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Abstract

Period fertility has declined rapidly in Norway in the 2010s, reaching record lows. While there is a clear education-fertility dynamic, significant educational shifts have occurred and it's unclear how much this contributed to recent fertility declines. To disentangle this, we utilize high-quality Norwegian register data and model yearly transitions between educational enrolment, attainment and childbearing for men and women born in 1964-2002. Using a counterfactual approach, we explore the contribution of educational expansion versus lower fertility by education to the decline in period and cohort fertility. Forecasting is used to complete fertility for cohorts aged 30+. We found that educational expansion contributed partially to the observed cohort fertility decline (2.11-2.01) for 1964-1974 female cohorts but stagnated for younger cohorts and the predicted decline thereafter (1.76 by the 1988 cohort), and the 2010s period fertility decline, is fully driven by decreased fertility across educational levels. For men, educational expansion was slower and didn't contribute to the fertility decline. For both genders, the contribution of changed fertility behavior was strongest among the lower educated, particularly for predicted ultimate childlessness. Our results suggest that increased education isn't the main fertility barrier in contemporary Norway. Instead, socioeconomic resources increasingly promote childbearing for both genders.

Keywords: Educational attainment, educational enrollment, fertility decline, Norway, multi-state model, fertility forecasting

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Introduction

Fertility rates in the Nordic countries, and in many parts of Europe, have seen a consistent decline since the 2010s. Between 2010 and 2022, the total fertility rate (TFR) in Norway dropped from 1.95 to 1.41, reaching the lowest level seen yet (Statistics Norway, 2023). While the decline in cohort fertility – which is not sensitive to the timing of births – shows a less steep decline, it is projected to decline significantly across more recent cohorts (Hellstrand et al., 2021). This is surprising, as traditionally the Nordic countries have experienced quite stable cohort fertility rates near replacement level, and the declines in period fertility are often attributed to the postponement of first births with higher fertility rates at older ages (Andersson et al., 2009; Jalovaara et al., 2019). Previous research has shown that first births are a significant contributor to the fertility decline observed in the Nordic countries, with 83% of the decline in Norway attributable to first births (Hellstrand et al., 2021). At the same time, the rates of ultimate childlessness have increased across cohorts, especially for men (Jalovaara et al., 2019).

To explain these observed fertility trends, educational expansion has often been tied to changes in both the timing of births, and the overall number of children. In the Nordic countries, however, educational expansion has previously been linked to the postponement of births with a recuperation in later ages and a weak association with overall cohort fertility or ultimate childlessness in women (Andersson et al., 2009). While previously the cohort fertility rates remained quite stable, the projected decline in cohort fertility brings into question whether educational expansion may explain part of the decline. However, although participation in higher education has increased across cohorts in Norway and particularly for women[1], the rates of dropout from upper secondary school have stagnated at nearly 30% since 1994 (Markussen et al., 2010, 2011). The expansion of higher education and stagnation of education at lower levels may

[1] Increasing from 19% in 1951 to 56% in 2009 (Lindbekk, 2015).

have differing effects on period and cohort fertility and ultimate childlessness, and disentangling these educational trends can provide an improved understanding of the general fertility decline and rising rates of ultimate childlessness.

Previous research has found somewhat stronger declines in first births during the 2010s among Nordic women with low educational attainment (Comolli et al., 2021). For cohort fertility, Jalovaara et al. (2019) find a convergence across educational groups in women born between 1970 and 1974, and for ultimate childlessness, they find not only a convergence across education groups, but a reversal of trends, with the lowest educated women experiencing the highest rates of childlessness. Among men, they find a widening gap in cohort fertility and ultimate childlessness between those with low education and those with medium and high education (Jalovaara et al., 2019). Given these striking inequalities in fertility and ultimate childlessness by educational attainment, it is important to understand the extent to which trends in fertility are driven by changes in the birth rates of different educational groups or by changes in educational enrollment and attainment across cohorts.

In this study, we contribute to the literature in several aspects. By combining cohort fertility forecasting, multistate modeling, and a counterfactual approach we disentangle the contributions of educational changes to the fertility decline for women and men still at childbearing ages. Most existing studies decompose the change in completed cohort fertility into educational composition and education-specific fertility only for individuals with completed childbearing histories[2]. Additionally, we examine both the period and cohort fertility perspective, allowing us to disentangle the differential effects of education on both measure of fertility. While looking at period fertility allows us to understand the contribution of education to fertility rates using up-to-date childbearing patterns, it might reflect tempo effects. Forecasts of cohort fertility helps us to study recent 2010s fertility decline without the distorting impact of changes in fertility timing.

In recent decades, many have called for the inclusion of men into fertility research

[2] See for instance Lazzari et al. (2021).

(Goldscheider & Kaufman, 1996; Van Bavel, 2017). However, studies on male fertility, and particularly studies examining men's education and fertility, are still rare. As educational changes are both gendered themselves and can have gender-specific influences on fertility, it is important to include men in fertility research. We fill this knowledge gap by providing estimates of completed cohort fertility and ultimate childlessness for both women and men up to the late 1980s cohorts, and importantly, we attribute the observed and predicted cohort fertility declines and increases in childlessness to changes in behavior – both in pursuing higher education, leaving school early, and childbearing – in different enrolment and attainment states. We also examine the contribution of educational changes to the current period fertility decline between 2010-2018 for both men and women.

Our approach also allows us to better capture and disentangle the impacts of educational enrollment and attainment compared to previous research, as most studies either remove those who are enrolled in education or combine all levels of enrollment into one group. Using age-specific transition probabilities between various educational enrollment and attainment states ("primary & enrolled", "primary & not enrolled", "secondary & enrolled", "secondary & not enrolled", "tertiary & enrolled", and "tertiary & not enrolled") and education- and age-specific fertility rates among both men and women and Norwegian register data covering the entire population, we provide important insights to understanding the drivers of the fertility decline in Norway. As Norway and the Nordic countries are often considered forerunners in family demographic and fertility behavior (Andersson et al., 2009), insights from this study may help to explain fertility trends more broadly in other low-fertility settings.

Education and Fertility: Theoretical Perspectives

Education has a strong link to fertility behaviors on the individual-level in many different aspects. Both actual enrollment in school and intentions for further enrollment can have important implications for fertility decisions, and the educational level attained may impact fertility behaviors through income and knowledge accumulation as well as influences on partnership formation and union stability. Additionally, societal changes and institutional factors may also help explain macro-level fertility changes among educational groups. Below we elaborate on the link between education and fertility in terms of enrollment, attainment, and macro-level societal changes.

Educational Enrollment

Enrollment in education may have an independent and important effect on fertility which can be broadly discussed in terms of two mechanisms; the costs of childbearing and the conflicting roles between student and parent (Kravdal, 2007; Kravdal & Rindfuss, 2008). The first mechanism involves both the economic and time costs associated with childbearing. The effect of time costs implies that students have limited time and of which schooling takes up a large proportion. Thus, students may wish to delay childbearing until after completing their education due to their perceived ability to dedicate the time required to raise a child (Kravdal, 2007). Previous research into the effects of compulsory education expansion on teenage fertility has discussed such time constraints in terms of an "incarceration effect" (Black et al., 2008). These effects of increased time spent in compulsory education are also argued to decrease available time to engage in "risky behaviors" which in turn may impact teenage fertility (Black et al., 2008). Beyond the time costs of childbearing, there are also financial costs related to having a child, and being enrolled in education is typically associated with low income levels (Kravdal, 2007). Thus, given that students are likely to expect an increase in their income once completing education, it may be an advantage to postpone childbearing until after education (Happel et al., 1984). There may also be norms regarding the conflicting roles between student and parent. There may be both inner and outer pressures to complete education before having children, and education can be seen and one of the major prerequisites needed prior to childbearing (Blossfeld & Huinink, 1991).

These constraints are typically discussed in terms of women's fertility, however, men's enrollment may also have an impact on their fertility. In the traditional perspective, the impact of men's enrollment on fertility may be attributed to an income effect rather than a deficit in time

(Kravdal, 2007). However, as men are increasingly involved in the time-intense aspects of childbearing and gender-roles are redefined (Goldscheider et al., 2015), educational enrollment may play an important role in fertility among men in terms of both time and economic costs.

Educational Attainment

As often discussed in the fertility literature, childbearing comes at a cost and thus an increased income is suggested to come with increased fertility (Becker, 1992a; Kravdal, 2007). Since higher educational attainment is often associated with higher incomes, it can be suggested that higher educational attainment results in higher fertility (Becker, 1992b). This "income effect" is often thought to be strongest for men's fertility, however higher education and income among women may influence fertility through an increase in household earnings (Kravdal, 2007). Alternatively, higher education and incomes also comes with an increased opportunity cost when having children, or "substitution effect", especially among women (Becker, 1992b). The larger loss in income potential that is perceived to come with childbearing is argued to result in a tendency for lower fertility desires among higher educated individuals (Becker, 1992b; Kravdal, 2007). An important caveat to the depressive effect of opportunity costs is the increased flexibility often associated with the jobs of higher educated individuals which can help reconcile the parent and worker roles (Kravdal, 2007). Therefore, the overall impacts on fertility through income and substitution effects are unclear and depend on various channels which can have opposing effects.

Finding a partner and stable unions are important determinants of fertility behavior. Lower education is commonly associated with difficulties in partnership formation and more union instability (Jalovaara & Fasang, 2017). Higher education is seen as an asset in finding a partner, and while this is often thought to impact men's partnership formation more strongly, women's education and economic resources are likely to have a similar effect on partnership formation, especially in more gender-egalitarian societies (Jalovaara et al., 2022). Previous studies have shown increasing ultimate childlessness and decreasing levels of overall fertility among both lower educated men and women in the Nordic countries, both of which are associated with lower levels of partnership formation and higher rates of union dissolution (Jalovaara et al., 2019, 2022).

