divided into tertiles computed by sex and cohort. Income is measured in terms of family disposable income. It includes tax-free income, plus imputed rent for homeowners, minus interest expenses, taxes, etc. It is divided into quartiles, corrected for inflation, computed by sex and cohort. Based on the International Standard Classification of Occupations (ISCO) classification, occupation is categorised into lower

[1] https://www.insee.fr/en/metadonnees/definition/c1742

manual workers (Skilled Agricultural, Forestry and Fishery Workers; and Craft and Related Trades Workers), upper manual and lower non-manual workers (Plant and Machine Operators and Assemblers; Elementary Occupations; Technicians and Associate Professionals; Clerical Support Workers; and Services and Sales Workers), and upper manual workers (Managers and Professionals).

We take advantage of the longitudinal nature of the registers to adopt a cohort rather than a period perspective (i.e. construct cohort lifetables). As pension reforms affect individuals based on their birth cohort, this framework seems to be the most appropriate (Ayuso, Bravo, and Holzmann 2021). We also focus on cohorts which were fully observed as of 31^{st} December 2019: for the probability of dying between ages 50 and 65, we analyse cohorts born between 1936 and 1954; for the probability of dying between ages 65 and 70, cohorts born between 1921 and 1949. Because we capture the number of children in the household at age 40, we can only include individuals born in 1946 or after. For pre-retirement mortality this reduces our observation period to cohorts born between 1946 and 1954. For post-retirement survival, this reduces the number of cohorts available to four, severely limiting the analysis of the time trends. Therefore, we do not consider this variable for analyses of post-retirement mortality.

In this work, we compare different groups in order to understand how a pension reform based on the average national mortality, such as that adopted by Denmark, may differentially affect specific groups. In order to explore this aspect, we calculate the average yearly rate of mortality improvement for each group from the first to the last cohort. Assuming a constant improvement from one cohort to the next, we can adapt the standard equation for the rate of population growth (Keyfitz & Caswell, 2005) and get:

$$r_i = -\frac{\ln\left({}_{15}q_{50}^{c_2,i}\right) - \ln\left({}_{15}q_{50}^{c_1,i}\right)}{c_2 - c_1}$$

where c_1 and c_2 are the first and last cohort, respectively, and ${}_{15}q_{50}^{c_1,i}$ and ${}_{15}q_{50}^{c_2,i}$ are the probabilities of dying between ages 50 and 65 for group i for the first and last cohort, respectively. For ages 65 to 70, it suffices to replace ${}_{15}q_{50}$ with ${}_{5}q_{65}$. This indicator can take both positive and negative values, indicating that mortality decreased or increased, respectively.

To further investigate between-groups differences, we employ the concept of equivalent age (Burger, Baudisch, and Vaupel 2012; Vaupel, Villavicencio, and Bergeron-Boucher 2021). We compare mortality between ages 50 and 65 of a target population (the most advantaged one) with all the other sub-populations and calculate the age when the same probability of dying of the target population is reached. This metric allows one to answer, for instance, the question: at what age does a single man reach the same probability of dying that a married man has between ages 50 and 65? The relative nature of this metric makes it easier to visualize whether inequalities across cohorts have been increasing or decreasing and to differentiate trends across sub-groups. This calculation is performed by cohort and sex, in addition to the variable(s) of interest. We also calculate the coefficient of variation (CV) for each stratum of the population (e.g. women born in 1940 in the middle education tertile). This metric gives a more general overview of the patterns of between group inequalities but does not inform on the trends of each sub-group (e.g. single women born in 1940 in the middle education tertile). We present results relative to the CV in the appendices.

The measures detailed so far instruct us on the inequality that exists between groups. In order to also account for within-group inequalities, we estimate the partial lifespan variation between ages 50 and 65 and between ages 65 and 70, using the relative Gini coefficient (Shkolnikov, Andreev, and Begun 2003):

$$ {}_{x_2}G_{x_1} = 1 - \frac{1}{{}_{x_2}e_{x_1}} \int_{x_1}^{x_2} [l(s)]^2 ds $$

where $_{x_2}e_{x_1}$ is the partial life expectancy between ages x_1 and x_2 and *l(s)* is the lifetable survival function. This measure can be interpreted as years of life gained (Pyatt 1976). However, we operationalise it as the average difference between the ages at death of those individuals in the population who die between ages 50 and 65, and ages 65 and 70.

For each subpopulation and measure, we compute the 95% confidence intervals of every estimate by bootstrapping 10.000 populations of 20.000 individuals each with the subpopulation's underlying lifetable death distribution.

In the main body of the text, we only present results for ages 50 to 65 and we focus on education tertile as a measure of SES. Results for ages 65 to 70, and by family income or occupation can be found in the appendices. These additional findings support our main conclusions, although with some nuances.

Results

Figure 1 shows how the prevalence of household type and number of children have shifted throughout the cohorts in our data, by sex and level of education. Specifically, panel A shows the changes in household type composition by tertile of length of education in the Danish population between ages 50 and 65. In general, we observe a reduction in the prevalence of married couples from the first (1936) to the last (1954) cohort in analysis. This pattern is more pronounced among men for whom we also observe a clearer educational gradient than for women: men in the first education tertile are considerably less likely to be married than those in the third tertile. Panel B shows differences in household type composition by number of coresident children at age 40. Among individuals with no children, the prevalence of single people reaches almost 50% among men and over 40% among women in the youngest cohort considered here. We also see differences in the household type composition among individuals with one and two or more children. The former are more likely to be in an unmarried partnership or to be living on their own compared to the latter. This pattern is more pronounced among women but is clearly visible among men as well. Panel C shows differences in the number of coresident children when individuals were aged 40 by tertile of length of education. There are apparent differences for individuals in the first education tertile when compared to those in the second and third tertile. The least educated group shows a higher prevalence of childless men and of women with a single child, and consequently a lower prevalence of men and women with two or more children. Among those in the second and third education tertile there are no compositional differences within sex, but the figure clearly shows that women are much less likely than men to be childless, while they are more likely to have one child.

Figure 2 shows the results of the survival analyses by sex, household type, and tertile of the length of education (panel A) or number of children (panel B) and by sex, number of children, and tertile of the length of education (panel C). Because we could use longitudinal data, it shows the mortality experienced by each group and cohort, rather than a cross-sectional picture of it. Overall, the mortality estimates presented in Figure 2 are characterised by narrow confidence intervals. Results are therefore robust for all the subgroups analysed across cohorts.

Panel A highlights a difference in the mortality trends among men and women. The former show very clear and constant differentials as their trend lines and confidence intervals never cross, with single men having the highest probability of dying, followed by men in complex households and in cohabitations, while married men have the lowest probability of dying. These differentials are wider in the lowest education tertile: for instance, for the 1936 cohort, there is a two-fold difference between the mortality of single (26%) and married (13%) men in the first education tertile, which grows to more than a three-fold difference for the 1954 cohort (27% vs 8%). For highly educated men, these differences remain smaller: for the 1936 cohort, single men experience a probability of dying double that of their married counterparts (21% vs 11%) and this difference only reaches the three-fold mark for the 1954 cohort (15% vs 5%). The probability of dying between ages 50 and 65 for all groups of men decreased, but much less so for single men. Figure 3 shows the average yearly rate of mortality improvement for each subpopulation. It reveals that, between the 1936 and 1954 cohorts, married men in the highest educational tertile experienced an average yearly improvement of 4.3%, while single men in the lowest educational tertile experienced a slight but significant average worsening.

Women have overall lower probabilities of dying than men: even the most educated men tend to have higher or similar probabilities of dying compared to the least educated women within the same household type. Except for married women, who show markedly higher survival, there are not significant differences between the other household types, whose trends and confidence intervals are overlapping and crossing each other. Even when compared to married women, inequalities in mortality generally stay between 10 and 5 percentage points, although they are larger for the lower education tertiles. Figure 3 suggests that married women, women in unmarried couples, and in complex households with the highest education experienced average yearly rates of mortality improvement between 3.4% and 4.1%, with the least educated ones improving at a slower pace than the others (1.4 to 2.0 percentage points difference). On the other hand, mortality for highly educated single women improved at a rate of 2.5% while we observe no improvement for the least educated single women, resulting in the gradual emergence of single women as the highest mortality group in younger cohorts.

Figure 2 panel B shows mortality inequalities between ages 50 and 65 by sex and household type, further stratified by number of children in the household when the individual was 40 years old. Among men with no children, those who were mostly single or living in complex households share a similar probability of dying before retirement age, at least twice as high as that of men living with their spouse (27% for childless men in complex households vs 10% for childless married men on average across cohorts). Single men emerge as the highest-mortality group among men with one and especially two children, with probabilities of dying hovering around 19% and 17% respectively. Among women with no children, those living in complex households are the most disadvantaged (with a probability of dying of around 20% across cohorts vs 9% for their married counterparts), followed by single women (16%). Among women with at least one child, however, probabilities are clustered much more closely, resulting in crossing trends and confidence intervals. The exception are married women, who remain the lowest-mortality group throughout (with around 7% of probability of dying). Figure 3 shows however significant inequalities in mortality improvement among married women, in favour of women with multiple children (4.1%). Married women with no or one child, on the other hand, experienced an improvement more in line with that of single women with no (0.9%) or one child (1.0%). Single and cohabiting men with no children did not experience mortality improvements across cohorts, while cohabiting men with one child experienced a slight but not significant worsening ([-0.5%;0.1%]). Again, women and men in complex households experienced considerable improvement, especially those with multiple children (4.7%).

Figure 2 panel C focuses on the probability of dying by number of children co-residing at age 40, sex and education tertile. Mortality levels and trends are similar to those shown in the two other panels. Men and individuals with lower education show greater inequalities than women and those with higher education. Childless individuals are the most disadvantaged ones across education groups and genders, while those with two or more children experience the lowest levels of mortality. There is no, or negligible, mortality improvement across cohorts for childless men and women in the first and second (only men) education tertiles. Similarly, men and women with one child in the first and third (only women) education tertile, present the same mortality levels for the youngest and oldest cohorts in the analysis (Figure 3).

In Figure 4, we see the trends in the Gini coefficient, representing inequalities in mortality within the sub-populations under analysis. Trends in lifespan inequality are remarkably similar to those of the probability of dying, both in terms of the relationship between the different groups and in terms of change through time. This result is not surprising, given the known relationship between mortality and lifespan inequality measures (Aburto et al. 2020), which is especially strong when considering shorter age ranges. The uncertainty around the estimates of the Gini coefficient is larger than that of the probability of dying by age 65, because this indicator is more sensitive to changes in age-specific mortality. Despite this, differences between groups remain largely significant, especially among men. Overall, the most disadvantaged populations in terms of mortality levels also suffer the greatest within-group inequality, with men not living in a couple and childless women and men experiencing particularly high levels of variation in their age at death.

Figure 5 shows the results of the equivalent age analyses by sex, household type, and tertile of the length of education (panel A) or number of children (panel B) and by sex, number of children, and tertile of the length of education (panel C). The confidence intervals around the estimates are narrow, as for Figure 2.

Focusing on changes across cohorts, rather than the levels of inequalities (while still large, they have already been described when commenting Figure 2), we see from panel A that mortality inequalities between married and single people have been increasing across cohorts. This is true for both sexes and different education tertiles. For instance, the probability of dying between ages 50 and 65 for a highly educated married man born in 1936 equals the probability of dying between ages 50 and 59.4 for a single man with the same level of education. For two men born in 1954 instead, a single man in any education tertile had the same probability of dying by about age 56 as a married man by age 65, both conditional on surviving to age 50. In contrast, the gap between married individuals and individuals in one of the other two household groups either remained stable or decreased between the first and the last cohort, except for the least educated individuals in complex households.

Figure 4 panel B shows that mortality inequalities between women have remained rather stable and have even reduced for childless cohabiting women. Inequalities among men with one child are also quite stable, whereas the inequalities between married and single men (for individuals with two or more children) and married and single men or men living in complex households (for childless individuals) have been increasing.

Figure 4 panel C shows rather stable mortality inequalities among men with at least one child in different levels of education, but an increasing gap with childless men. Among women in the lowest education tertile, mortality inequalities between those with at least two children and fewer than two children clearly increased, as well as inequalities between those with one vs. two or more children among highly educated women.

Discussion

Consistent mortality gradients

It is well-known that living arrangements and marital status are correlated with mortality levels, especially for men (Franke and Kulu 2018; Drefahl 2012; Kandler et al. 2007). Previous studies also highlight mortality inequalities among socioeconomic groups in Denmark and elsewhere (Strozza et al. 2022; Mackenbach et al. 2015). What our results show is the magnitude of differentials when combining these two sources of inequalities. Over a quarter of the men in the first education tertile born in 1954 who were mostly single between ages 50 and 65, died before reaching retirement, as opposed to fewer than one in 10 of men with the same level of education who were mostly married. Between these groups there is more than a threefold difference, which only increases if we add differences by education tertile and sex (married men and women in the highest education tertile had a 5.2% and 3.8% probability of dying before retirement, respectively). These inequalities remain in all of our results, but they are modulated along some characteristics.

This study joins previous literature in finding a much stronger mortality gradient for men as compared to women, concerning both living arrangements and education tertiles. That female mortality is not as strongly linked to living arrangements and marital status is a recurrent finding in the literature (Zueras, Rutigliano, and Trias-Llimós 2020; Staehelin et al. 2012; Kandler et al. 2007; Williams and Umberson 2004). Women might benefit less from the protective effect of marriage and partnerships. Scafato *et al.* (2008) argue that the traditional gender roles within marriage may burden women with taking care of their husbands. While such expectations naturally vary across societies, they may have been stronger for older cohorts, such as those we consider here. Indeed, women are more likely to attempt to regulate their (male) partner's health habits and be successful in changing them (Rook et al. 2011; Berg and Upchurch 2007; Westmaas, Wild, and Ferrence 2002; Umberson 1992), as well as to provide emotional support within the marriage (Kiecolt-Glaser and Newton 2001). Unmarried men are more likely than their married counterparts to have unhealthy behaviours, such as smoking, or die of cardiovascular and external causes, while this difference is smaller for women (Wang et al. 2020; Hilz and Wagner 2018; Peltonen et al. 2017; Martikainen et al. 2005). Men's health also tends to worsen more after divorce, compared to women's, although women suffer more from the loss of income that follows (Leopold 2018). In Denmark, however, the welfare system may temper such economic consequences. At the same time, selection acts differently on men and women. As we see in figure 1A, higher educated men are less likely to be single than their less educated counterparts, while the relationship is not as strong for women. In fact, highly educated women are more likely to be single compared to their male counterparts (Staehelin et al. 2012; Martikainen et al. 2005). The emergence of single individuals as the highest mortality group among women points to developments in these selection mechanisms. Increased gender equality within couples in Nordic countries (Harsløf, Scarpa, and Andersen 2013) could have encouraged highly educated women to enter a partnership, as has been argued in the case of childbearing (Jalovaara et al. 2019).

These same factors could also explain the smaller mortality gradient among women when stratifying for the number of children. In fact, these trends mirror closely the trends when stratifying by education tertile. There is, however, one considerable difference. Among childless individuals it is not single men and women who experience the highest mortality, but rather men and women living in complex households. Childless individuals living in complex households may be a particularly selected group. Since in the Nordic countries it is uncommon to live with people other than children or a partner (Iacovou and Skew 2011; Tai and Treas 2009), working age individuals may be driven to do so by necessity, rather than by choice, due to health or economic constraints. Men and women with at least one child and who live in complex households may be more likely to live in their child's household, rather than in an institution. On the contrary, single individuals with at least one child may suffer from lack of support in raising a child and, thus, bear the brunt of the stress and adverse consequences associated with it (Campbell et al. 2016; Benzeval 1998).

The difference between single childless individuals and those living in complex households reduces with time. This could point to a shift from institutionalisation to care at home for people needing assistance ("NYT: Fortsat færre ældre bor i pleje- og ældreboliger" 2021), with childless people living in complex households today more likely to be living in shared houses or intergenerational households than before. The mortality trends for men with one child living in a complex household is also intriguing. For cohorts born before 1950, the mortality of this group was similar to that of single men. Cohorts born in the 1950s, however, experienced a sharp decline in mortality, reaching levels comparable with those of cohabiting men. Once again, this suggests a shift in the composition of complex households, although a more careful study of this category at the turn of the millennium would be needed to completely elucidate this result.

Patterns are similar when considering differences by the number of children, stratified by education tertile. Figure 1B showed how household type and the number of children are linked. Having just one child drastically increases the probability of being married across cohorts, even to the disadvantage of the probability of cohabiting, and this probability increases even further with two or more children. With marriage being the privileged framework for stable relationships involving children, it is no surprise that the gradient for the number of children so closely mirrors that for household type. However, as having children has become less associated with marriage for more recent Danish cohorts, the two gradients could become less similar in the future.