Macro-Level Perspectives

Just as the education-fertility dynamic is affected in complex and sometimes opposing ways on the individual-level, the macro-level fertility trends in the presence of educational expansion and rising educational participation is an increasingly complex puzzle. A period of declining marriage and fertility rates coincided with increasing divorce rates and women's education and labor force participation, referred to as the second demographic transition (SDT) (Goldscheider et al., 2015). Women's increased participation in the labor market alongside widening educational opportunities was linked to delays in partnership formation and childbearing, and was often associated with low levels of fertility (Blossfeld & Jaenichen, 1992; Brewster & Rindfuss, 2000). Educational expansion and increasing time spent in education has been linked to significant delays in the onset of childbearing across cohorts, often described as fertility postponement (Neels et al., 2017). Previous research has estimated that between 57% and 74% of the increase in average age at first birth can be attributed to increasing educational enrollment in the UK, France, and Belgium (Neels et al., 2017). Researchers found that educational expansion contributed to fertility postponement not only through increasing time spent enrolled, but also through delaying mediating factors such as entry into the labor market (Neels et al., 2017). The rising age at first birth has been followed in many cases by an increase in birth rates at older ages, with women "catching up" with a quicker succession of births in later ages (Lappegård & Rønsen, 2005; Ní Bhrolcháin & Beaujouan, 2012). The increasing postponement of first births, however, has led to concerns regarding the implications of delayed childbearing for the realization of fertility intentions at older ages (Neels et al., 2017).

Despite initial evidence supporting higher fertility rates among countries with the lowest levels of labor market participation among women, this trend appeared to reverse with countries in Southern Europe experiencing steeper declines in fertility rates, while Scandinavian countries characterized by higher female participation experienced a slower decline (Goldscheider et al., 2015). This has led to theories of gender equity driving the fertility reversal. Lappegård and Rønsen (2005) have developed a framework which seeks to understand the changing fertility and union dynamics in light of changing gender relationships. They describe a two-part gender revolution, beginning with the dramatic increase in female participation in the labor market and a weakening of the family (Lappegård & Rønsen, 2005). According to the gender revolution framework, this increase in the demand for women's participation in paid work was accompanied by little change in the gendered division of labor in the home, thus resulting in a decrease in fertility (Lappegård & Rønsen, 2005). However, Lappegård and Rønsen (2005) theorize that the second half of the gender revolution will be characterized by increasing participation of men in the childbearing and family responsibilities and that this may lead to increasing fertility rates. It is also theorized that increasing gender egalitarianism on the greater societal level will contribute to increasing fertility (Lappegård & Rønsen, 2005). Thus, gender egalitarian institutional policies which promote the combination of worker and parent roles may reduce the opportunity costs of childbearing, especially among the highest educated individuals. This may contribute to the recent trends which suggest a weakening of the educational gradient in women's fertility in the Nordic countries, and in some cases a reversal of these trends (Jalovaara et al., 2019).

Overall, while educational expansion is linked to fertility postponement, it is not clear whether this results in lower overall fertility levels. Some theories suggest that the higher educational attainment of women in particular is linked with higher self-realization and career desires which may be at odds with fertility, leading to the negative relationship between educational expansion and fertility. In line with these theories, stagnation of educational expansion may have a positive impact on fertility levels. On the other hand, higher educational attainment often comes with higher incomes and job flexibility on the individual level and more gender-egalitarian family policies which often benefit higher educated women the most, thus leading to the potential positive effect of educational expansion on fertility levels. If lower education is indicative of weaker labor market attachment and lower incomes, and not reconcilable with the costs of childbearing, educational stagnation could then have a negative impact on fertility levels.

Institutional Context

Educational Expansion in Norway

The Nordic school model developed as an integral component of the social democratic welfare state which spread throughout the Scandinavian countries following the Second World War (Elstad, 2023). Universalism was a key principle in the development of the Norwegian education system in the post-war period, including a strong focus on both the equality of educational opportunity and removing the social gradient in the uptake of education despite equal access (Elstad, 2023).

The Primary and Lower Secondary Education Act of 1969 gave children and youth the right and obligation to attend primary and lower secondary education, and expanded compulsory school to 9-years in length (Thuen & Volckmar, 2020). At the same time, work was being done to reform the upper secondary school system to match the new comprehensive primary and lower secondary system, with the goal of creating a common school for those aged 16-19. In 1974 the Upper Secondary Education Act was introduced which combined general and vocational upper secondary schools into a common upper secondary system, and in 1994 all youth aged 16-19 were given the right to 3-years of upper secondary education (Thuen & Volckmar, 2020). This reform improved the access to higher education for individuals, and allowed more flexibility for vocational education students to transition into higher education programs (Thuen & Volckmar, 2020).

The post-war period was characterized by massive expansion and reforms to the education system. The expansions to the compulsory and upper secondary systems simultaneously resulted in a large demand for and increase in enrollment in higher education, especially among women. Between 1960 and 1975 the number of students enrolled in universities quadrupled from 10,000 to 40,000 (Aamodt, 1995). From 1965 to 1970 the government appointed The Ottosen Commission who was tasked with developing the future of post-secondary education in Norway

(Aamodt, 1995). Resulting from this commission and local initiatives there was the establishment of 15 regional colleges from 1969 to 1986 which focused on areas not previously near a higher education institution (Rogne, 2023). The largest changes to the higher education system during this time, however, was the "upgrading" and centralization of previously post-secondary non-tertiary education institutions which focused mainly on vocational fields (Rogne, 2023). This also included a standardization and formalization of the requirements and curriculums for these educational programs, along with an increase in student capacity at these institutions (Rogne, 2023).

To describe the development of both educational attainment and enrollment across those born between 1964 and 1996, the distribution of women and men in the different education states is presented in Figure 1. We observe an increase in the proportion enrolled in education across cohorts at all educational levels for both women and men. At age 16, 79% of boys and 85% of girls born in 1964 were enrolled in education. For those born in 1996, this proportion increased to over 98% of both boys and girls. At age 20, 13% of men and 20% of women born in 1964 had obtained a secondary degree and were enrolled in further education. Among those born in 1988, this number increased to 28% of men and 47% of women, and for the 1996 cohort this was 36% of men and 56% of women. A large increase across cohorts was also seen among those with a tertiary degree who were enrolled in an education program. Among those born in 1964, only 7-8% of men and women had obtained a tertiary degree and were enrolled in further education at age 25, however for those born in 1992, this increased to 17% of men and 24% of women.

While the length of time spent in educational enrollment has increased, the timing of when individuals are enrolled at each level appears to be relatively similar across cohorts. Attainment of secondary education and leaving education peaks around age 20 and tertiary education peaks during the mid- to late-20s. The rising educational attainment is reflected in the decrease in proportion leaving school with primary or secondary education and the increase in tertiary educated across cohorts. This pattern is especially seen among women. For those born in 1964 the proportion of women leaving school with a tertiary education at age 30 was just below

25% and increased significantly to nearly 50% in the 1988 birth cohort. Nevertheless, there has been a stagnation in educational expansion among the most recent cohorts, which can be seen by the increase in the share primary and not enrolled from from the 1976 cohort to the 1988 cohort for both men and women. Earlier research has identified a slight increase in the share of upper secondary school dropouts between cohorts born in the early 1980s especially among those enrolled in a vocational education program (Bäckman et al., 2011). One explanation for this may be the comprehensive upper secondary school reform in 1994, which reduced the number of programs from over 300 to 13 (Lindbekk, 2015). This reduction in the diversity of programs offered, and the increased focus on theoretical subjects over vocational training may have particularly diminished the completion rates of upper secondary school among students from disadvantaged backgrounds (Lindbekk, 2015). The stagnation in education among recent cohort may be part of a broader Nordic trend: for instance in Finland the increase in educational attainment in the age group 30–39 turned into a decrease after 2013 (Official Statistics of Finland (OSF), 2020).

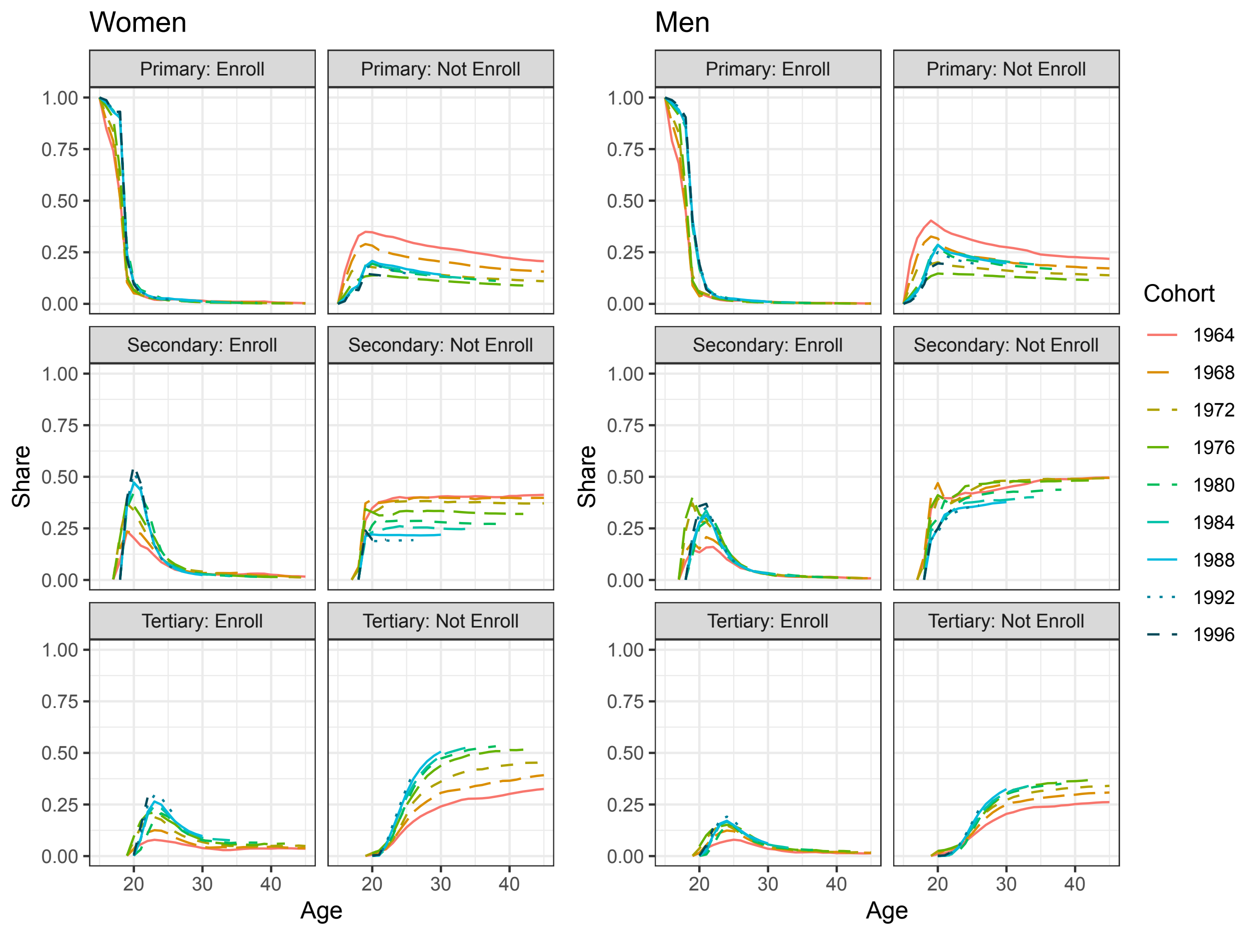

Figure 1. The distribution of women and men by education state, age, and cohort. *Note.* Shares with 10 or fewer individuals are not shown. All individuals are assumed to be in state primary & enrolled at age 15.

Fertility and Institutional Support

The Nordic countries have shown similar patterns of near-replacement fertility rates along high labor force participation among women, leading to the development of the so called "Nordic fertility regime" (Andersson et al., 2009). Norway, as in the other Nordic countries, experienced a large decline in the Total Fertility Rate (TFR) during the 1960's and 1970's, dropping from nearly 3.0 children per woman in 1960 to around 1.7 children per woman in 1975, before stabilizing for many decades (Andersson et al., 2009). Completed cohort fertility remained right below 2.1 children per woman since the 1950s birth cohorts (Human Fertility Database, 2024). At the same time, the average age at first birth has been steadily rising, from 23 for women and 26 for men in 1970 to 30 for women and 32 for men in 2022. The relatively stable fertility compared to many other countries with lower labor force participation among women, and high levels of recuperation despite increasing fertility postponement has led many to see the Nordic countries as a success story.

The relatively high levels of fertility in Norway and the Nordic countries led many to attribute this to the generous institutional support to parents and families and widespread gender egalitarianism. These institutional factors are thought to reduce the barriers to combining work and family life, and thus protect against strong declines in fertility rates (Andersson et al., 2009). The most common family policies thought to impact fertility are parental leave programs and subsidized formal childcare availability (Lappegård, 2010). Between 1977 and 1993 parental leave in Norway increased gradually from 18 to 42 weeks with full salary (Longva et al., 1996, p.215). This policy was established initially to support the balance between female employment and family life by both securing the right of mothers to return to their employment following maternity leave, and by reducing the impact of childbearing on income loss (Lappegård, 2010). In 1993 a "father's quota" was introduced, securing four weeks of leave for fathers and later was expanded to 10 weeks (Lappegård, 2010).

Formal childcare in Norway began with the first kindergarten law in 1975 which required municipalities to establish and organize kindergartens (Jonassen, 2015). In 1980, only 19.3% of children between the ages 1 and 5 were enrolled in formal childcare, with this proportion rising drastically to 62% in 2000 (Stabell, 2017). A reform introduced in 2003 aimed to increase this number further, and instituted both a max price for kindergartens and required equal financial treatment between private and public kindergartens (Moafi et al., 2022). The right to receive a place in formal childcare was established in 2009, which led to a further increase in the coverage of kindergartens, especially amongst the youngest children. Formal early childcare now has near full coverage of all children between the ages of 1 and 5, with over 93% enrolled as of 2023 (Statistics Norway, 2024).

However, despite the generous institutional support to families and high levels of gender egalitarianism, Norway has seen a marked decline in the period total fertility rate in recent years, from 1.98 in 2009 to 1.41 children per woman in 2022. While this decline has sparked concerns among policymakers, period fertility rates are sensitive to birth timing and whether the recent trends point to a overall change in the cohort fertility rates or simply reflects accelerating fertility postponement remains unclear. However, forecasts of cohort fertility show that the recent fertility decline in Norway may not be entirely explained by fertility postponement, and that the period fertility decline is likely to reflect in lower completed cohort fertility rates (Hellstrand et al., 2021).

Data and Methods

Data

In this study, we used Norwegian register data from Statistics Norway covering the entire Norwegian population. Individual-level information on fertility and educational enrollment and attainment was obtained through the linkage of the Norwegian Population Register and the National Education Database using unique personal identifiers. The study population consists of all individuals born in Norway between 1964 and 2002 who were alive and living in Norway between the ages 15 and 45, or until the end of data availability (2019). A small proportion of the population with incomplete information on education were excluded (<4%), leaving the analytical sample at 1,869,265 individuals.

We follow each individual in the study population transitioning into and out of educational enrollment, gaining higher education, and having children. Enrollment is defined as being registered as enrolled in an education program, while educational attainment is defined as the highest attained education level, per October 1st each year. We consider three educational categories: primary, secondary and tertiary education. Primary education is defined as lower secondary or below (ISCED levels 0-2), secondary education is defined as upper secondary and post-secondary non-tertiary education or short-cycle tertiary (ISCED levels 3-5), and tertiary education is defined as university education at the bachelor's level and above (ISCED levels 6-8). As information on educational attainment and enrollment is available beginning from age 16 and children finish compulsory schooling at this age, all individuals are assumed to be in state "primary & enrolled" at age 15. We form annual transitions between education states, which are defined by the highest educational level attained and whether an individual is enrolled in education or not. All analyses are carried out separately for men and women. We also complete the analyses for women by childhood socioeconomic status measured by father's highest educational attainment at age 16 (see Appendix D). We use father's education as proxy for own education to avoid forecasting final education for younger cohorts. Results by father's education are rather similar for all educational groups, though paternal education may not be as good of a proxy for own education in the younger cohorts.

Methods

We used transition probabilities from a Markov chain multistate approach (Briggs & Sculpher, 1998) to describe the transitions between a given set of education states. A Markov chain moves step-by-step from one state to another and has the property of being memoryless, meaning that a transition probability depends only in the previous step attained and not on the full history of events (Kemeny & Snell, 1971). The transition probabilities from state *i* to state *j* at age *a* and time *t* is given by:

$$p_{ij}(a,t) = pr(State_t = j | State_{t-1} = i; a_{t-1}) \tag{1}$$

Our state space includes the states of “primary & enrolled”, “primary & not enrolled”, “secondary & enrolled”, ”secondary & not enrolled”, “tertiary & enrolled”, and “tertiary & not enrolled” and the step size is one year. Figure 2 illustrates the state spaces and the transitions between these states. Individuals can attain higher education, e.g. transitioning from “primary & enrolled” to “secondary & enrolled”, but individuals cannot move back to lower levels of education as indicated by the arrow directions. The grey arrows indicate rare but still observable transitions in the data. We estimate the annual age-specific transition probabilities between states for cohorts 1964–1988 from age 15 to 45 or until year 2018 as

$$p_{ij}(a,c) = \frac{\#\text{ individuals in state } j \text{ aged } a \text{ for cohort } c \text{ and in state } i \text{ at age } a-1}{\#\text{ individuals aged } a-1 \text{ in state } i \text{ for cohort } c} \qquad (2)$$

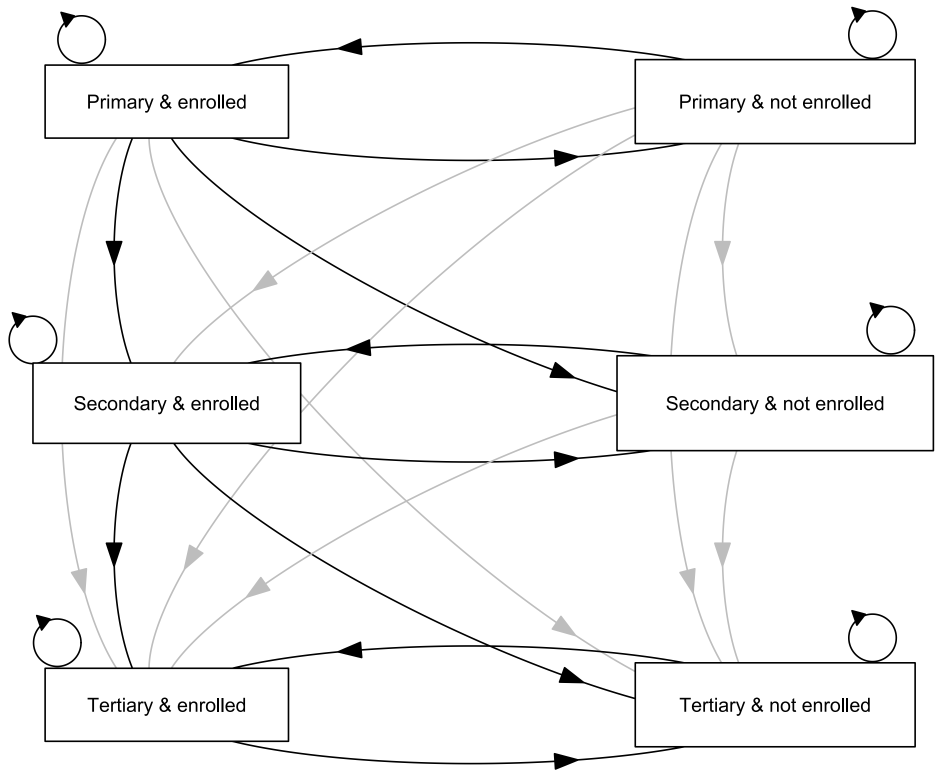

Figure 2. The state space and the transitions between states in the Markov chain. *Note.* The grey arrows indicate the less likely but yet observable educational transitions.