While the mortality gradient by living arrangement and number of children holds across our analyses, it is not constant across strata. Rather, it narrows noticeably as education or the number of children increase. These patterns point to an accumulation of disadvantages by the most vulnerable groups, on which we will focus in the next paragraphs.

Widening inequalities

While the inequalities we just described are large, they do not address the central question of this paper. In order to understand whether a universal increase in the retirement age would affect all groups equally, we need to know whether survival improves homogeneously across all groups. Using equivalent age, Figure 5 shows that this is not the case, whether we consider household type or number of children. Cohabiting men and women have maintained a rather constant difference from their married counterparts, but the difference from single individuals or those living in complex households actually increased between the 1936 and the 1954 cohorts, especially for men when considering household type and for women when considering the number of children. This is true across education tertiles and number of children. While higher values in these variables lead to lower mortality levels for all groups and narrow the absolute inequalities between them, they are not associated with lower relative differences, nor with a more advantageous time trend. The strengthening of the mortality gradient by living arrangement in Denmark mirrors a wider trend that has been documented since the 1970s (Murphy, Grundy, and Kalogirou 2007; Valkonen, Martikainen, and Blomgren 2004) in low mortality countries. While living arrangements and education are strongly associated, we show here that this trend is not completely due to the inequalities by SES that have been documented for Denmark in the same period (Strozza et al. 2022).

Figure 3 uses the average yearly rates of mortality improvement to answer the same central question. In terms of household type, it shows two clear trends. Firstly, improvements were faster for higher educated people and people with more children, regardless of household type. Secondly, the gradient within the same education tertile or number of children is not as clear as with other measures. However, single men and women clearly emerge as the household type for which mortality improved the least. Thus, both in terms of relative differences and absolute survival improvement, the situation of single individuals worsened compared to the other groups. This is counterintuitive because being single between ages 50 and 65 actually became more common in Denmark during the same period, meaning that single individuals are less (negatively) selected now than before. This positive influence was more than offset by other disadvantaging mechanisms, possibly tied to the structure of public health policies. The same reasoning holds for individuals with no children, with childless individuals being the most disadvantaged group, despite childlessness becoming less selective for younger cohorts (Figure 1C).

As outlined above, there is a broad literature on the potential explanations for mortality differences by living arrangement and parity. The development of prevention and social policies, including the way they target a population, as well as their uptake, could contribute to explain why some groups benefitted more than others from the improvement in survival experienced overall by the Danish population. Moreover, female Danish life expectancy stagnated between the late 1970s and the early 1990s. This stagnation has been mainly attributed to smoking (Kallestrup- Lamb, Kjærgaard, and Rosenskjold 2020; Lindahl-Jacobsen et al. 2016), which is more prevalent among single and childless individuals (Görlitz and Tamm 2020; Nielsen et al. 2006).

Differences in within-group inequality

These inequalities in the absolute levels of mortality between different groups are reflected in the differences of inequality within each group (Figure 3). This is also due to the tight relationship between mortality levels and lifespan variation, especially in short age-spans, but it highlights another dimension of disadvantage (Aburto et al. 2020). While lifespan variation is not a direct measure of uncertainty about the length of one's own expected lifespan, it is a good substitute when such specific survey measures are not available. Such uncertainty can have very concrete consequences on preparedness for old age, as individuals decide whether to invest in their own future (e.g. by getting a higher education or saving for retirement) based on the likelihood they will actually get to enjoy returns on their investments (Edwards and Tuljapurkar 2005). In fact, based on the few data available, Edwards (2013) calculates that US residents would even be willing to have shorter lives, in order to enjoy more certainty.

Accumulation of disadvantages

Single and childless individuals are both clearly disadvantaged in terms of mortality. But our results allow a more refined interpretation. Figure 2 shows that the inequalities by household types and number of children decrease with higher education or with more children. For the 1954 cohort, the mortality of married men and women decreases by about 0.3 points between the lowest and the highest education tertile, whereas the mortality of single women decreases by 0.8 points and that of single men by a full point. To a lesser extent, the same is true when considering household type by the number of children or the number of children by education tertile. Thus, advantageous household types (e.g. being married or cohabiting) or a high number of children are protective against the negative association between education/number of children and mortality. On the contrary, single individuals and those living in complex households and without children are much more vulnerable to the consequences of other characteristics, such as low education and childlessness.

The accumulation of disadvantage does not solely concern individuals' characteristics, but also the various dimensions of mortality examined in this paper. Single, low educated and childless men and women suffer from much higher levels of mortality, compared to other groups. We also show that these groups did not benefit from the overall improvement in survival in Denmark to the same extent as other parts of the population, leading to a widening of these mortality differentials. These same groups also suffer from systematically higher within-group lifespan inequality, meaning that their members die at more disparate ages than members of other groups. These results have very concrete consequences. From the perspective of retirement, they show that single, childless, and less educated men and women have fewer chances to reach retirement after surviving to age 50 and that those that do may be less prepared to sustain the changes (above all in income) that retirement entails. And that these inequalities are not getting better.

Consequences for retirement age

The main result of this paper is that some groups in the Danish population accumulate disadvantages across a range of characteristics, with dramatic consequences for their survival to retirement age. Even more relevant to the question of this paper, the survival of these groups is improving more slowly than that of others. Because of this, a retirement age that increases with national life expectancy risks further accentuating their mortality disadvantage.

The Danish retirement system is flexible, allowing early retirement, a practice that remains very popular among Danish workers (Meng, Sundstrup, and Andersen 2020). These policies, however, are mainly tied to length or type of occupation, time spent in the labour market, and health capacity to work, and only marginally include considerations of living arrangements ("Denmark - Old-Age Pension, Early Retirement and Survivors - Employment, Social Affairs & Inclusion - European

Commission" n.d.; *Lov Om Ændring Af Lov Om Social Pension Og Forskellige Andre Love* 2019). Increasing awareness of the mortality differentials that exist in terms of living arrangements is crucial in order to develop policies aimed at more broadly reducing inequalities in access to retirement. Historically, Denmark has allowed single women to retire 5 years earlier than the rest of working Danes (62 years instead of 67). This shows that mortality inequalities associated with marital status have been taken into account in the past (Sørensen 2018).

Tailoring retirement systems to living arrangements certainly has its drawbacks and it has been argued that the reduction of inequalities might not be the main objective of retirement systems (Vanhuysse, Medgyesi, and Gal 2021). However, the existence of such large inequalities and especially their widening with time questions the effectiveness of those policies that should ensure similar opportunities and economic returns to everyone. Such policies (e.g. health prevention campaigns) should explicitly take into account the differences in the population, including those in living arrangements and the differences in resources they entail. But while some policies may be the designated mean to mitigate the inequalities we have highlighted, pension policies should take care not to magnify these further by looking through averages at an extremely heterogeneous population.

Limitations

By considering a single household type per person, we neglect the dynamic nature of living arrangements. Analyses not shown here reveal that most of the individuals analysed remain in the same household type throughout the observation period. However, the likelihood of transitioning between household types was lower for individuals who spent most of this period married or cohabiting. Given that household transitions can have a strong effect on mortality, especially when concerning couple dissolutions (Williams and Umberson 2004; Liu 2012), part of the mortality disadvantage that we capture for individuals living alone and in complex households could be related to a higher number of transitions, rather than to the fact of living alone or in a complex household itself. A sequence analysis or multistate modelling approach could better account for transitions in household type throughout the observation period while increasing the complexity of the analysis and influencing the interpretation of the results.

We did not have access to data on the number of children ever born. Therefore, we used the number of children coresident with the individual when aged 40, as a proxy for parity. In Denmark children tend to leave the home around age 18, meaning that we would especially miss individuals who had children before age 22 and after age 40. For the cohorts under study, up to 26% of children were born to women outside of our age range. This is due to the considerable proportion of women having children between ages 18 and 22, especially childless women, meaning up to 35% of first-born children were born to women outside of our age-range[2]. This represents a strong limitation to our analyses when considering the number of children. While we control for education level and household type, other characteristics could be influencing whether women had children before age 22, e.g. health, which could in turn act on the relationship we find between number of children and mortality. Our analysis might therefore underestimate the selection of childless women and, consequently, their disadvantage. We expect this limitation to be less relevant for men, as fathers tend to be older than mothers. We could have considered the number of co-resident children at an earlier age. However, given the time coverage of Danish registries, this would have further restricted the number of cohorts under study, undermining the interest of the analyses. By using a fixed measure, we also cannot capture variations in the number of coresident children. This is particularly important in the case of blended families. However, given that we are considering relatively old cohorts, we expect the proportion of blended families to be rather small. The correspondence

[2] Own analyses on data from the Human Fertility Database (Jasilioniene et al. 2016)

between coresiding with children at age 40 and being married for most of the time between age 50 and 65 (Figure 1B) supports this hypothesis.

We also do not include any information on health. While health characteristics are also thought to influence the probability of entering a partnership (Requena and Reher 2021), controlling for both SES and health would have risked excessively fragmenting the population. Already by controlling for SES only, some groups (especially complex households, the smallest sub-population) showed substantial year-to-year variations. Future research should take advantage of the wealth of information on health contained in the Danish registries.

Finally, based on these findings we cannot claim any causal relationship between living arrangements and mortality. However, we believe that this does not substantially limit the scope of this paper, as our aim was to identify disadvantaged sub-groups within the Danish population and quantify the magnitude of their disadvantage in light of a specific retirement policy.

Conclusion

Within the framework of the recent policy linking retirement age with national life expectancy, we set out to analyse differentials in mortality and its improvement across cohorts of Danish residents, depending on their living arrangements. Using the population-wide data available in the Danish registries, we could construct several mortality measures by characteristics such as household type, number of children and SES. Because these data are longitudinal, rather than cross-sectional, we were not limited to a period perspective, but could instead adopt a cohort approach, more suited to investigations of pension policies. Focusing on mortality between ages 50 and 65, we found that single and childless individuals are consistently disadvantaged on multiple dimensions regardless of length of education. They are more likely to die before reaching retirement and experience greater lifespan variation, a measure that has been linked to higher uncertainty about one own's time at death and possibly to lower investments into one's old age (Edwards and Tuljapurkar 2005). They also experienced slower improvements in mortality between cohorts born in 1936 and 1954. These results suggest that they would be particularly disadvantaged by a retirement age that increases synchronously with national life expectancy. Given that most of the focus on inequalities in term of retirement tends to be on measures of SES, and especially occupation, we want to highlight how other dimensions of life, in this case living arrangements, should also be considered when setting up early retirement schemes and prevention programmes.

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Figure 1 – Prevalence of household type by length of education (A), household type by number of children (B) and number of children by length of education (C) and by sex, birth cohorts 1936 – 1954 or 1946 – 1954.

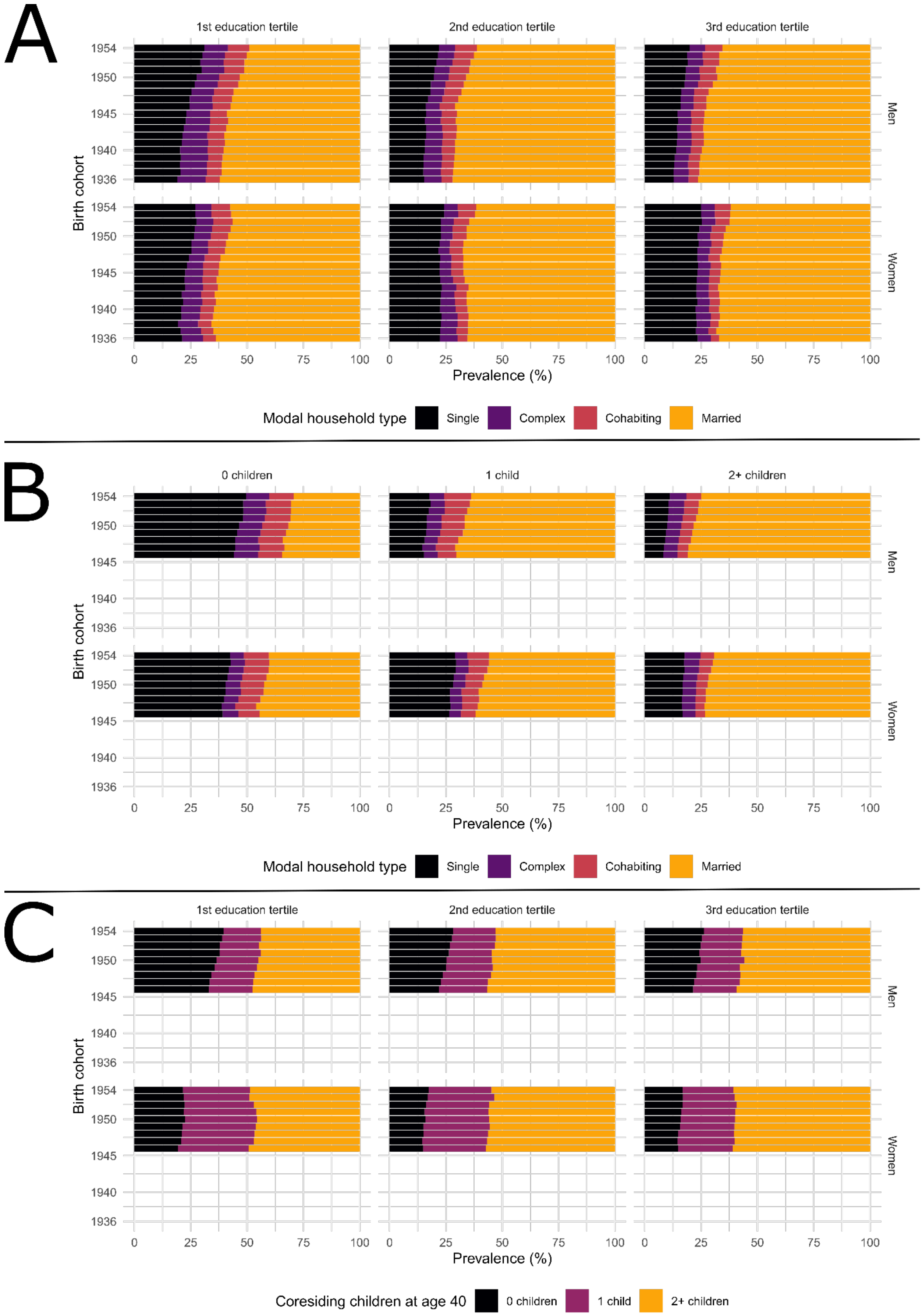


Figure 2 – Probability of dying between ages 50 and 65 by household type and length of education (A), household type and number of children (B) and number of children and length of education (C) and by sex, birth cohorts 1936 – 1954 or 1946 – 1954.