Further, we estimate the average age-specific fertility rate for each of the educational states. Using these fertility rates we can calculate the completed cohort fertility rate, which we consider complete at age 44. For cohorts aged 30 or more with incomplete education transition and fertility schedules (cohorts 1975–1988) we forecast completed cohort fertility rate using the freeze rate method. This method freezes the current age-specific fertility rates into the future. Here, we also keep the educational transition rates at current levels. Although this is a simple method, it outperforms many other more sophisticated cohort fertility forecasting methods (Bohk-Ewald et al., 2018) and is a particularly good choice in times of abrupt trend changes like in the Nordic countries after 2010 (Hellstrand et al., 2021). We calculate/predict ultimate childlessness in a similar manner, but then we add to the Markov chain (Figure 2) the event of a first birth as an absorbing state from each of the education states, meaning that that once it has been entered it cannot be left. Consequently, when an individual has a first birth they are excluded from the analysis. For analyses of TFR we consider fertility rates for a given year (2010-2018) including all individuals aged between 15 and 44 during that year (birth cohorts 1964-2002).

Using the educational transition probabilities, the average fertility rates and counterfactual simulations, we can estimate the amount of the observed/predicted changes in period and cohort fertility, and ultimate childlessness that is attributed to changes in educational patterns versus fertility by education state. We change each (set) of the education-specific fertility rates and education transition probabilities one at a time according to observed trends while keeping the other constant. Alternatively, we keep each (set) of the fertility rates and transition probabilities constant while allowing the rest to change according to the observed trends. For specific details, see the Technical Appendix A.

Results

Transitions Between Education States

The expansion in educational attainment and enrollment across the older cohorts and the stagnation in recent cohorts are shown in more detail by the transition probabilities between education states for females in Figure 3. School dropout (the transition from primary and enrolled to primary and not enrolled) decreased continuously at younger ages: for instance, at age 17, the probability fell from 19% for the 1964 birth cohort to 6% for the 1996 birth cohort. At around 20 years, school dropout shows a slight U-shaped trend, with the highest probabilities for both the youngest and the oldest cohorts. An increase in going back to school after dropping out (the transition from primary and not enrolled to primary and enrolled) was observed over cohorts, but this transition also stagnated in the early 20s for the more recent cohorts.

The rise in enrollment is reflected in the simultaneously decreasing trend in graduating from higher education without being enrolled in further education. We observed a decline in the transition from primary and enrolled to secondary and not enrolled, and from secondary and enrolled to secondary and not enrolled as well as to tertiary and not enrolled. Instead, a pronounced increase in the probability of continuing enrollment after attaining an initial tertiary degree across cohorts is shown by the increase in the transition from secondary and enrolled to tertiary and enrolled (from 6% to 32% at age 23 between the 1964 and 1988 cohorts). Less pronounced changes have been observed for men (see Appendix B).

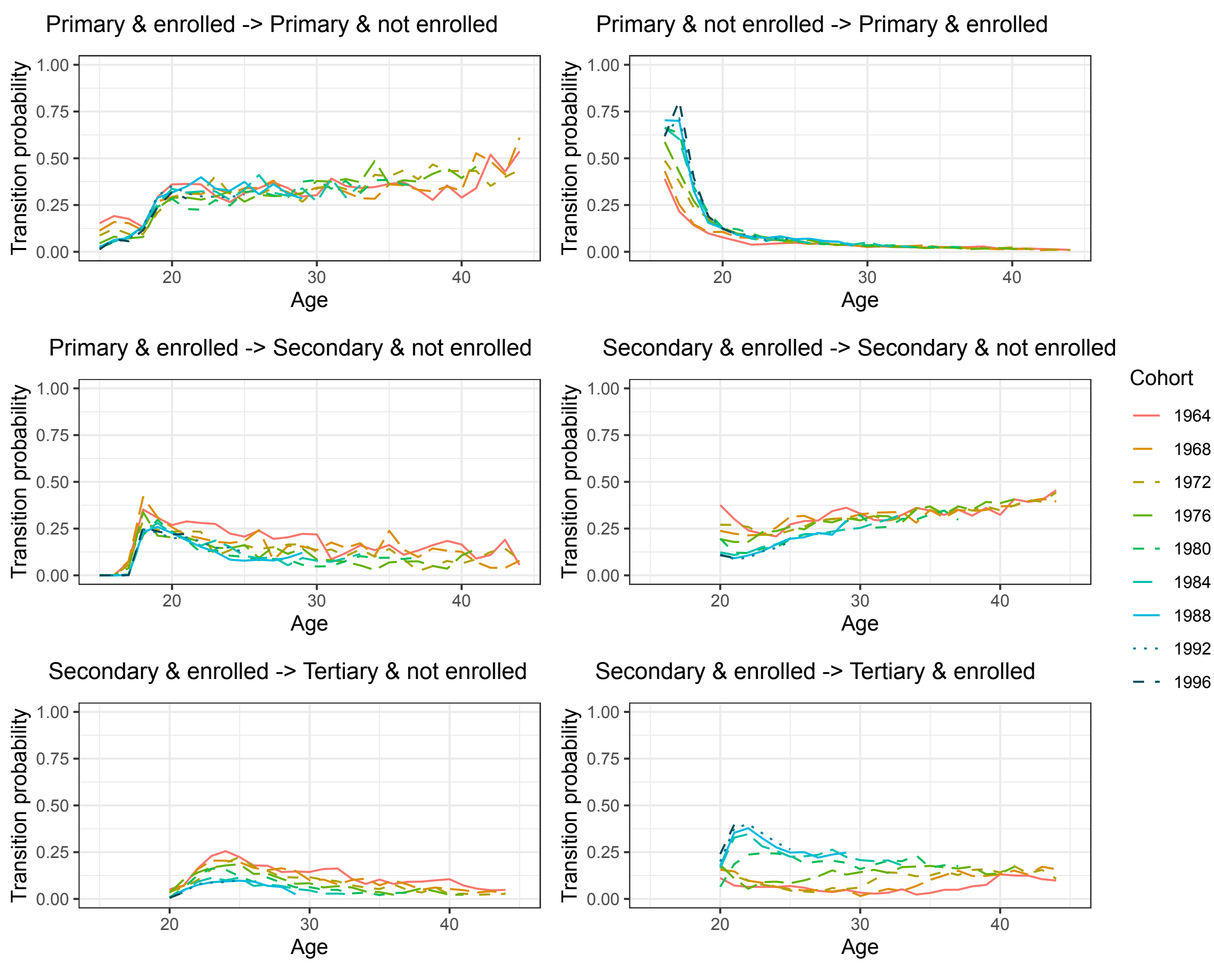

Figure 3. Age-specific transition probabilities between education states across cohorts, women.

Fertility by Education State

Age-specific fertility rates are displayed by education state, age, and cohort for men and women in Figure 4. The strongest decline is seen among the primary educated and not enrolled women and men across cohorts, followed by a decline among the secondary educated and not enrolled. For instance among women, the peak fell from 0.15 in the 1964 cohort to 0.09 for the 1992 cohort among the primary educated and not enrolled at age 25 and from 0.17 in the 1964 cohort to 0.13 in the 1988 cohort among the secondary and not enrolled at age 26. For those with a tertiary education, a decline is seen mainly among the most recent cohorts. There appears to be relatively stable rates among those enrolled in education at all levels, except for the small group of primary educated and enrolled men in their late 20s, who have a stronger decline across cohorts than enrolled women at all levels and enrolled men at the secondary and tertiary educated level. We see a similar pattern for first birth rates (see Appendix C) with a clear decline in first births across cohorts at the primary and secondary educated levels, and a small decline among the tertiary educated mainly occurring in the most recent cohort. Rates in Figure 4 are raw age-specific birth rates, for smoothed rates of older cohorts see Appendix C.

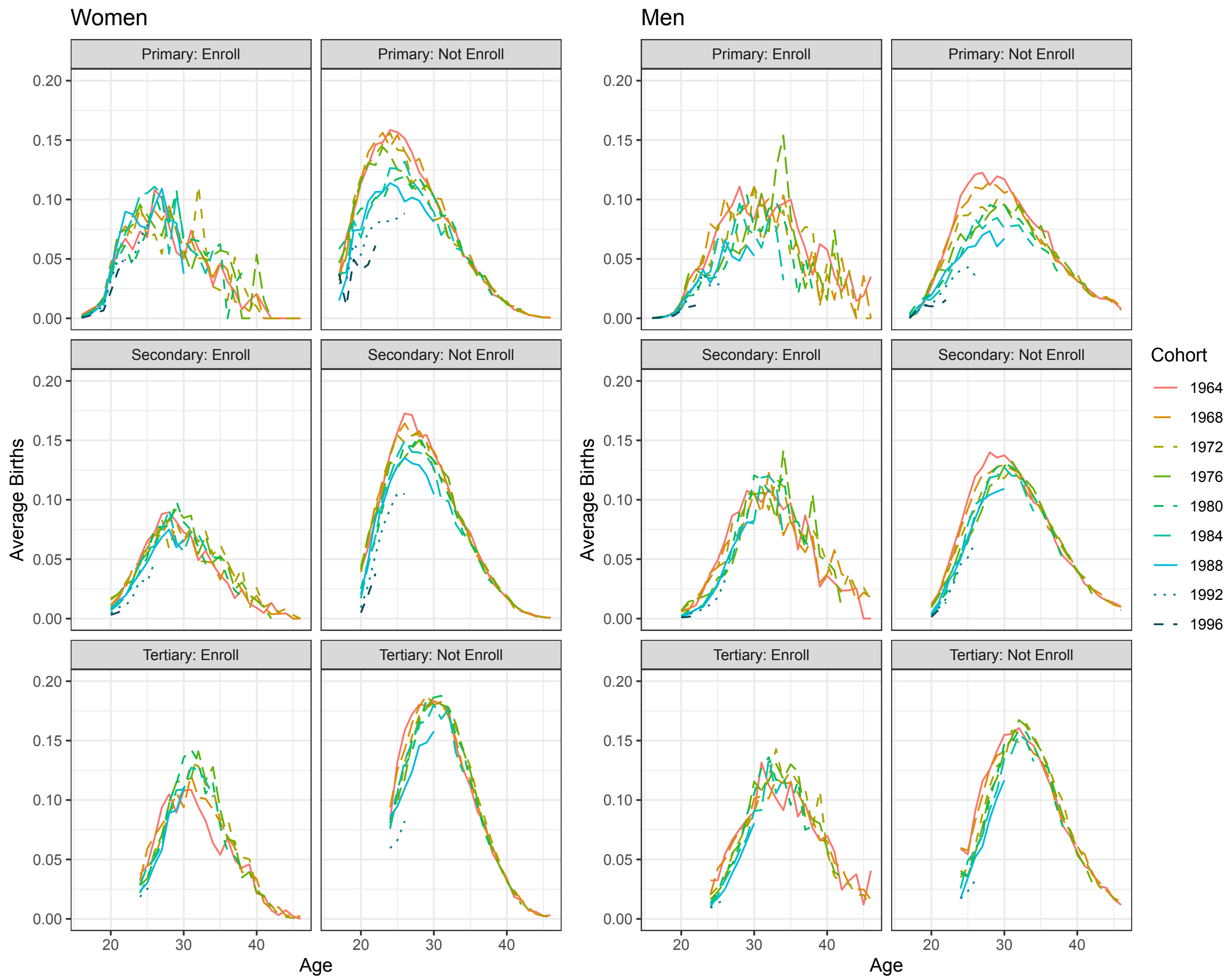

Figure 4. Age-specific fertility rate by education state and cohort, women and men. *Note.* Rates at older ages for those enrolled in education should be read with caution do to the small numbers of individuals in these groups.