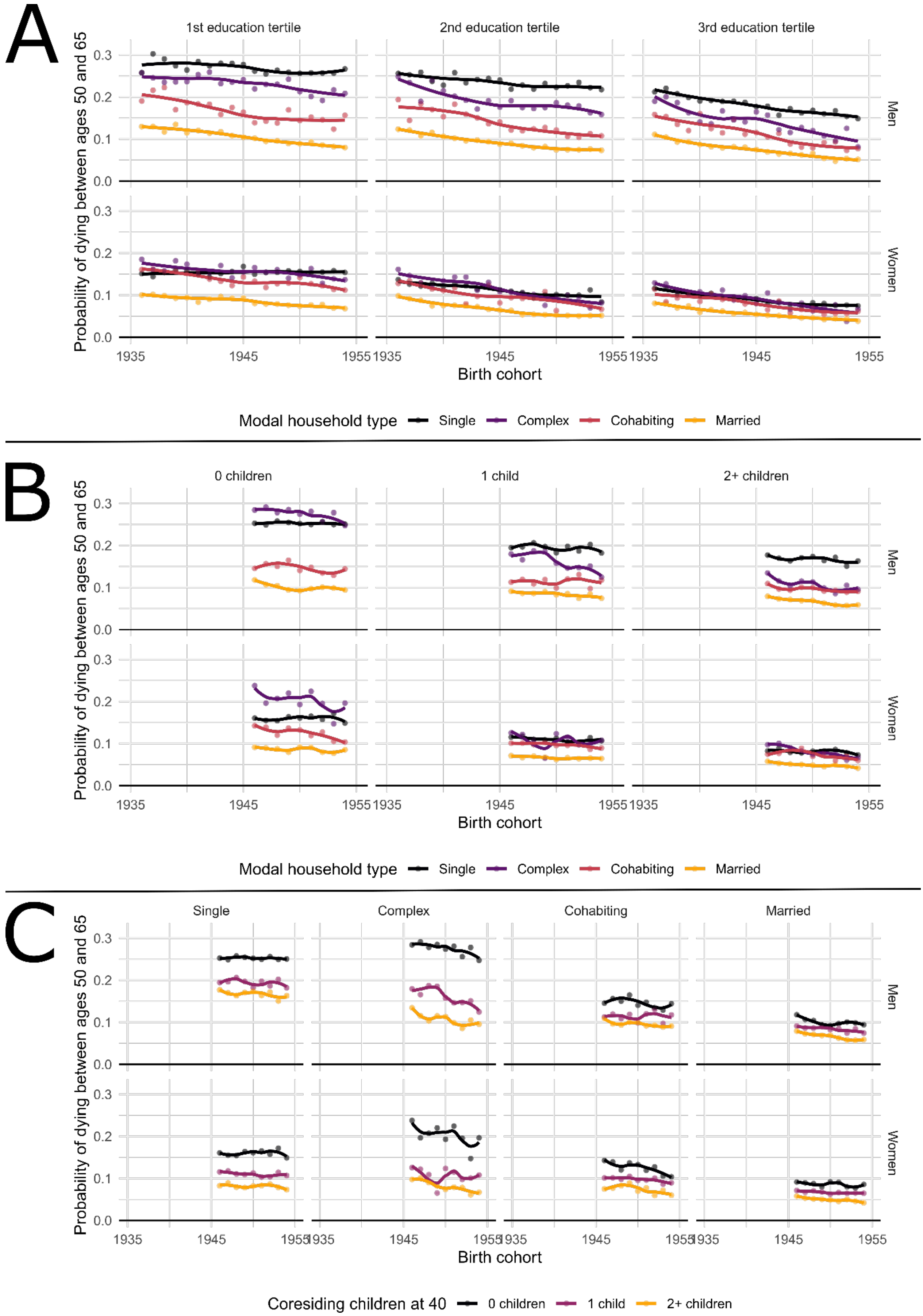


Figure 3 – Average yearly rate of mortality improvement by household type and length of education (A), household type and number of children (B) and number of children and length of education (C) and by sex, birth cohorts 1936 – 1954 or 1946 – 1954.

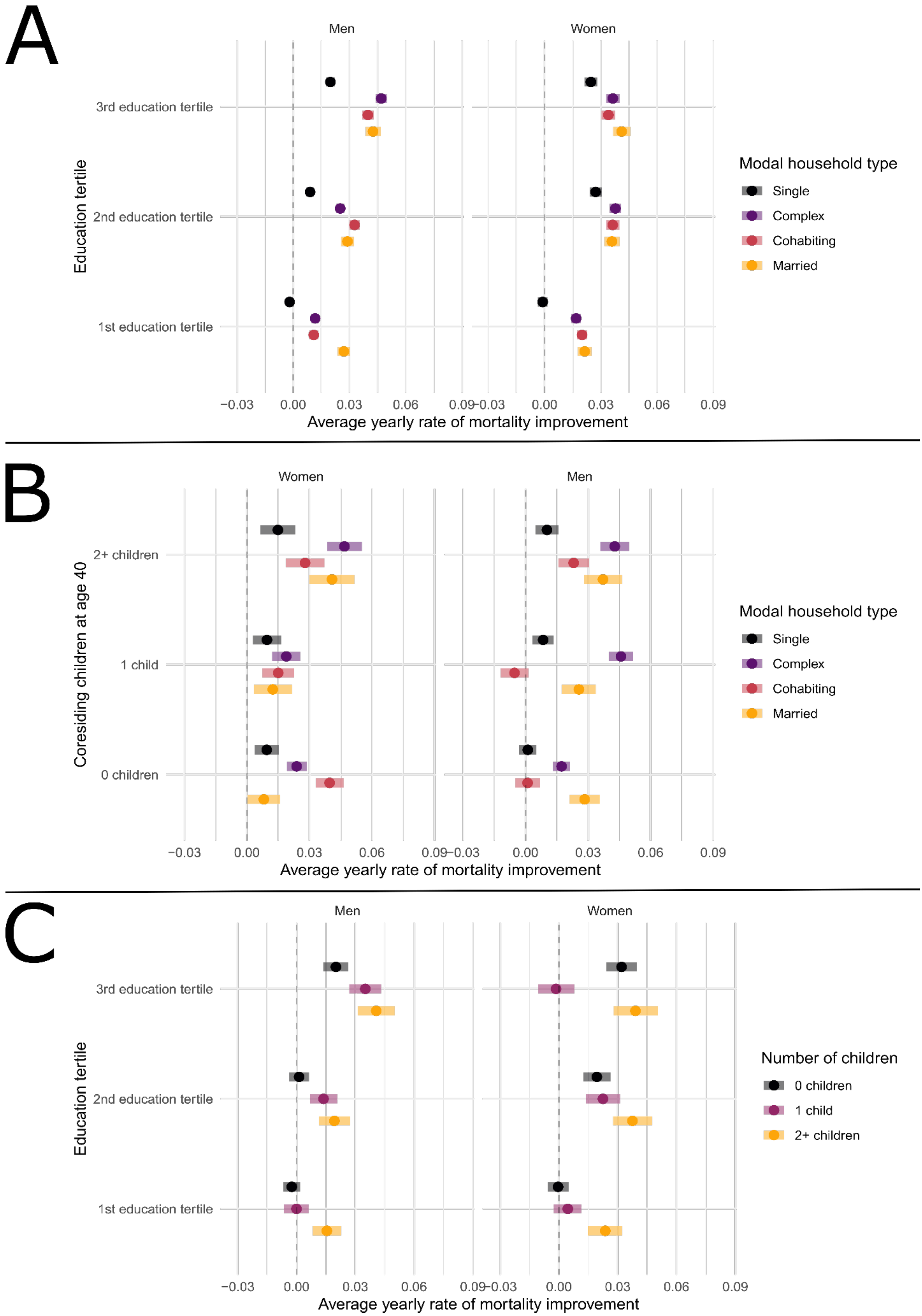
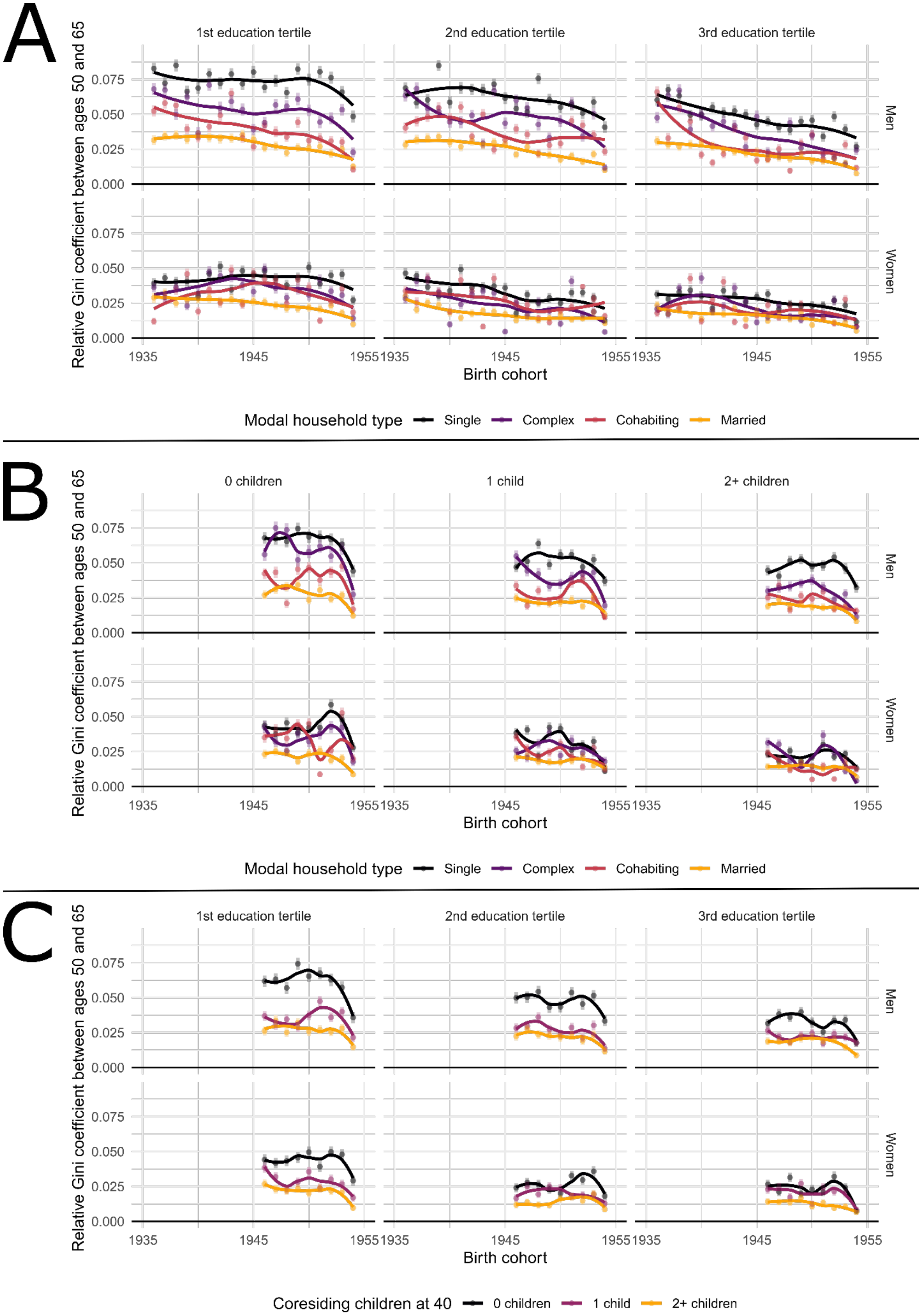
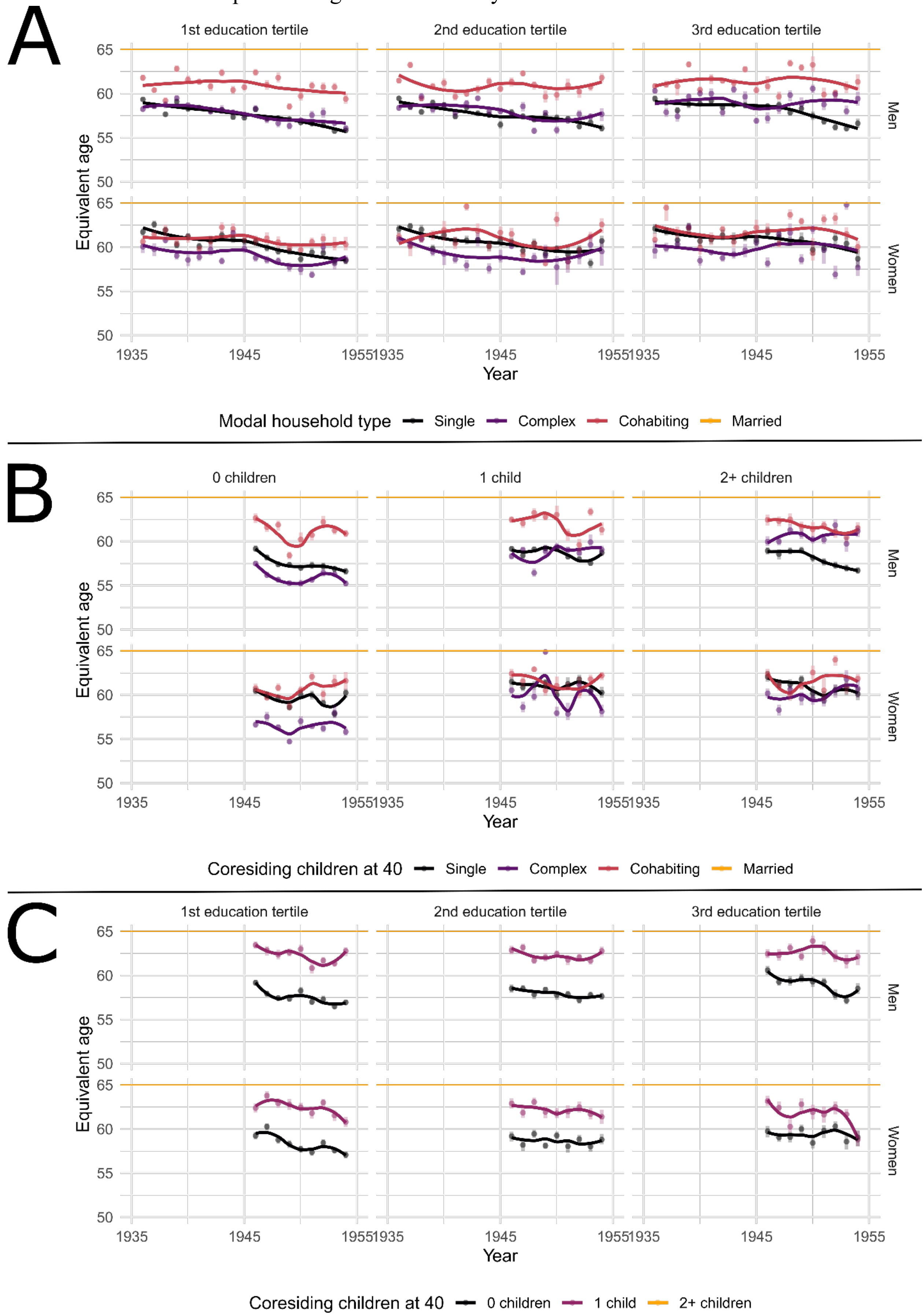


Figure 4 – Relative Gini coefficient between ages 50 and 65 by household type and length of education (A), household type and number of children (B) and number of children and length of education (C) and by sex, birth cohorts 1936 – 1954 or 1946 – 1954.



Note. The Gini coefficient can be interpreted as the average difference between the ages at death between random pairs of individuals in the population. It represents how unequal ages at death are within a (sub-)population.

Figure 5 – Equivalent age by household type and length of education (A), household type and number of children (B) and number of children and length of education (C) and by sex, birth cohorts 1936 – 1954 or 1946 – 1954. Reference for equivalent age calculation in yellow.



Note. The equivalent age shows at which age an individual alive at age 50 in a (sub-)population (e.g. single men) has the same probability of dying as an individual from a reference group between age 50 and 65. The reference group is shown with the yellow line and consists of married individuals in panels A and B and in individuals with at least two children in panel C.

Appendix A – Coefficient of variation

Figure A1 – Coefficient of variation by household type and length of education (A), household type and number of children (B) and number of children and length of education (C) and by sex, birth cohorts 1936 – 1954 or 1946 – 1954.