Completed Cohort Fertility and Ultimate Childlessness

The observed and predicted completed cohort fertility rate and ultimate childlessness for women and men are shown in Figure 5. Completed cohort fertility declined from 2.10 births per woman to 2.01 for cohorts born between 1964 and 1974, and is further predicted to fall to 1.76 births per woman for the most recent birth cohort given that rates in educational attainment and enrollment and the birth rates remain at the latest observed values in the future. The corresponding decline among men drops from 1.9 to 1.77 between the 1964 and 1974 birth cohorts and is predicted to further decline to 1.5 births per man in the 1988 birth cohort. The observed, weak decline for women born between 1964 and 1973 can be equally attributed to educational expansion and declining fertility by education level. Had birth rates remained stable and education transitions changed according to observed trends, and vice versa, completed fertility would have declined to 2.05 for cohort 1973. The combination of birth and education changes resulted in a slightly more pronounced decline. However, for cohorts born from 1974 and onwards, the decline is fully driven by declining birth rates. As educational expansion stagnated for these cohorts, this produced a constant or even increasing rate in completed cohort fertility, had birth rates remained unchanged. For men, educational changes contributed very little to the decline, had birth rates remained unchanged. Instead, the stagnation in educational expansion appears to have reduced the decline to a slight extent.

Ultimate childlessness among women stayed relatively stable at 10% between the 1964 to 1973 birth cohorts, however, an increase began from 1973 cohorts onward and is predicted to continue to nearly 19% for the 1988 birth cohort, if birth rates and educational changes remain at the latest observed values in the future. Among men, the proportion childless steadily increased from 17% in the 1964 birth cohort to 20% in the 1974 birth cohort, and is predicted to continue rising across the 1975 to 1988 cohorts, ultimately to 27%. Among women, if not for the changes in birth rates across the 1964 to 1974 birth cohorts, educational expansion would have led to an increase in the proportion ultimately childless for these cohorts. However, the predicted increase for cohorts born from 1975 and onwards is driven by the decline in birth rates, with the stagnation of educational expansion leading to little change in ultimate childlessness from the level of the 1973 cohorts (11%) had birth rates remained unchanged. For men, educational changes contributed little to the rising childlessness, had birth rates remained unchanged. Though, similarly to the results for completed fertility, the stagnation in educational expansion may have slightly reduced the rising rates of childlessness.

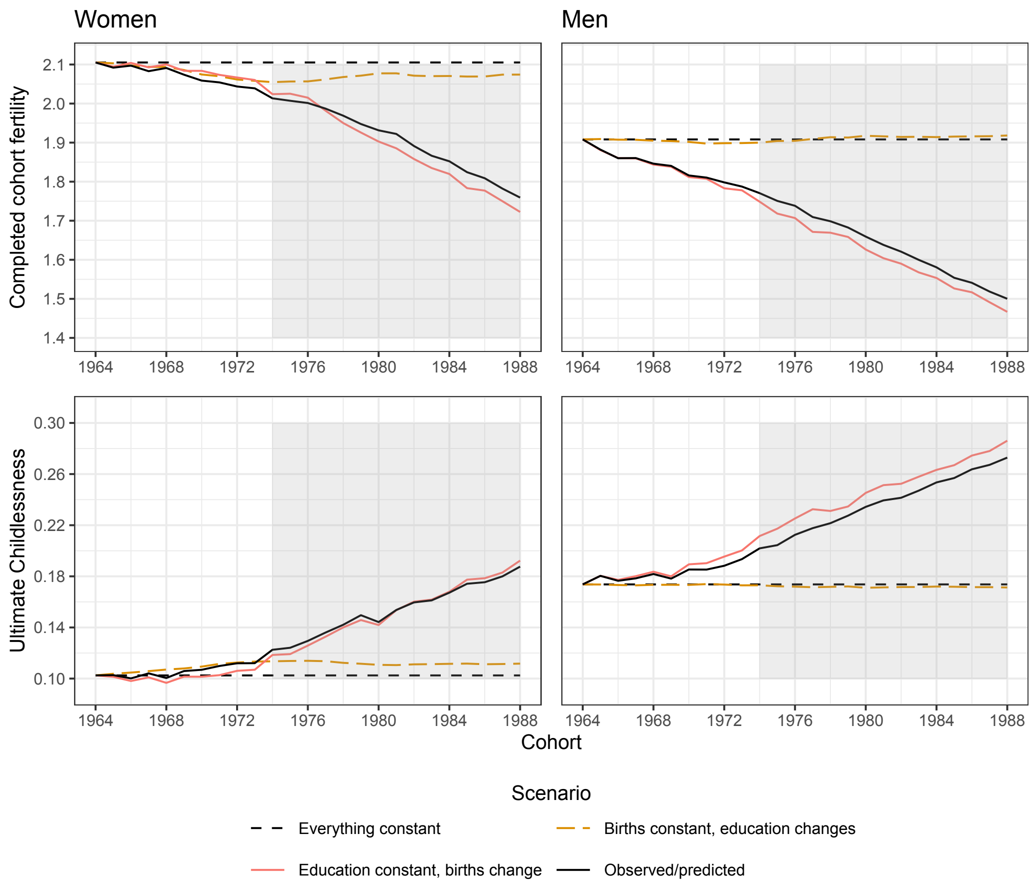

Figure 5. Observed completed cohort fertility and ultimate childlessness for cohorts 1964–1974 and predicted completed cohort fertility and ultimate childlessness for cohorts 1975–1988 in different scenarios, women and men. *Note.* The grey area indicates predicted values.

Figure 6 splits the contribution to changes in completed cohort fertility and ultimate childlessness between changes in the education transitions (left-hand side) and in births rates (right-hand side) for each education state among women and men. For women, the main contribution from changes in educational transitions occurred among the primary educated and enrolled group. The changes in the education behavior among this group contributed the strongest to the changes in observed/predicted completed cohort fertility and ultimate childlessness, had everything else remained constant. When it comes to changes in birth rates, the long-term decline in birth rates among the primary and secondary educated contributed the strongest. The change in births rates among the primary educated contributed equally to the decline as the change among the secondary educated, although the former is a smaller group. The change in birth rates among the tertiary educated initially contributed positively, until the 1975 birth cohort. For the younger cohorts, the change in births among the tertiary educated also contributed to the the fertility decline. For ultimate childlessness, we see a similar story with the changes in first birth rates among the primary and secondary educated contributing the strongest. Changes in first birth rates among the tertiary educated contributed in fact to slightly declining rates of ultimate childlessness until around the 1984 cohort. Changes in the birth rates among those enrolled in education, regardless of educational level, did not significantly contribute to any changes in completed cohort fertility or ultimate childlessness.

For men, changes in educational transitions did not appear to contribute significantly to the observed/predicted fertility decline or to ultimate childlessness, though the changes among the primary educated and not enrolled group appeared to contribute positively to a small extent had everything remained constant. For fertility behavior, as among women, the change among the primary and secondary educated and not enrolled contributed the strongest to both the completed cohort fertility decline and ultimate childlessness increase.

Appendix E figure E1 shows the corresponding results when education and fertility behavior change according to observed trends, but each of these changes are set constant one at a time. For female completed cohort fertility, unchanged fertility behavior reduces the predicted decline similarly for all levels of education despite their different sizes, resulting from the stronger fertility declines among the lower educated. Further, some education changes become visible for younger men when birth rates change according to observed trends, but as shown in Figure 5, these even each other out.