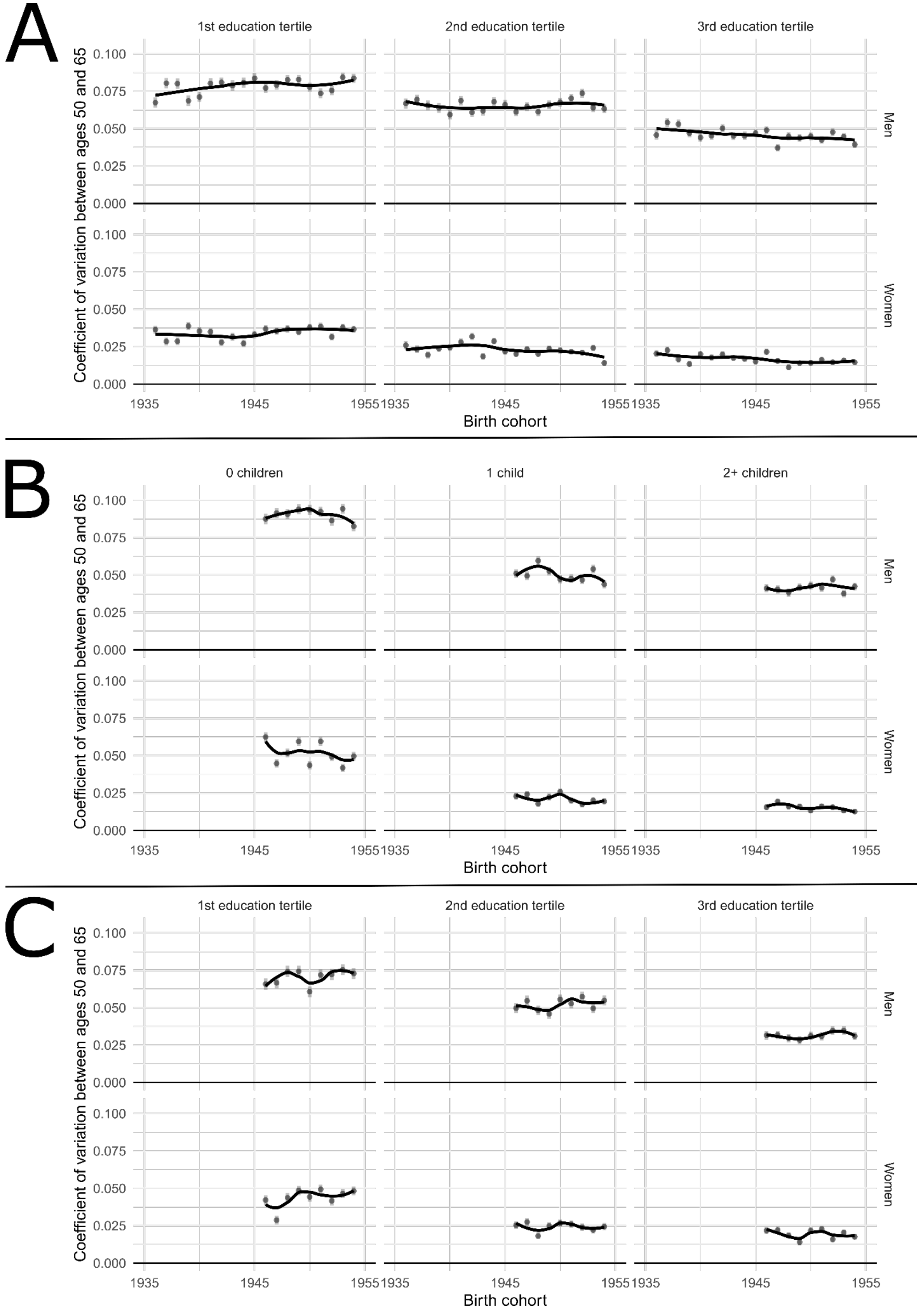
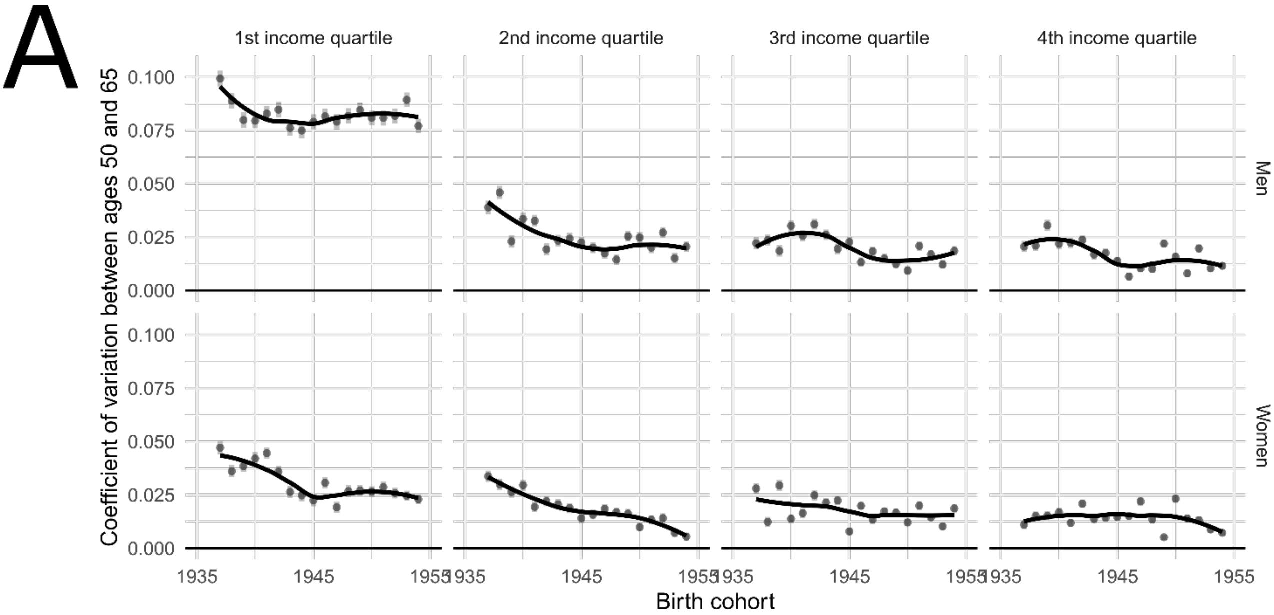


Figure A2 – Coefficient of variation by household type and family disposable income (A) and household type and occupation type (B) and by sex, birth cohorts 1936 – 1954 or 1946 – 1954.



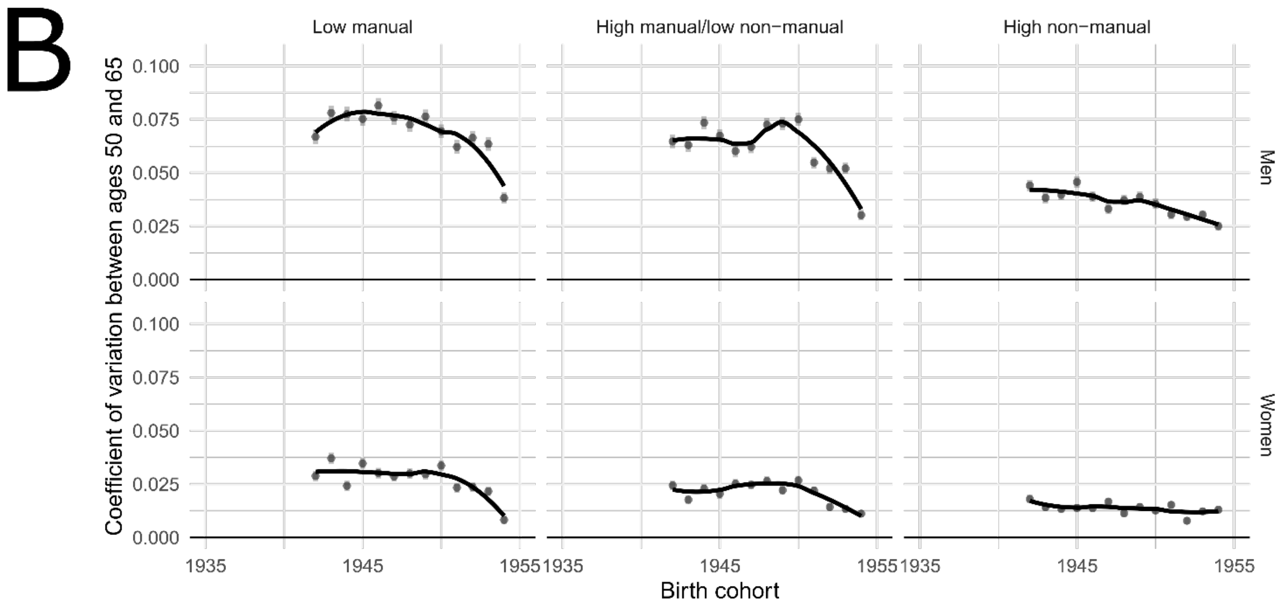


Figure A3 – Coefficient of variation by number of children and household type (A), number of children and family disposable income (B) and number of children and occupation type (C) and by sex, birth cohorts 1936 – 1954 or 1946 – 1954.

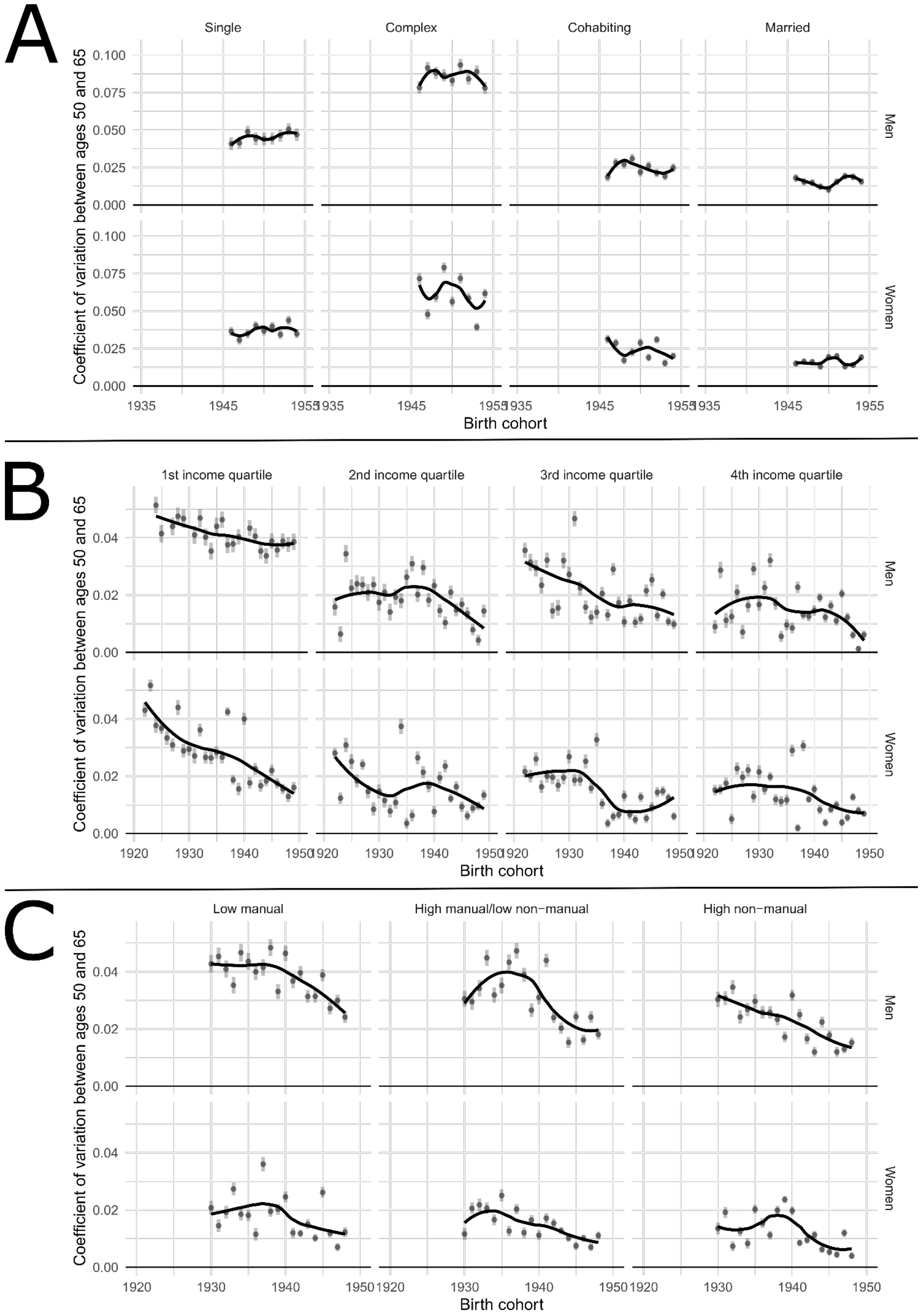
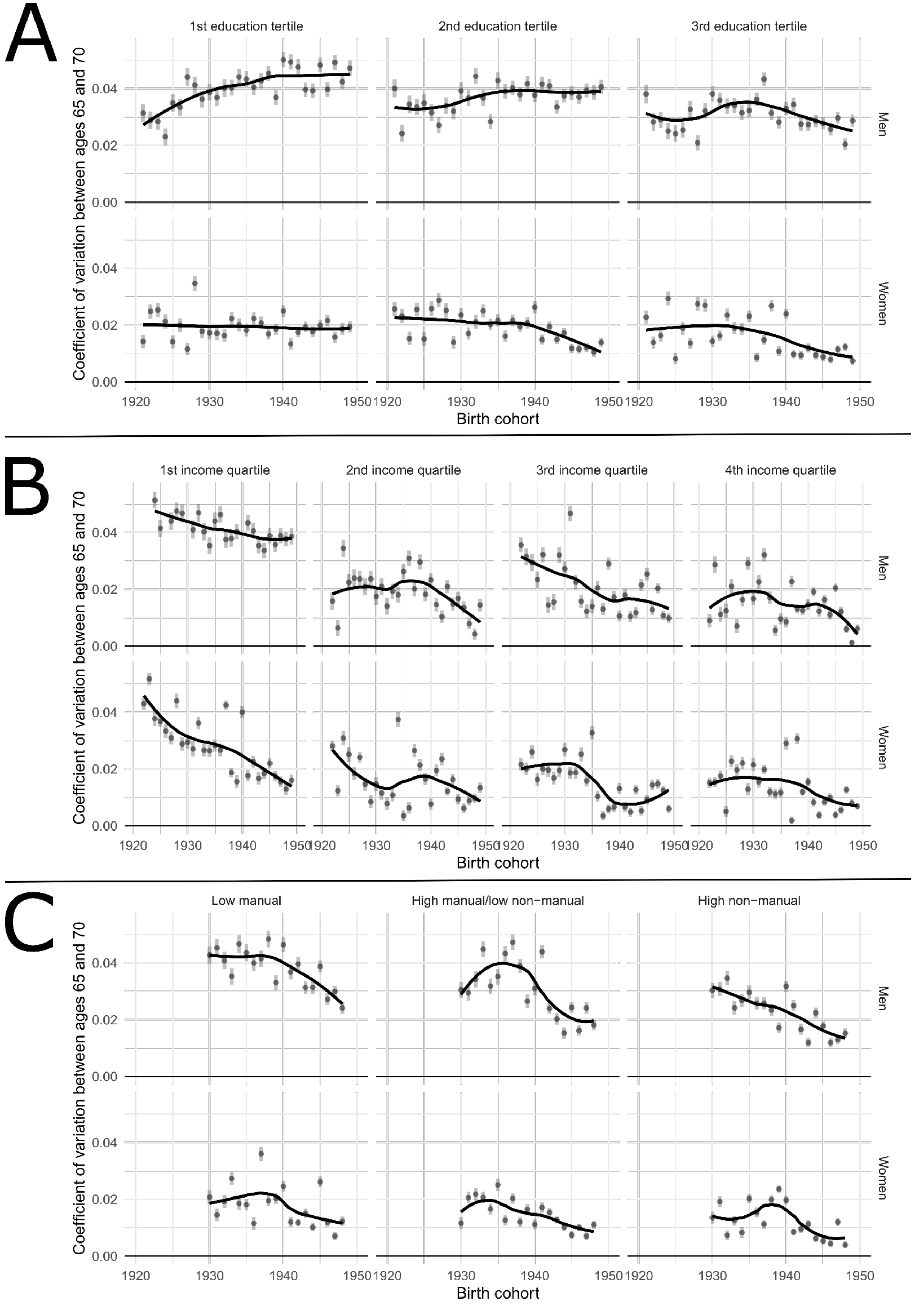


Figure A4 – Coefficient of variation by household type and length of education (A), household type and family disposable income (A) and household type and occupation type (B) and by sex, birth cohorts 1921 – 1949 or 1931 – 1949, ages 65 – 70.



Appendix B – Results for ages 65 to 70

Figure B1 – Prevalence of household type by length of education (A), household type by family disposable income (B) and household type by occupation type (C) and by sex, birth cohorts 1921 – 1949 or 1931 – 1949, ages 65 – 70.

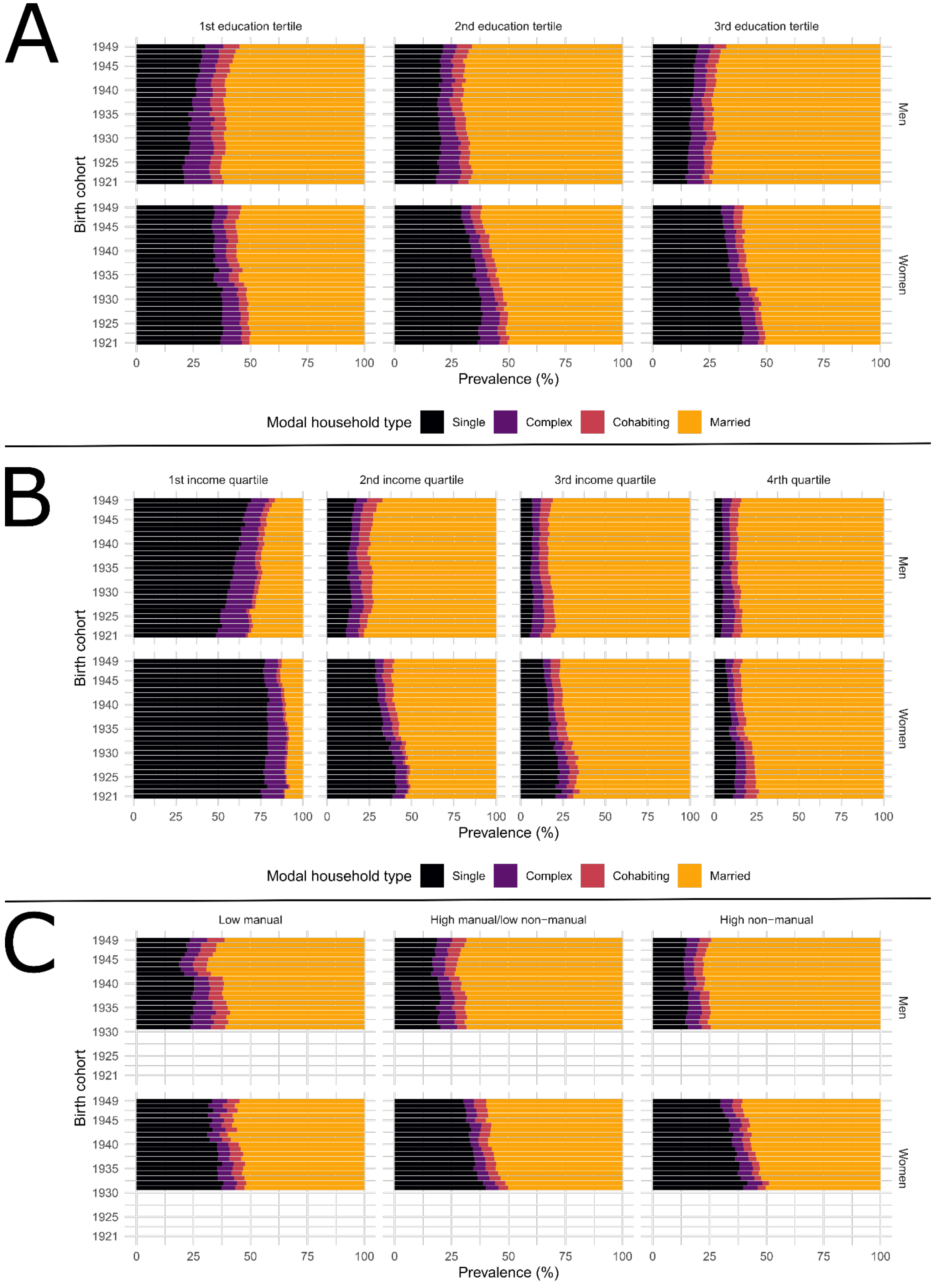


Figure B2 – Probability of dying between ages 65 and 70 by household type and length of education (A), household type and number of children (B) and number of children and length of education (C) by sex, birth cohorts 1921 – 1949 or 1931 – 1949.

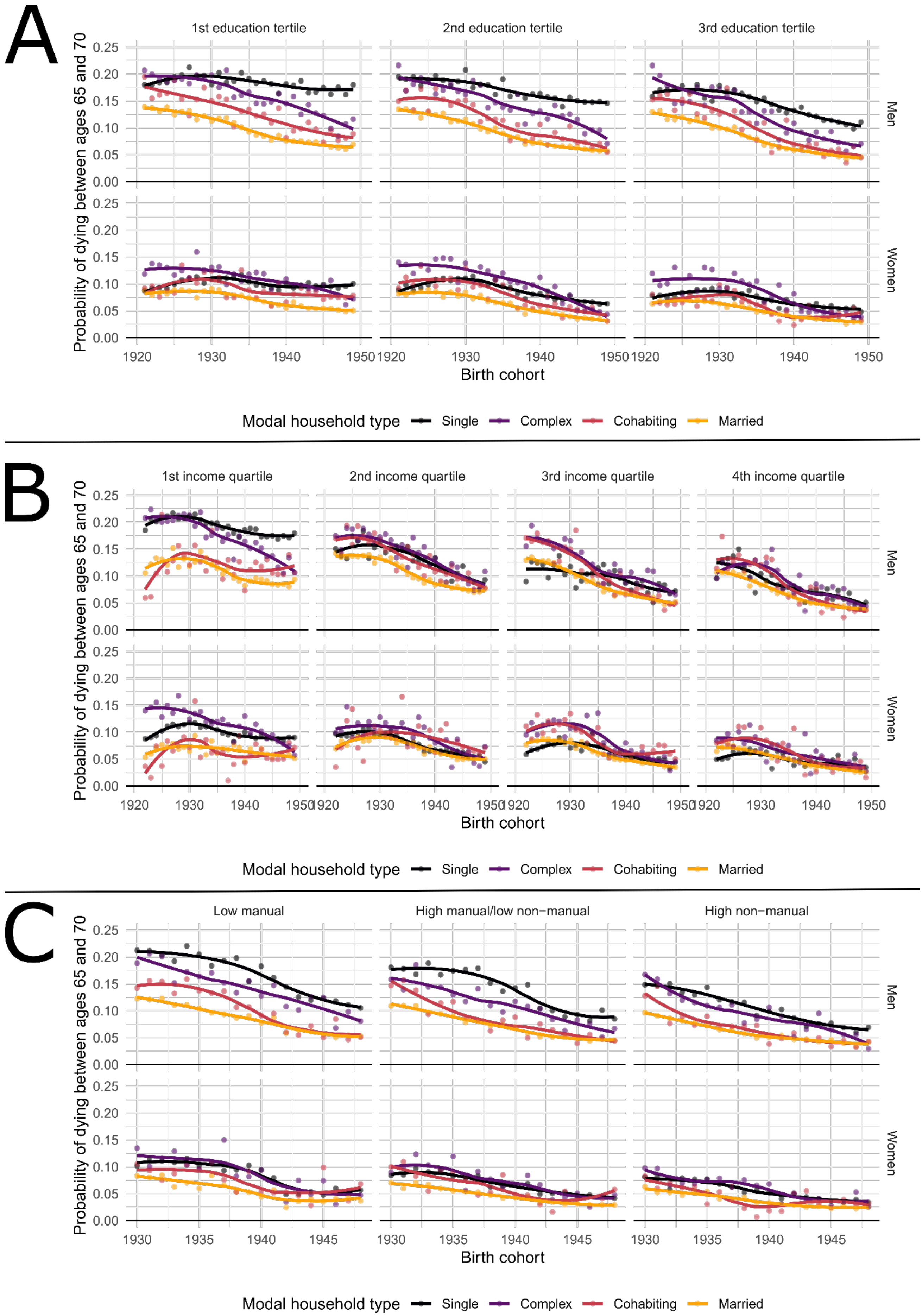


Figure B3 – Average yearly rate of mortality improvement by household type and length of education (A), household type and number of children (B) and number of children and length of education (C) and by sex, birth cohorts 1921 – 1949 or 1931 – 1949, ages 65 – 70.

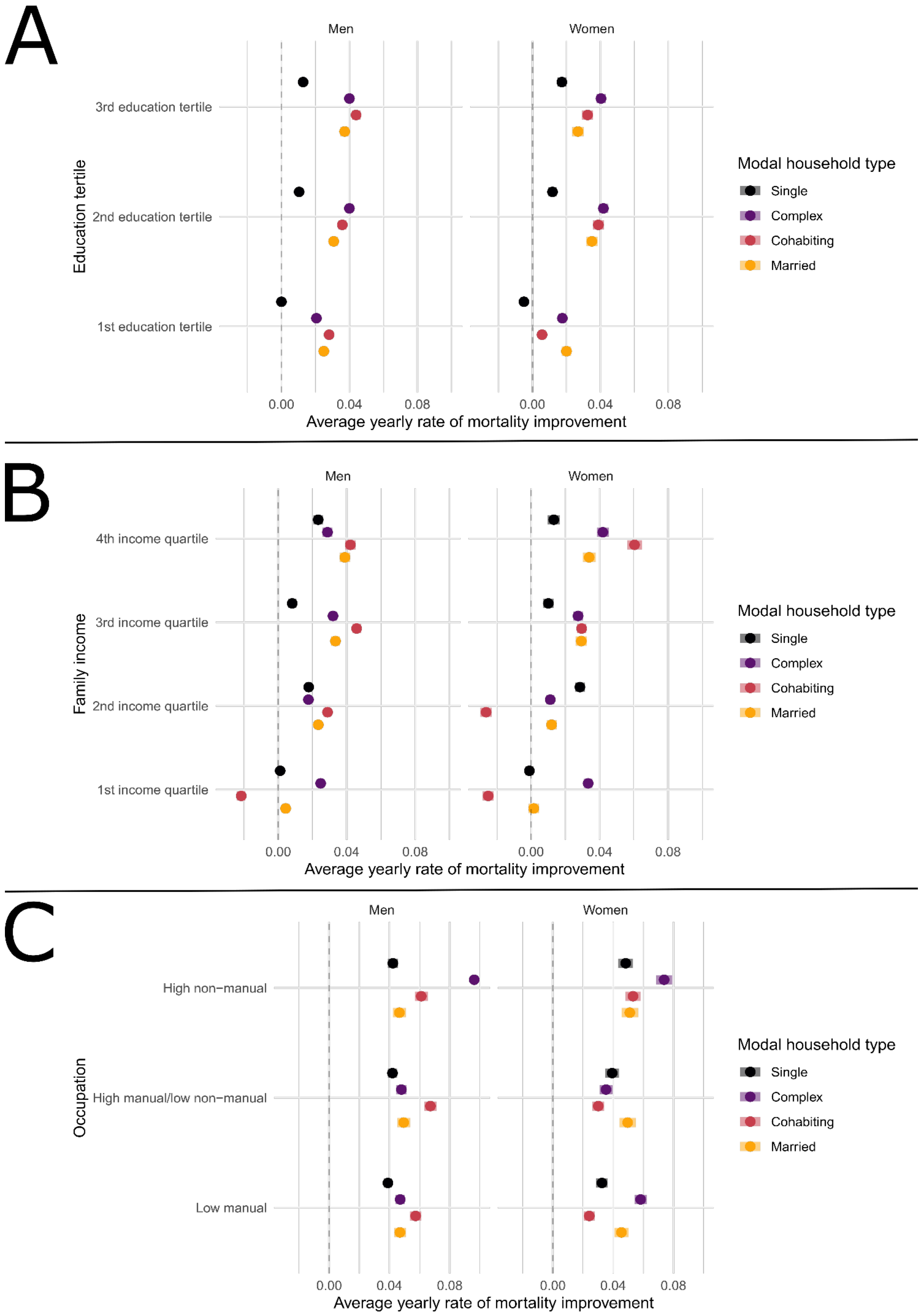


Figure B4 – Relative Gini coefficient between ages 65 and 70 by household type and length of education (A), household type and number of children (B) and number of children and length of education (C) and by sex, birth cohorts 1921 – 1949 or 1931 – 1949.

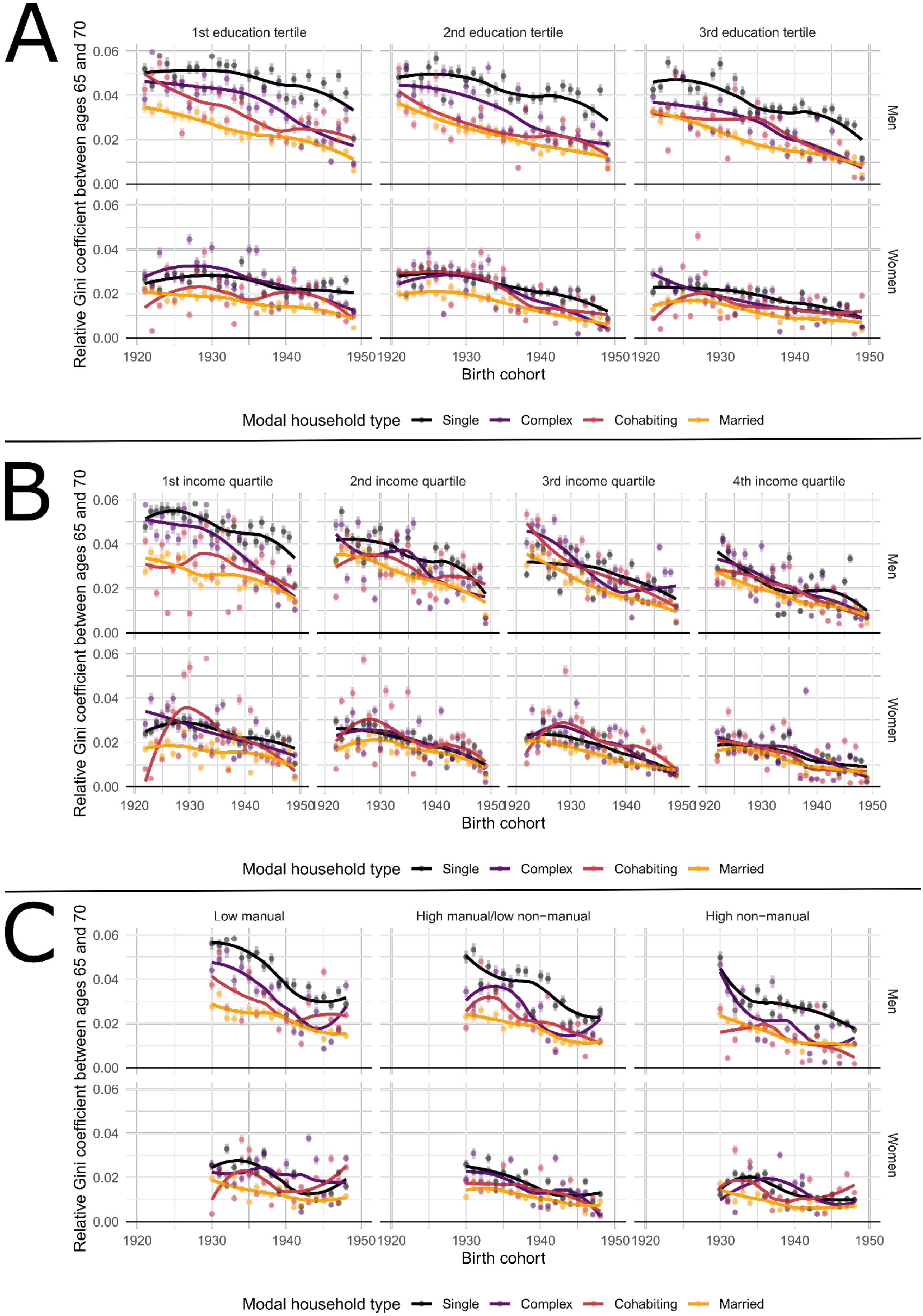
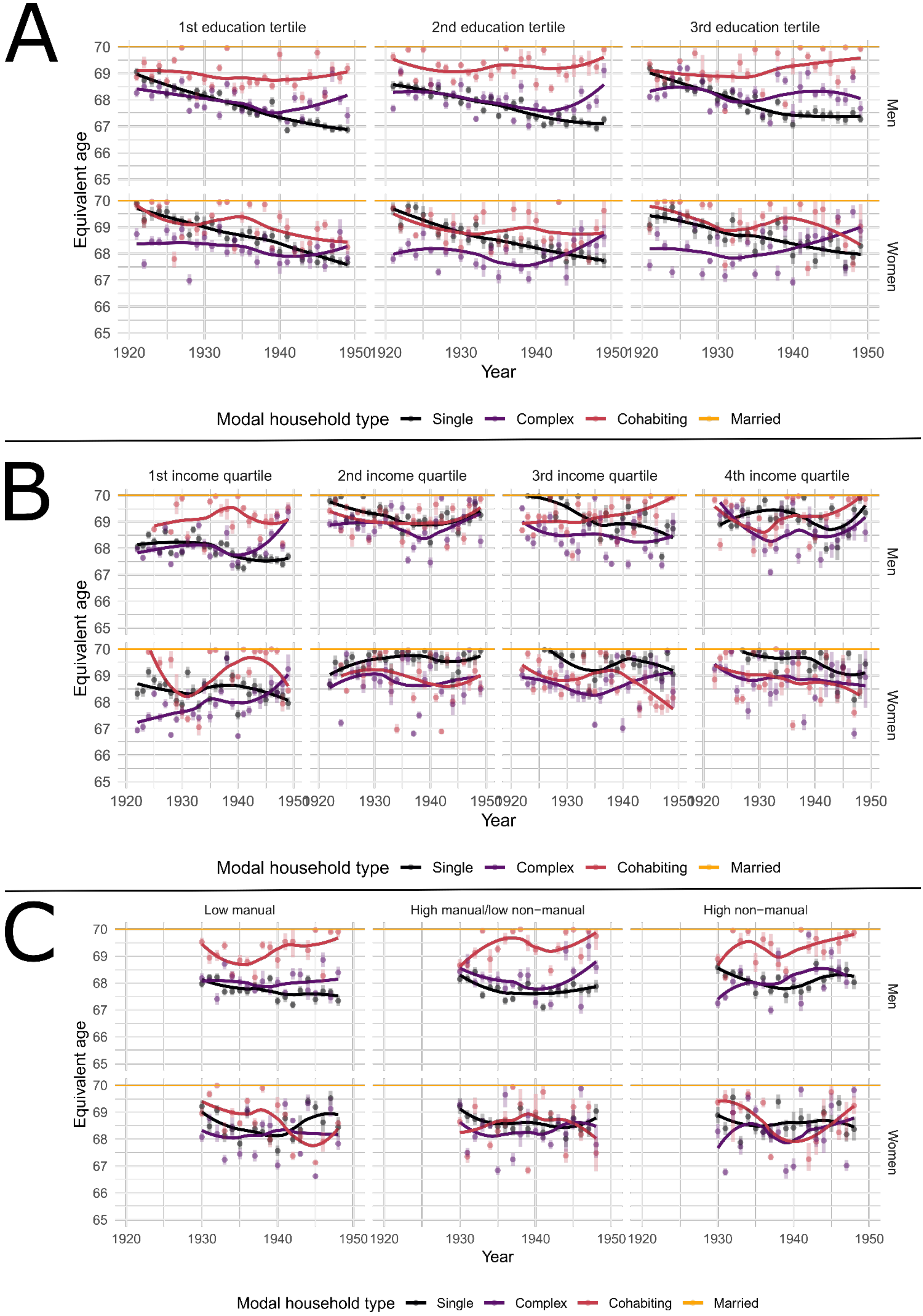
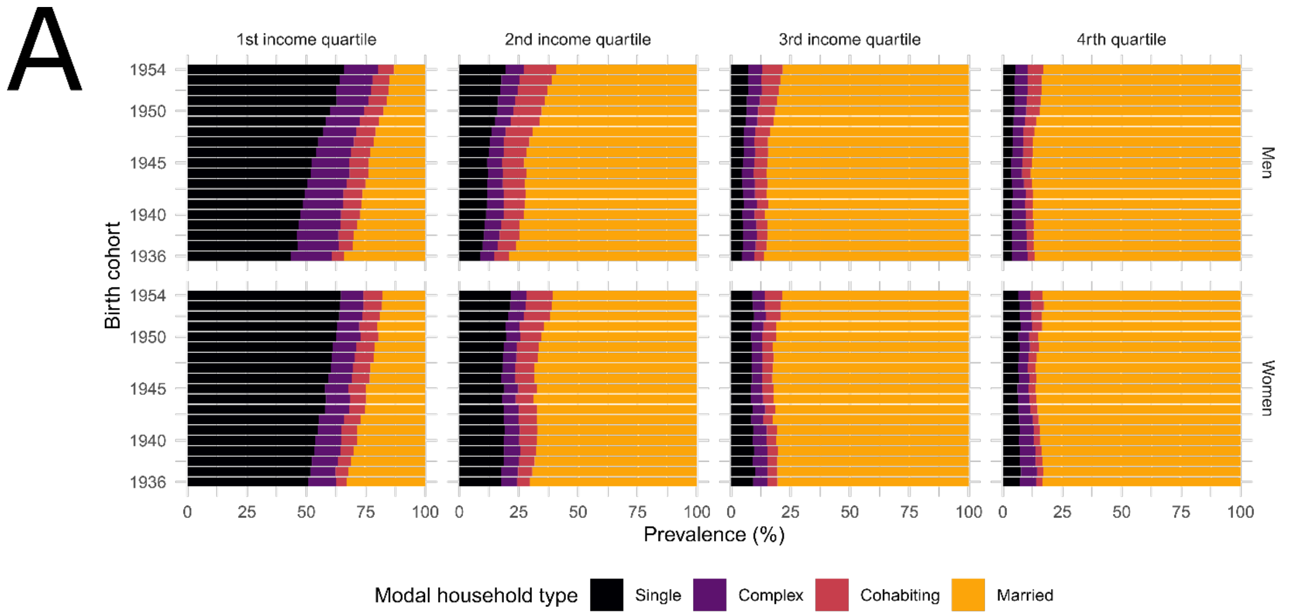