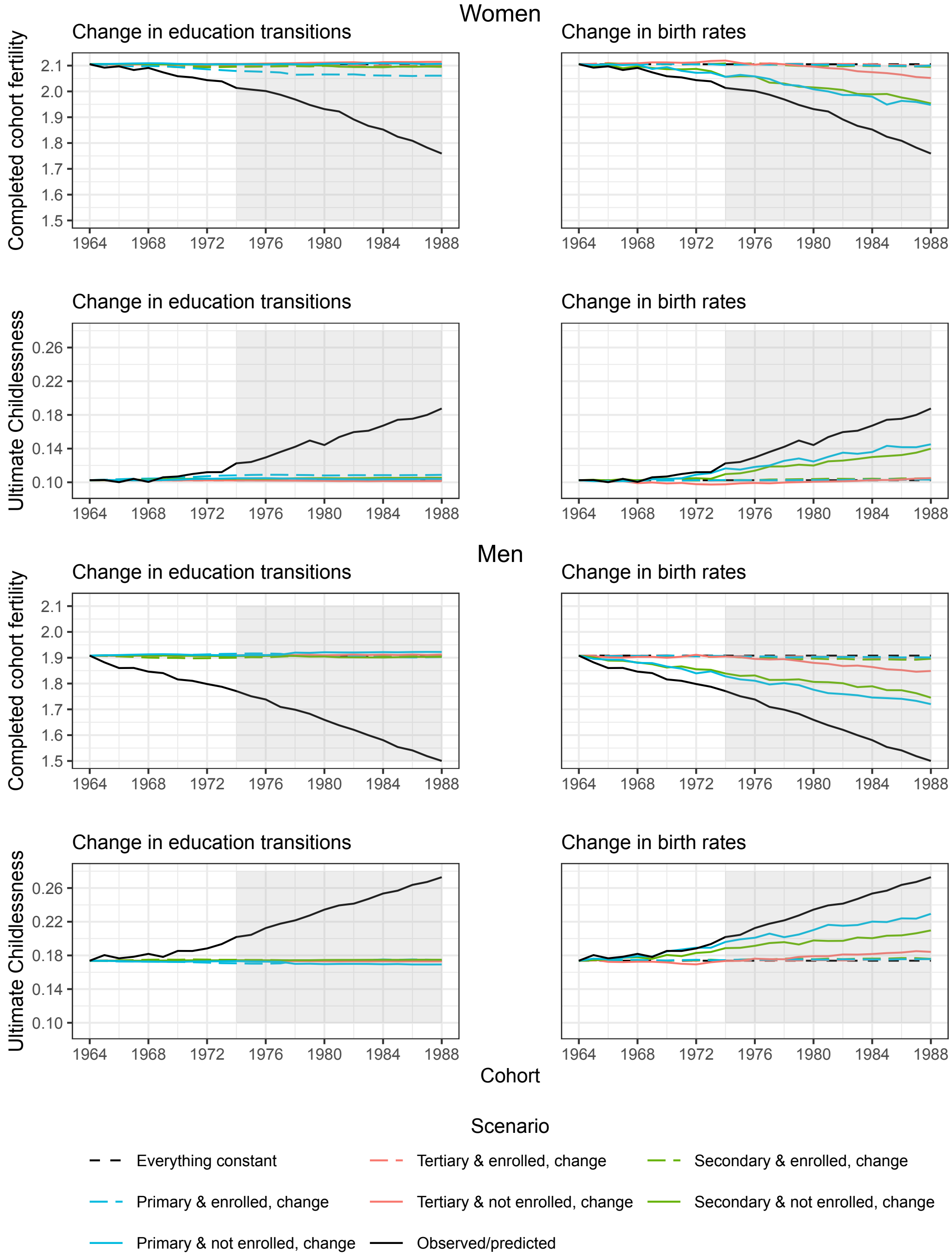

Figure 6. Observed and predicted completed cohort fertility and ultimate childlessness for men and women when everything is held constant, but education transitions (left) versus birth rates (right) change one at a time.

In Figure 7 we look more into the contributions of each specific educational transition to the fertility decline. Here, we see that the contribution among the primary and enrolled women is mainly driven by the decrease in school dropout among older cohorts. If we break down the stable fertility in the scenario where only those in the secondary and enrolled group changed their education behavior, we see a negative contribution of the decrease in the transition from secondary and enrolled to tertiary and not enrolled, but a positive contribution of the increase in the transition from secondary and enrolled to tertiary and enrolled, this is also seen among men (see Appendix F). The other educational transitions do not appear to contribute significantly to the fertility decline among women or men. Results for childlessness show very little contribution of changes in educational transitions to the increasing rates of childlessness for men or women, these results are presented in Appendix G.

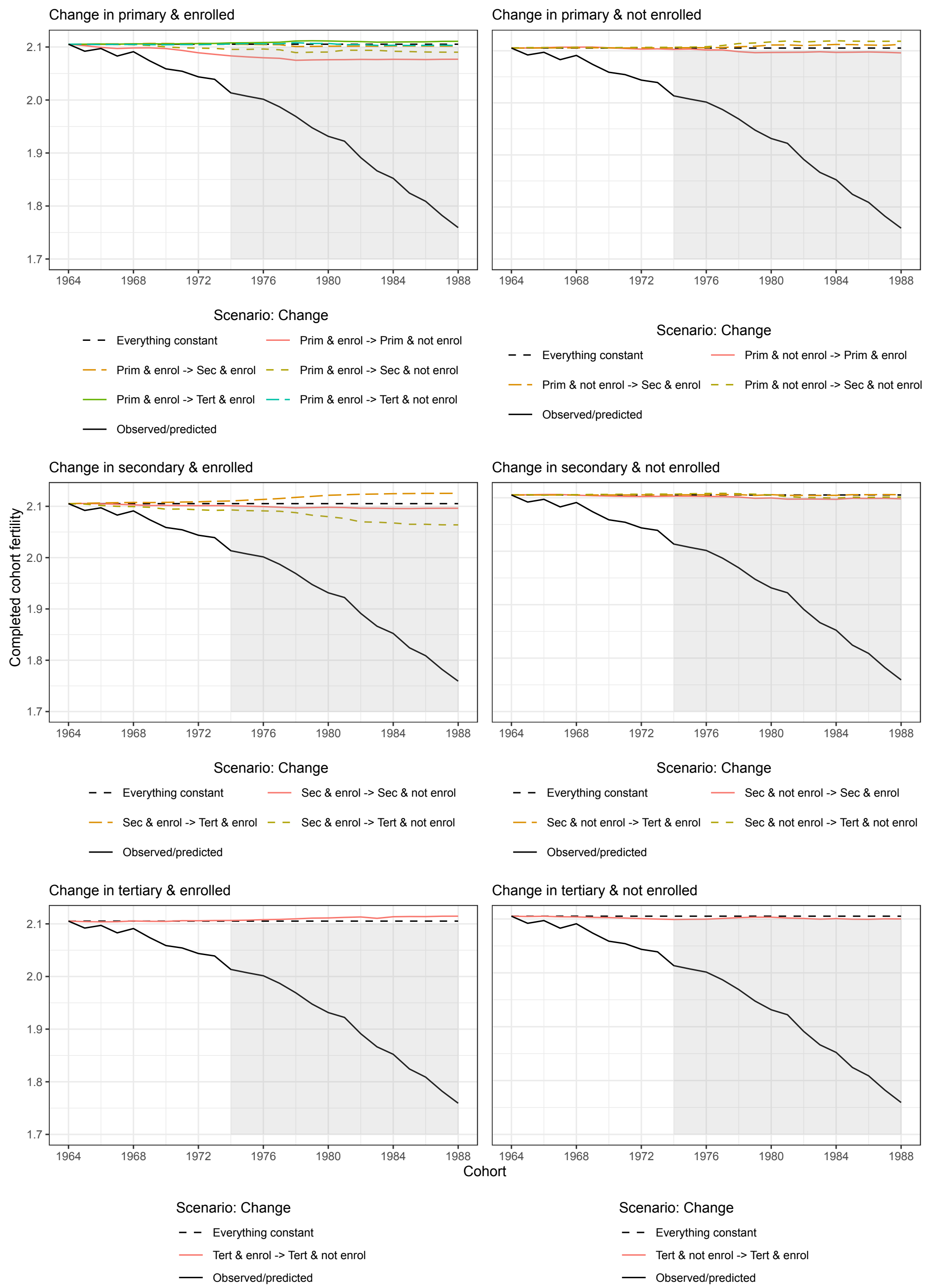

Figure 7. Observed and predicted completed cohort fertility when everything is held constant, but each of the education transitions change one at a time, women.

Total Fertility Rate

The observed TFR for men and women between 2010 and 2018 is shown in Figure 8. The total fertility rate among women declined from 1.95 in 2010 to 1.51 children per woman in 2018. Among men, the corresponding decline was from 1.79 to 1.37 children per man. The observed decline in TFR among both men and women was fully driven by declining birth rates. For women, the decline in births among the highest educated women not enrolled in education contributed the strongest, with declines among primary and secondary educated women contributing to a lesser extent. This is in contrast to the results for completed cohort fertility where the decline was driven primarily by declines in birth rates among the lower educated women. For men, declines in birth rates across educational attainment groups contributed to a similar extent to the decline in TFR, with a slight contribution from declines in birth rates among enrolled men at all levels.