Figure B5 – Equivalent age by household type and length of education (A), household type and number of children (B) and number of children and length of education (C) and by sex, birth cohorts 1921 – 1949 or 1931 – 1949, ages 65 – 70. Reference for equivalent age calculation in yellow.



Appendix C – Results for additional variables, ages 50 to 65

Figure C1a – Prevalence of household type by family disposable income (A) and by occupation type (B) and by sex, birth cohorts 1936 – 1954 or 1946 – 1954.



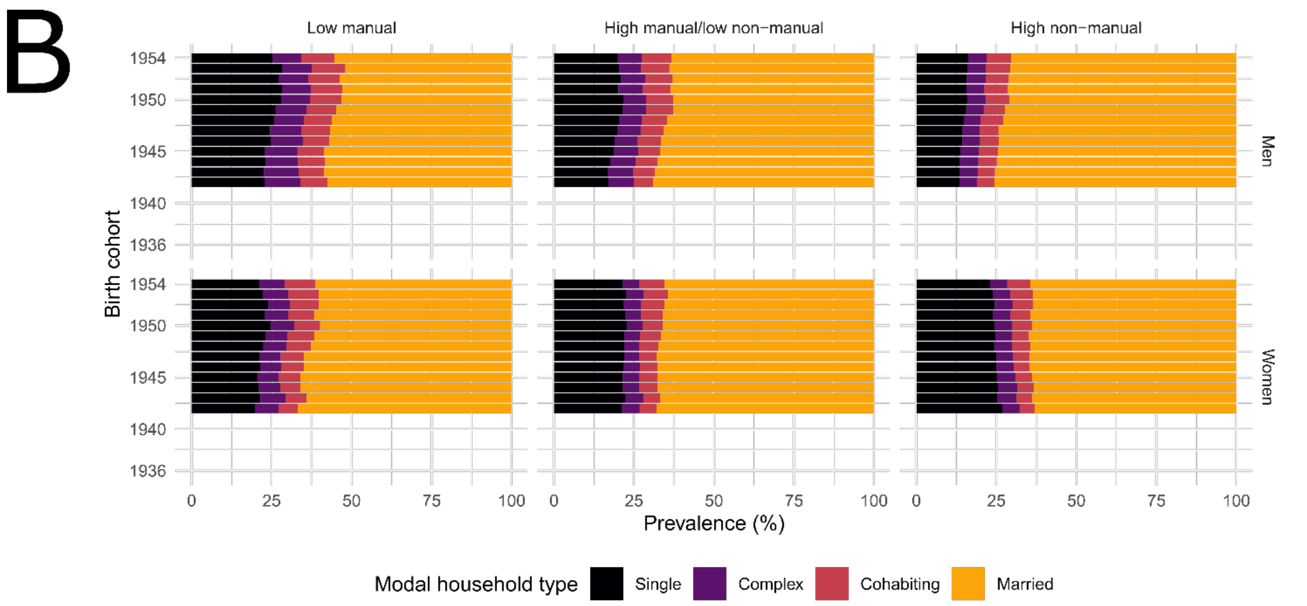


Figure C1b – Prevalence of number of children by household type (A), by family disposable income (B) and by occupation type (C) and by sex, birth cohorts 1936 – 1954 or 1946 – 1954.

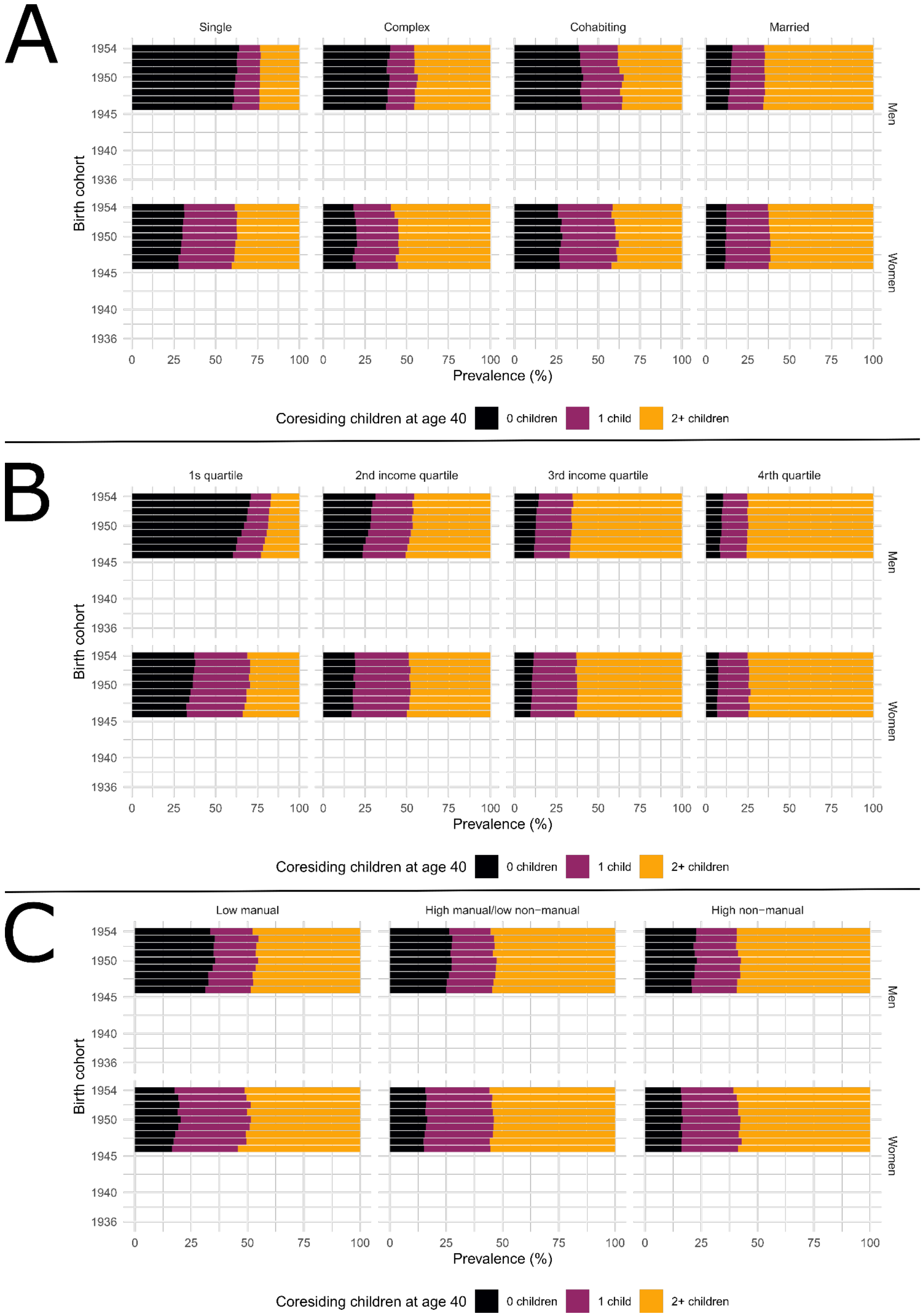
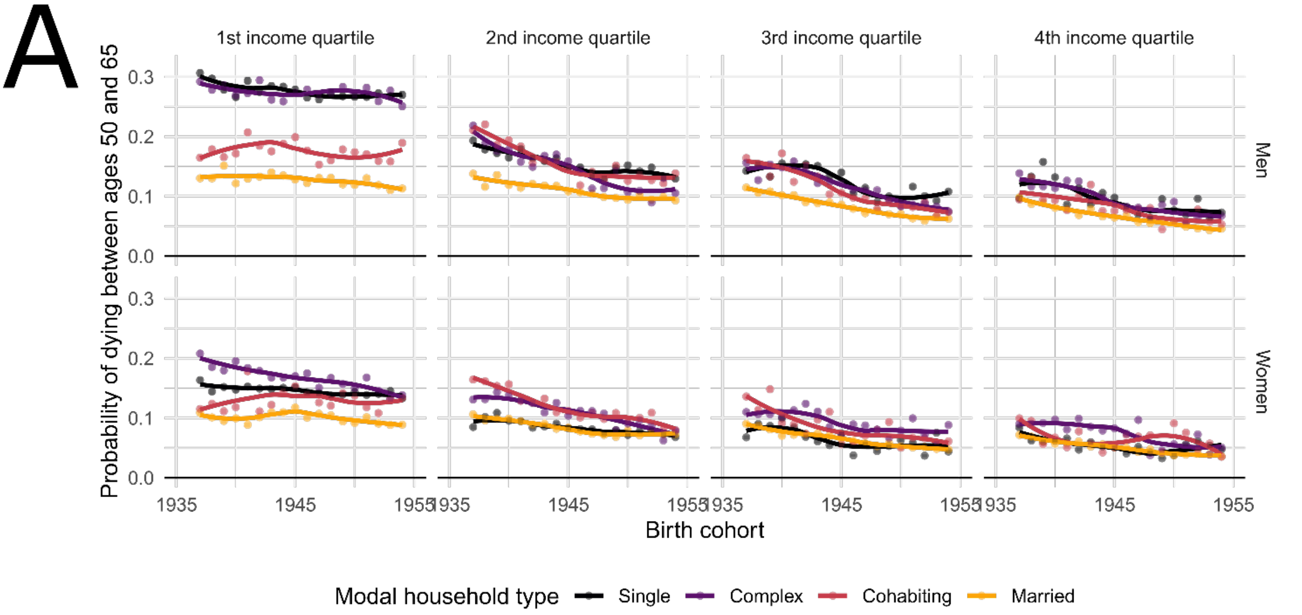


Figure C2a – Probability of dying between ages 50 and 65 by household type and family disposable income (A) and by household type and occupation type (B) and by sex, birth cohorts 1936 – 1954 or 1946 – 1954.