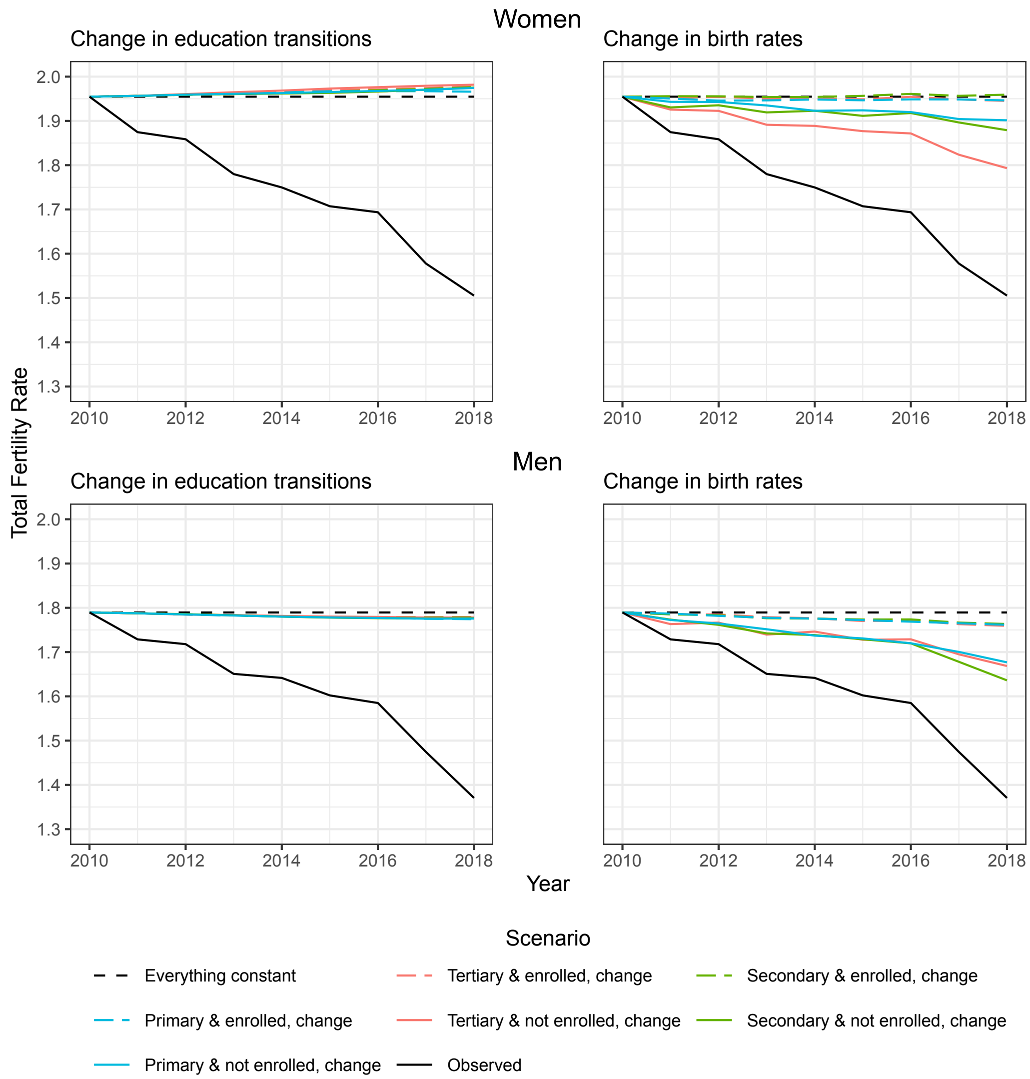

Figure 8. Observed total fertility rate (TFR) between 2010-2018 for men and women when everything is held constant, but education transitions (left) versus birth rates (right) change one at a time. *Note.* Analyses for TFR include 1964 to 2002 birth cohorts.

Discussion and Conclusion

This study explored the relationship between education changes and fertility declines in Norway during the recent decade(s). More specifically, it investigated the contribution of changes in educational enrolment and attainment to the observed and predicted changes in cohort fertility and ultimate childlessness across Norwegian men and women born between 1964 and 1988, and the contribution to the decline in TFR between 2010 and 2018. Across those born between 1964 and 1988, there has been significant changes in both the time spent in education and the overall educational attainment of the population. Educational expansion reduced dropout rates among the older cohorts (1964-1974) and increased the proportion enrolling in tertiary education and obtaining higher education, whereas the most recent cohorts experienced educational stagnation with a slight increase in the share leaving school with a primary education after a period of declining trends. The changes in the upper secondary education system in 1994 which significantly reduced the diversity of programs offered and placed a larger emphasis on academic tracks may have contributed to the increased dropout among the younger cohorts, particularly among students from more disadvantaged backgrounds (Lindbekk, 2015).

As period fertility measures can be sensitive to changes in fertility timing, which may result from changes in education, it is important to understand to what extent the fertility decline occurs due to changes in educational transitions or due to changes in the fertility behaviors of different educational groups. Using register data covering the educational enrollment, attainment, and childbearing histories for the entire Norwegian population born since 1964, a multi-state model and a counterfactual approach, we analysed changes in the transition probabilities between educational states and the contribution to changes in observed and predicted completed cohort fertility and ultimate childlessness for men and women. At the same time, we also estimated the contribution of educational changes to the recent decline in TFR for both men and women. Combining a period and cohort perspective is beneficial to provide a more complete understanding of the education-fertility dynamic. Using period fertility allows us to understand the impact of educational changes on current fertility trends, while cohort fertility is not susceptible to distortions arising from changes in fertility tempo.

We observed a decline in cohort fertility across the cohorts with complete childbearing information (from 2.1 to 2.01 for women and from 1.9 to 1.77 for men) and this decline was predicted to continue across the 1975-1988 birth cohorts for both men and women, dropping as low as 1.76 for women and 1.5 for men in the most recent cohorts, should education transitions and birth rates remain constant in the future. This is in line with earlier findings for women

(Hellstrand et al., 2021), but a new finding for men. For ultimate childlessness, we observed steady rates until the 1974 cohort at 10-12% for women and thereafter ultimate childlessness is predicted to increase to 19% in the latest cohort. For men, we observed a steady increase in childlessness which is predicted to continue in recent cohorts, rising from 17% to as much as 27% in the 1988 birth cohort.

We highlight that the simple freeze-rate method used to predict completed cohort fertility and ultimate childlessness assumes that future education transitions and fertility rates will remain constant. Moreover, it lacks uncertainty bounds around the forecasts. Sophisticated forecasts of completed cohort fertility show variation at around 1.65-1.92 for the 1988 female cohort (Hellstrand et al., 2021), depending on whether the recent 30+ fertility decline will continue, stop or recover. Nevertheless, observed trends in age-specific fertility at ages 30+ beyond 2018 (our latest data point) are relatively stable, with a small peak in 2021 and a drop thereafter (Statistics Norway, 2023). This indicates that the freeze-rate estimates are likely to be relativity good estimates even for younger cohorts. Furthermore, education is largely complete at age 30, so freezing education transitions beyond this age is suitable.

The observed decline in completed cohort fertility and increase in ultimate childlessness among women born until 1974 was equally driven by educational expansion and falling birth rates, thereafter falling birth rates are the sole driver of the predicted decline for younger women. Among men, the falling completed cohort fertility and rising childlessness was driven entirely by falling birth rates, with educational stagnation reducing the decline in fertility and rise in childlessness slightly.

The educational expansion among women depressing fertility in older cohorts (1964-1974) was driven by the decrease in school drop out among the primary educated, whereas other educational changes contributed very little. A slight contribution from the secondary and enrolled group was mainly driven by the increase in continuing enrollment after obtaining a tertiary degree. When education is held constant at the 1964 cohort's level but birth rates change according to observed trends, the largest contribution came from changes in the birth rates among the primary and secondary educated groups, with the tertiary educated group contributing to a lesser extent – mainly in the most recent cohorts and mainly with regards to completed fertility. When education is allowed to change according to observed trends and we keep each birth rate stable one at a time, the contribution to the decline in cohort fertility for the youngest cohorts is similar across education groups, reflecting the smaller number but stronger fertility decline among the lower educated women and the opposite among the higher educated women.

Despite the educational stagnation experienced by the younger cohorts, we see little contribution of educational changes to the fertility decline in this group, and rather a strong contribution from changed fertility behavior across education groups. This is supported by previous research which forecasted fertility in Finland and found that continuing educational expansion or stagnation was of minor importance to changes in future fertility (Ciganda et al., 2023). Instead, future cohort fertility was more dependent on the developments in family size preferences (Ciganda et al., 2023). Norwegian findings show that fertility desires have decreased for women currently at childbearing ages, but not to the same extent that observed/predicted cohort fertility is declining, implying increasing barriers to realize childbearing plans (Fallesen et al., 2022).

The largest drivers of the decline in cohort fertility among the most recent cohorts were the changes in birth rates among the primary and secondary educated groups, for both men and women. Traditionally, higher education has been linked to lower individual fertility and higher levels of ultimate childlessness among women. However, Jalovaara et al. (2019) find a convergence in women's cohort fertility across education groups, and even a reversal of trends in ultimate childlessness with the lowest educated women experiencing the highest rates in the early 1970s cohorts. Our predictions highlight the importance of the lower education groups on cohort fertility and childlessness. Among men, Jalovaara et al. (2019) find a widening educational gradient in fertility and ultimate childlessness across cohorts. In our analyses, we see the most pronounced contribution of changes in fertility behavior among the primary and secondary educated men. Thus, the results suggest that for both men and women there may be increasing social inequalities in childbearing across the most recent cohorts, and that those with the lowest levels of education are increasingly being left behind. This is in line with previous evidence from Sweden and Finland which find somewhat stronger declines in first births among individuals with weaker labor market attachment (Ohlsson-Wijk & Andersson, 2022) and education in fields with higher levels of economic uncertainty (Hellstrand et al., 2024).

When we look at fertility from a period perspective, however, we see that the decline in TFR between 2010 and 2018 among women was mainly driven by declining birth rates among the highest educated group and to a lesser extent by the lower educated women, as opposed to the results for cohort fertility. This may result from the tendency for highly educated women to postpone childbearing while "catching-up" with higher relative fertility rates at older ages compared to their lower educated peers, whereas completed fertility may be declining overall among the primary and secondary educated women due to barriers to childbearing. Among men, we see a similar contribution of declining births to the period fertility decline across education groups, and to a small extent a decline among men enrolled in education.

Our findings have important implications for theoretical framework underlying the linkage between educational enrollment and attainment to fertility. In terms of income effects, our results suggest that educational expansion has had a depressive effect on fertility, until a certain saturation point, thereafter changes in the fertility behavior among educational groups are more important than educational changes. The birth rates among the lowest education groups being the largest driver of cohort fertility declines in younger cohorts suggests that socioeconomic resources may be an increasingly important factor in childbearing. While institutional support policies may suppress some of this effect, previous evidence has found that policies that aim to reconcile the combination of work and childbearing, such as parental leave reforms, have had the strongest effects for highly educated mothers (Bergsvik et al., 2021). Family support policies may therefore have differential effects on fertility by education group, and there still appears to be barriers to childbearing for low-educated men and women. Future studies could investigate whether the fertility gap between realized and desired fertility is changing differently across education groups.

In recent decades many demographers have called for including men in fertility analyses (Goldscheider & Kaufman, 1996; Van Bavel, 2017). Our results support this notion of understanding the gender-specific determinants of fertility by providing important insights into the gender-specific contribution of changes in education and birth rates by educational attainment to fertility trends. While educational expansion has also increased the educational attainment of men, we find little effect of this on fertility or ultimate childlessness. We do see, however, a similarity between genders in the effect of the decreasing birth rates among the lowest educated groups on cohort fertility, highlighting the importance of a gendered perspective in understanding the intersection of gender and education on fertility behaviors. We also see that declines in birth rates among enrolled men contributed slightly to the decline in period fertility. This could be both due to the income effect of being enrolled in education and through the time cost of childbearing as gender-roles in childbearing are redefined (Goldscheider et al., 2015; Kravdal, 2007).