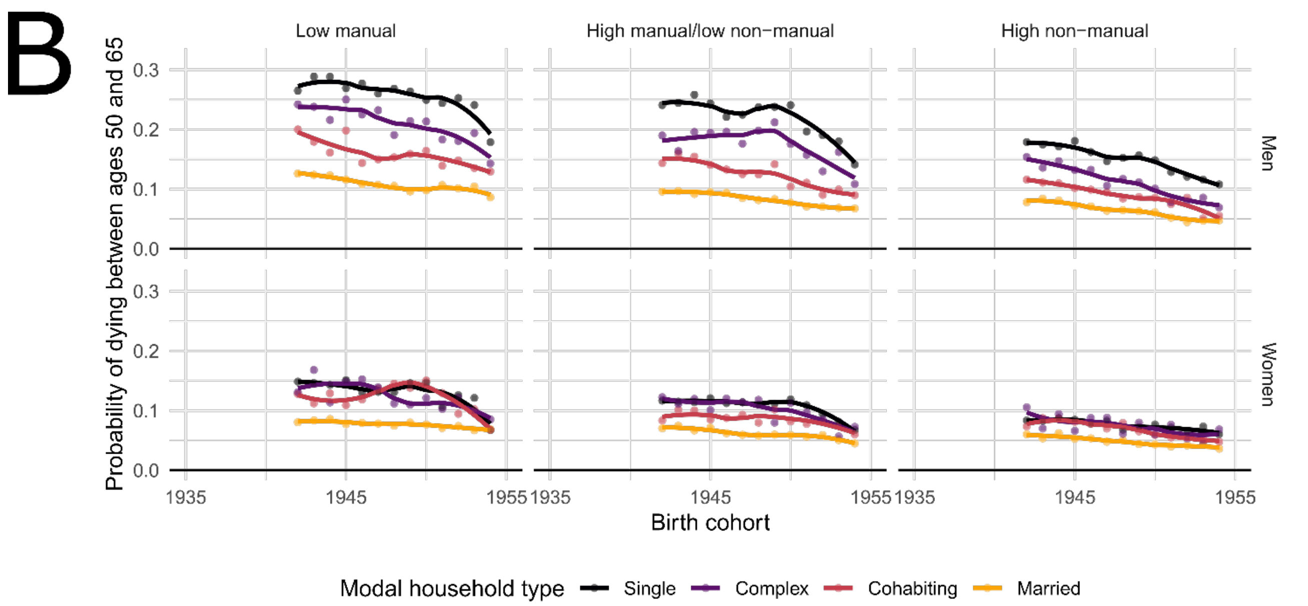
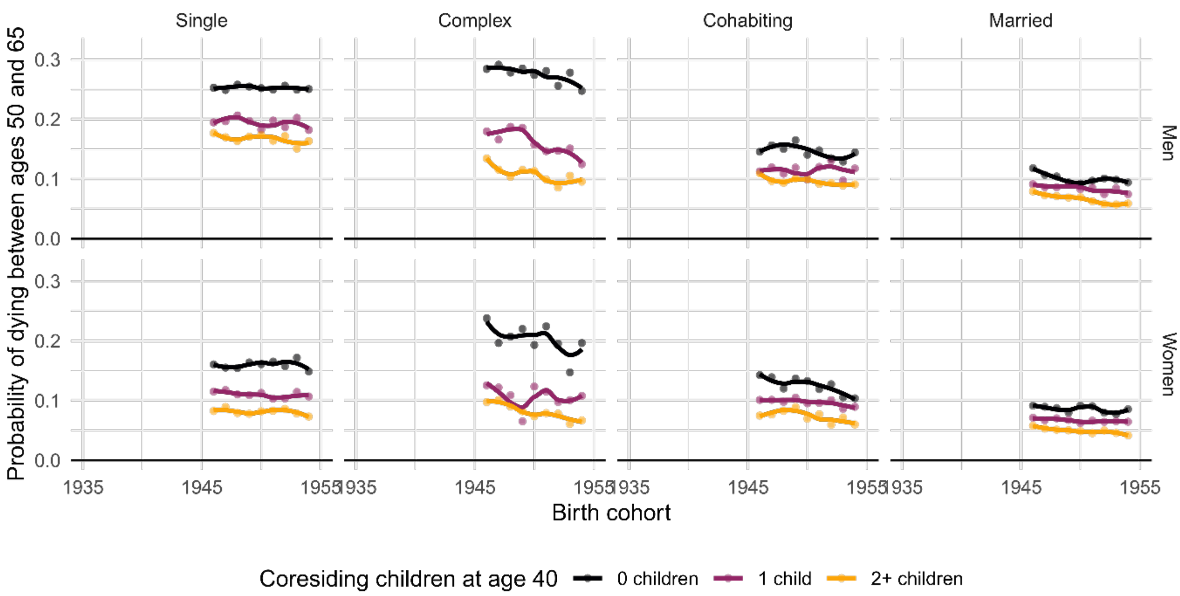
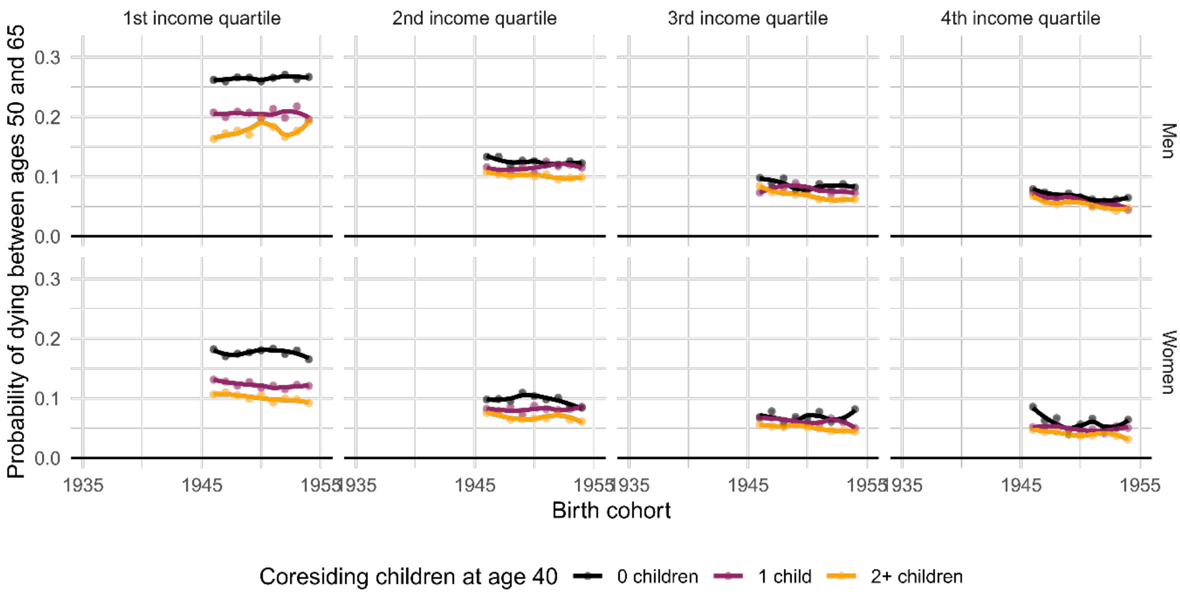


Figure C2b – Probability of dying between ages 50 and 65 by number of children and household type (A), by number of children and family disposable income (B) and by number of children and occupation type (C) and by sex, birth cohorts 1936 – 1954 or 1946 – 1954.

A



B



C

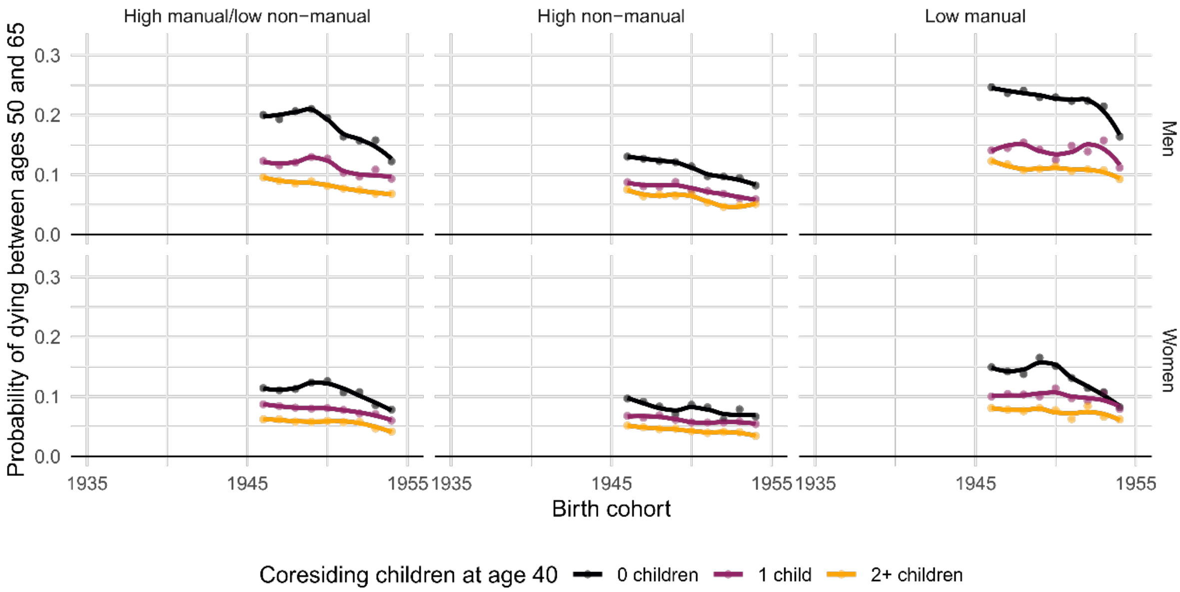


Figure C3a – Average yearly rate of mortality improvement by household type and family disposable income (A) and by household type and occupation type (B) and by sex, birth cohorts 1936 – 1954 or 1946 – 1954.

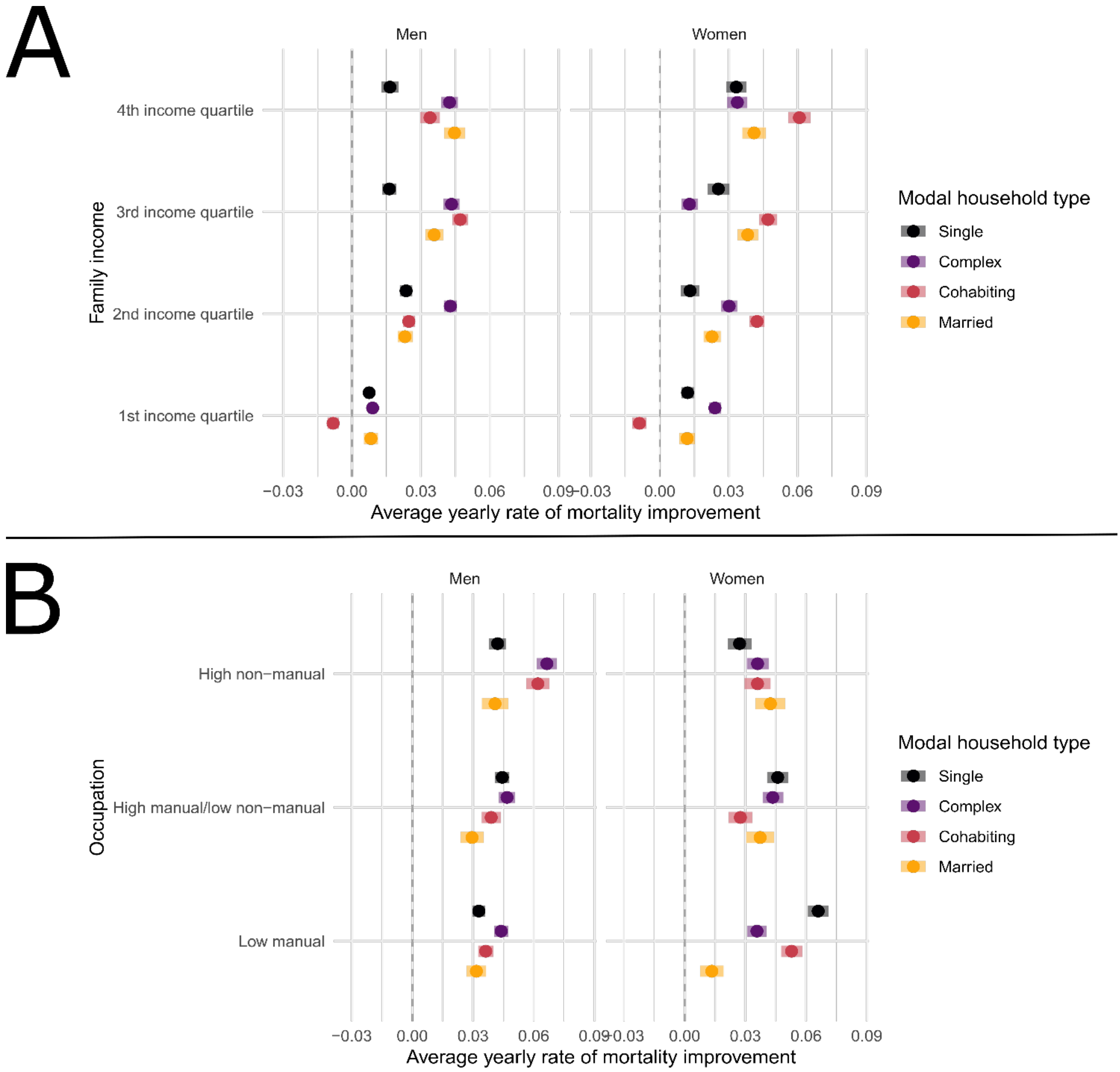


Figure C3b – Average yearly rate of mortality improvement by number of children and household type (A), by number of children and family disposable income (B) and by number of children and occupation type (C) and by sex, birth cohorts 1936 – 1954 or 1946 – 1954.

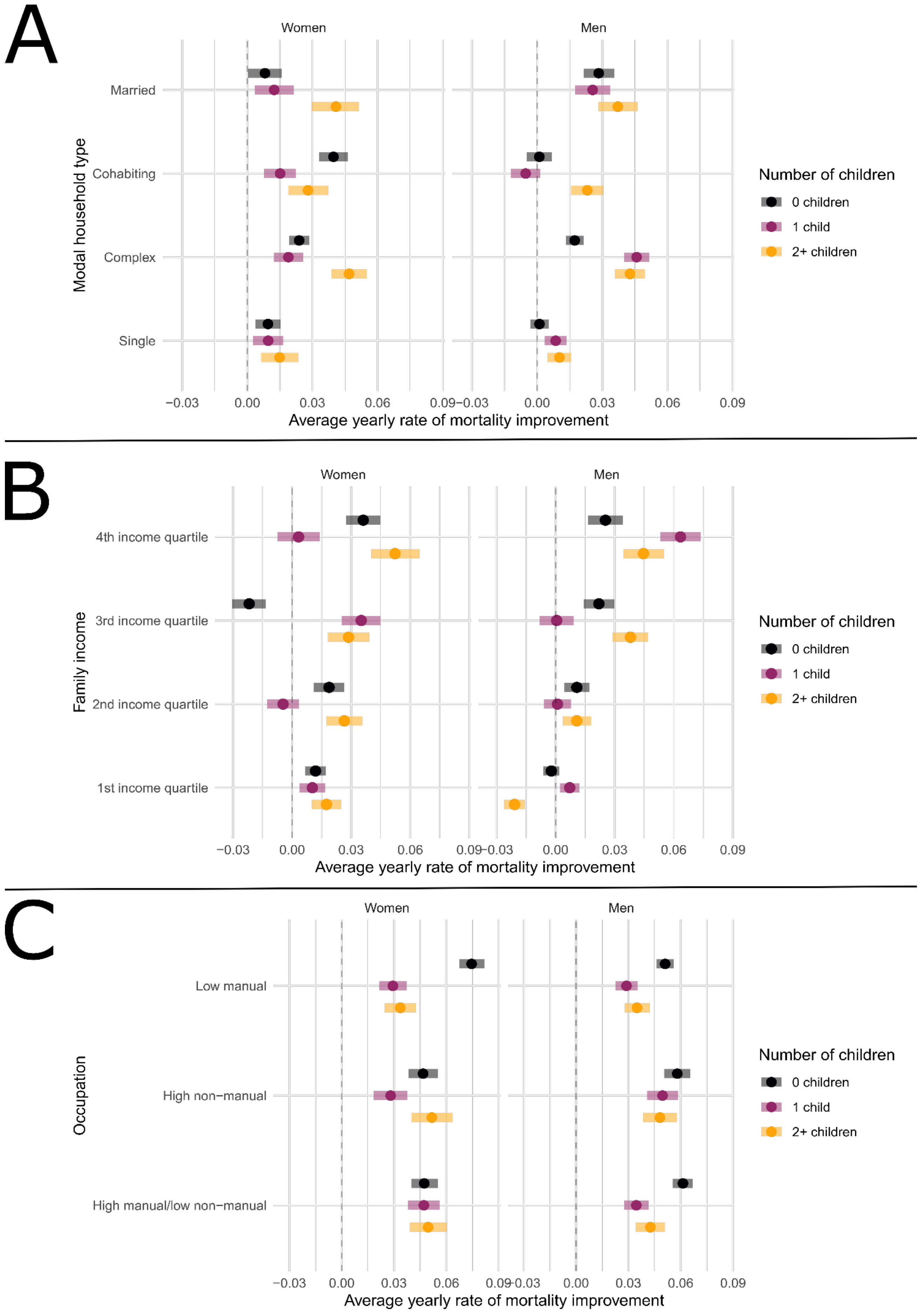


Figure C4a – Relative Gini coefficient between ages 50 and 65 by household type and family disposable income (A) and by household type and occupation type (B) and by sex, birth cohorts 1936 – 1954 or 1946 – 1954.

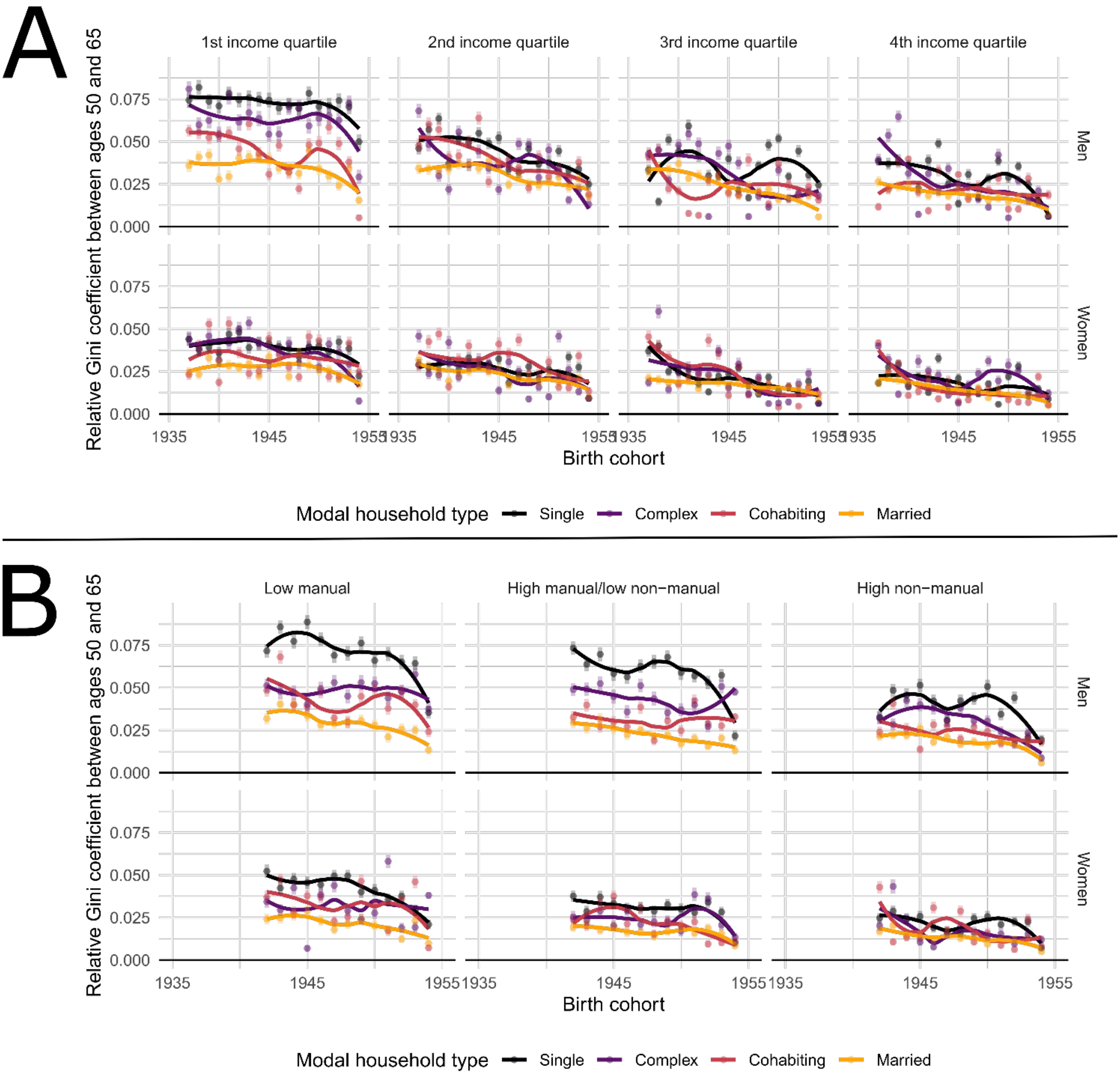


Figure C4b – Relative Gini coefficient between ages 50 and 65 by number of children and household type (A), by number of children and family disposable income (B) and by number of children and occupation type (C) and by sex, birth cohorts 1936 – 1954 or 1946 – 1954.

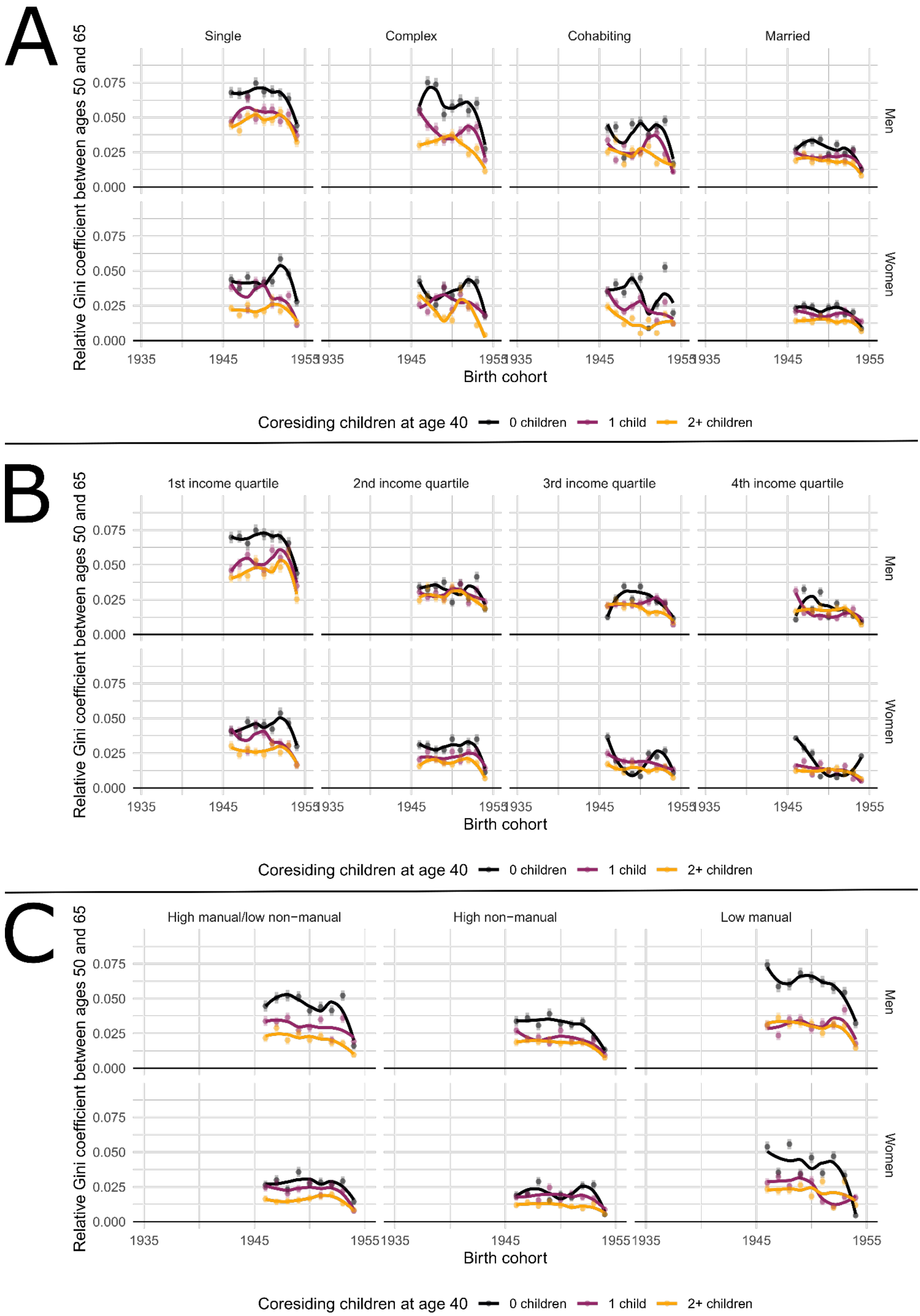
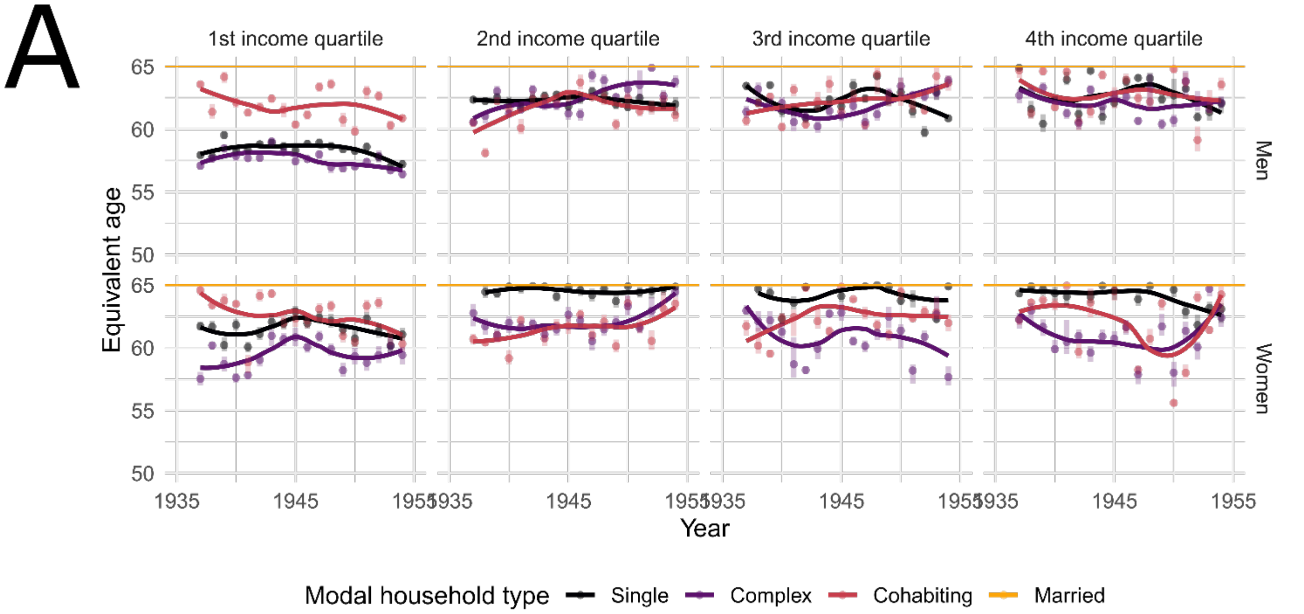


Figure C5a – Equivalent age by household type and family disposable income (A) and by household type and occupation type (B) and by sex, birth cohorts 1936 – 1954 or 1946 – 1954. Reference for equivalent age calculation in yellow.



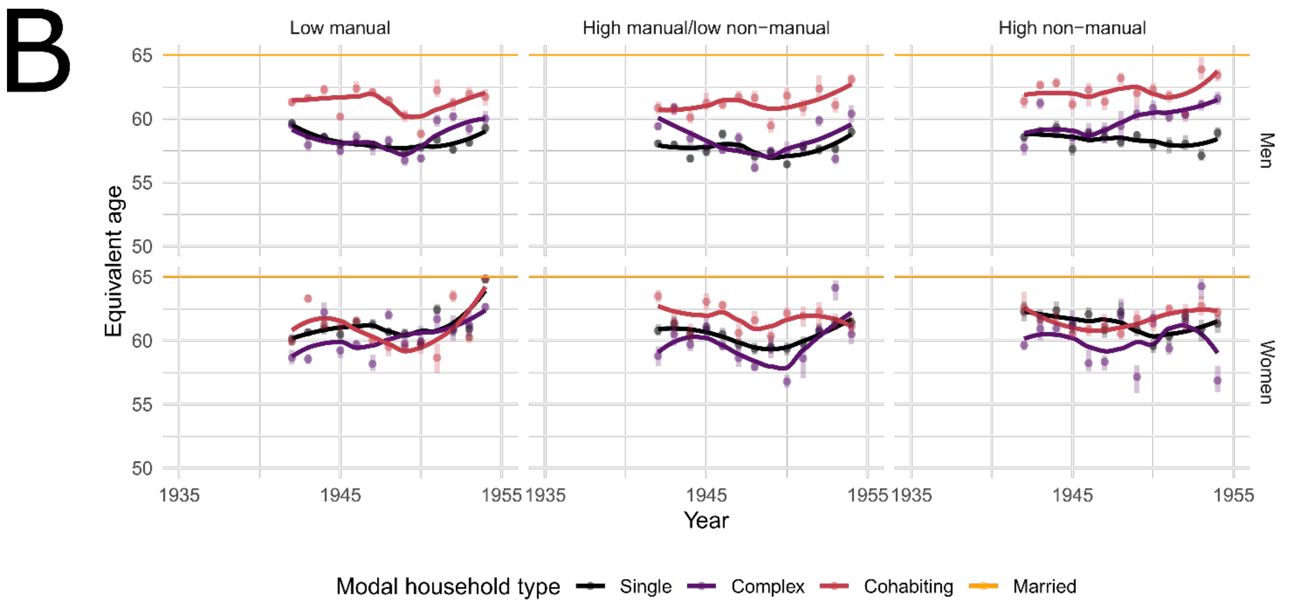
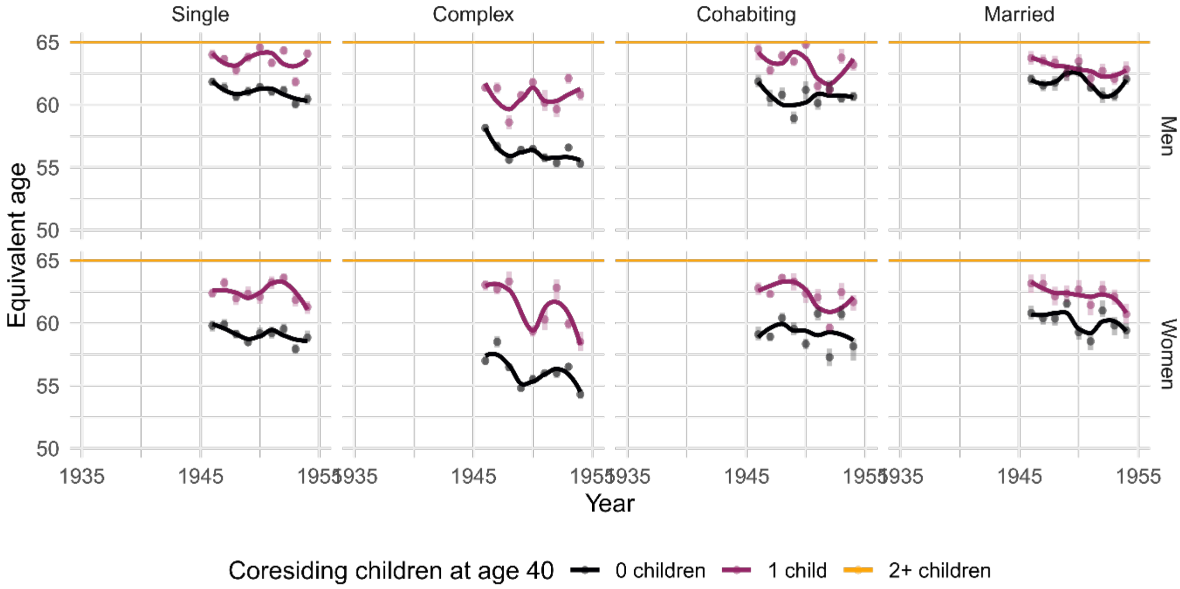
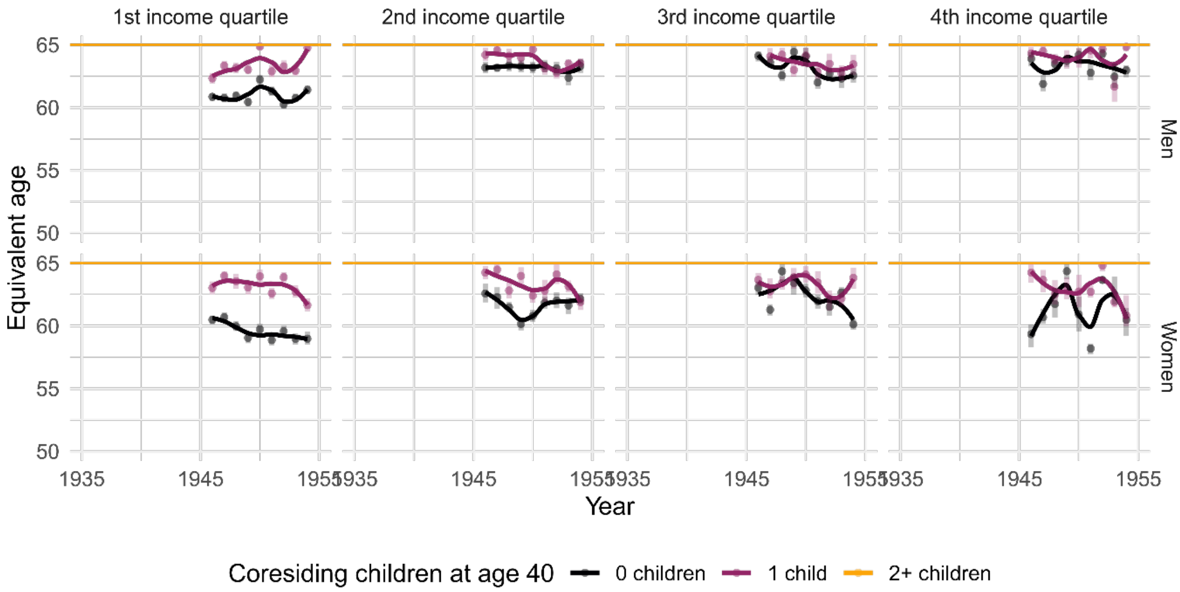


Figure C5b – Equivalent age by number of children and household type (A), by number of children and family disposable income (B) and by number of children and occupation type (C) and by sex, birth cohorts 1936 – 1954 or 1946 – 1954. Reference for equivalent age calculation in yellow.

A



B



C