This study has shown that the period decline in the 2010s and the corresponding predicted decline in cohort fertility among women and men born in the 1980s has not been driven by educational expansion. In fact, these cohorts experienced stagnation in education, which contributed slightly positively to fertility. The decline in cohort fertility is fully driven by declining birth rates, which were observe in all education groups but most pronounced among the lower educated women and men. Overall, this study highlights the importance of disentangling the effects of changes in educational enrollment and attainment within the population and changes in the fertility behavior across educational groups, and the importance of including a gendered perspective in understanding the drivers of the fertility decline. Our results suggest that longer time spent in education and higher educational attainment is not a major hindrance for fertility in contemporary Norway, but rather that socioeconomic resources increasingly promote childbearing for both genders.

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Appendix A

Technical Appendix

The age-specific education transition probabilities for a specific cohort were collected in the following 180 x 180 dimension transition matrix:

$$M = \begin{bmatrix} p_{prim'enrol-prim'enrol} & p_{prim-prim'enrol} & 0 & 0 & 0 & 0 \\ p_{prim'enrol-prim} & p_{prim-prim} & 0 & 0 & 0 & 0 \\ p_{prim'enrol-sec'enrol} & p_{prim-sec'enrol} & p_{sec'enrol-sec'enrol} & p_{sec-sec'enrol} & 0 & 0 \\ p_{prim'enrol-sec} & p_{prim-sec} & p_{sec'enrol-sec} & p_{sec-sec} & 0 & 0 \\ p_{prim'enrol-tert'enrol} & p_{prim-tert'enrol} & p_{sec'enrol-tert'enrol} & p_{sec-tert'enrol} & p_{tert'enrol-tert'enrol} & p_{tert-tert'enrol} \\ p_{prim'enrol-tert} & p_{prim-tert} & p_{sec'enrol-tert} & p_{sec-tert} & p_{tert'enrol-tert} & p_{tert-tert} \end{bmatrix}$$

where $p_{prim'enrol-prim'enrol}$,..., $p_{tert-tert}$ are 30 x 30 matrix blocks with non-zero elements only on the first subdiagonal. The 30 x 30 matrix blocks contain the age-specific education transition probabilities at ages 15 through 44. For instance, the element in column one and row two of $p_{prim'enrol-prim'enrol}$ refers to the probability of remaining enrolled in education among the primary educated between the ages of 15 and 16. The number of individuals of a given cohort by age and education state is organised in a 180 x 1 population matrix:

$$N = \begin{bmatrix} n_{prim'enrol} \\ n_{prim} \\ n_{sec'enrol} \\ n_{sec} \\ n_{tert'enrol} \\ n_{tert} \end{bmatrix}$$

where $n_{prim'enrol}$,..., n_{tert} are 30 x 1 matrices with the number of individuals in a given education state aged 15 to 44. The input comprises the observed number of individuals primary educated and enrolled in education at age 15. The corresponding cohort is aging and transitioning to education states by multiplying the transition matrix M with population matrix N until the cohort reaches age 44. The age- and education-specific birth rates of a given cohort are organised in a 1 x 180 birth matrix:

$$B = \begin{bmatrix} b_{prim'enrol} & b_{prim} & b_{sec'enrol} & b_{sec} & b_{tert'enrol} & b_{tert} \end{bmatrix}$$

where $b_{prim'enrol}$,..., b_{tert} are 1 x 30 matrices with the age- and education-specific birth rates in a given education state at ages 15 to 44. Lifetime fertility is calculated for a given cohort as $\sum BN/n_{prim'enrol'15}$.

We simulate lifetime fertility in different scenarios: we keep each of the education transition probabilities/birth rate stable one at a time while the rest of the education transition probabilities/birth rate change according to observed trends – or alternatively: we allow each of the education transition probabilities/birth rate to change according to observed trends one at a time while the rest of the education transition probabilities/birth rate are held constant. In order for the education transition probabilities from an initial state to sum up to 1, we adjust the transition probability remaining in that initial state as follows:

For the transition from primary education and enrollment to primary education:

$$\begin{aligned} p_{prim'enrol-prim'enrol-new} = 1 &- p_{prim'enrol-prim-scenario} \\ &- p_{prim'enrol-sec'enrol} \\ &- p_{prim'enrol-sec} \\ &- p_{prim'enrol-tert'enrol} \\ &- p_{prim'enrol-tert} \end{aligned}$$

For the transition from primary education and enrollment to secondary education and enrollment:

$$
\begin{aligned}
p_{prim'enrol-prim'enrol-new} = 1 - & \; p_{prim'enrol-prim} \\
& - p_{prim'enrol-sec'enrol-scenario} \\
& - p_{prim'enrol-sec} \\
& - p_{prim'enrol-tert'enrol} \\
& - p_{prim'enrol-tert}
\end{aligned}
$$

For the transition from primary education and enrollment to secondary education:

$$
\begin{aligned}
p_{prim'enrol-prim'enrol-new} = 1 - & \; p_{prim'enrol-prim} \\
& - p_{prim'enrol-sec'enrol} \\
& - p_{prim'enrol-sec-scenario} \\
& - p_{prim'enrol-tert'enrol} \\
& - p_{prim'enrol-tert}
\end{aligned}
$$

For the transition from primary education and enrollment to tertiary education and enrollment:

$$
\begin{aligned}
p_{prim'enrol-prim'enrol-new} = 1 - & \; p_{prim'enrol-prim} \\
& - p_{prim'enrol-sec'enrol} \\
& - p_{prim'enrol-sec} \\
& - p_{prim'enrol-tert'enrol-scenario} \\
& - p_{prim'enrol-tert}
\end{aligned}
$$

For the transition from primary education and enrollment to tertiary education:

$$\begin{aligned} p_{prim'enrol-prim'enrol-new} = 1 &- p_{prim'enrol-prim} \\ &- p_{prim'enrol-sec'enrol} \\ &- p_{prim'enrol-sec} \\ &- p_{prim'enrol-tert'enrol} \\ &- p_{prim'enrol-tert-scenario} \end{aligned}$$

For the transition from primary education to primary education and enrollment:

$$\begin{aligned} p_{prim-prim-new} = 1 &- p_{prim-prim'enrol-scenario} \\ &- p_{prim-sec'enrol} \\ &- p_{prim-sec} \\ &- p_{prim-tert'enrol} \\ &- p_{prim-tert} \end{aligned}$$

For the transition from primary education to secondary education and enrollment:

$$\begin{aligned} p_{prim-prim-new} = 1 &- p_{prim-prim'enrol} \\ &- p_{prim-sec'enrol-scenario} \\ &- p_{prim-sec} \\ &- p_{prim-tert'enrol} \\ &- p_{prim-tert} \end{aligned}$$

For the transition from primary education to secondary education:

$$
\begin{aligned}
p_{prim-prim-new} = 1 &- p_{prim-prim'enrol} \\
&- p_{prim-sec'enrol} \\
&- p_{prim-sec-scenario} \\
&- p_{prim-tert'enrol} \\
&- p_{prim-tert}
\end{aligned}
$$

For the transition from primary education to tertiary education and enrollment:

$$
\begin{aligned}
p_{prim-prim-new} = 1 &- p_{prim-prim'enrol} \\
&- p_{prim-sec'enrol} \\
&- p_{prim-sec} \\
&- p_{prim-tert'enrol-scenario} \\
&- p_{prim-tert}
\end{aligned}
$$

For the transition from primary education to tertiary education:

$$
\begin{aligned}
p_{prim-prim-new} = 1 &- p_{prim-prim'enrol} \\
&- p_{prim-sec'enrol} \\
&- p_{prim-sec} \\
&- p_{prim-tert'enrol} \\
&- p_{prim-tert-scenario}
\end{aligned}
$$

For the transition from secondary education and enrollment to secondary education:

$$\begin{aligned} p_{sec'enrol-sec'enrol-new} = 1 &- p_{sec'enrol-sec-scenario} \\ &- p_{sec'enrol-tert'enrol} \\ &- p_{sec'enrol-tert} \end{aligned}$$

For the transition from secondary education and enrollment to tertiary education and enrollment:

$$\begin{aligned} p_{sec'enrol-sec'enrol-new} = 1 &- p_{sec'enrol-sec} \\ &- p_{sec'enrol-tert'enrol-scenario} \\ &- p_{sec'enrol-tert} \end{aligned}$$

For the transition from secondary education and enrollment to tertiary education:

$$\begin{aligned} p_{sec'enrol-sec'enrol-new} = 1 &- p_{sec'enrol-sec} \\ &- p_{sec'enrol-tert'enrol} \\ &- p_{sec'enrol-tert-scenario} \end{aligned}$$

For the transition from secondary education to secondary education and enrollment:

$$\begin{aligned} p_{sec-sec-new} = 1 &- p_{sec-sec'enrol-scenario} \\ &- p_{sec-tert'enrol} \\ &- p_{sec-tert} \end{aligned}$$

For the transition from secondary education to tertiary education and enrollment:

$$
\begin{aligned}
p_{sec-sec-new} = 1 &- p_{sec-sec'enrol} \\
&- p_{sec-tert'enrol-scenario} \\
&- p_{sec-tert}
\end{aligned}
$$

For the transition from secondary education to tertiary education:

$$
\begin{aligned}
p_{sec-sec-new} = 1 &- p_{sec-sec'enrol} \\
&- p_{sec-tert'enrol} \\
&- p_{sec-tert-scenario}
\end{aligned}
$$

For the transition from tertiary education and enrollment to tertiary education:

$$p_{tert'enrol-tert'enrol-new} = 1 - p_{tert'enrol-tert-scenario}$$

For the transition from tertiary education to tertiary education and enrollment:

$$p_{tert-tert-new} = 1 - p_{tert-tert'enroll-scenario}$$

Appendix B

Age-Specific Transition Probabilities for Men

Figure B1 provides the age-specific transition probabilities between educational states for men. Similarly to women, we see an increase in going back to school after dropping out across cohorts (moving from primary & not enrolled to primary & enrolled), and an increase in continuing in education after attaining a tertiary degree, albeit to a smaller magnitute than for women.

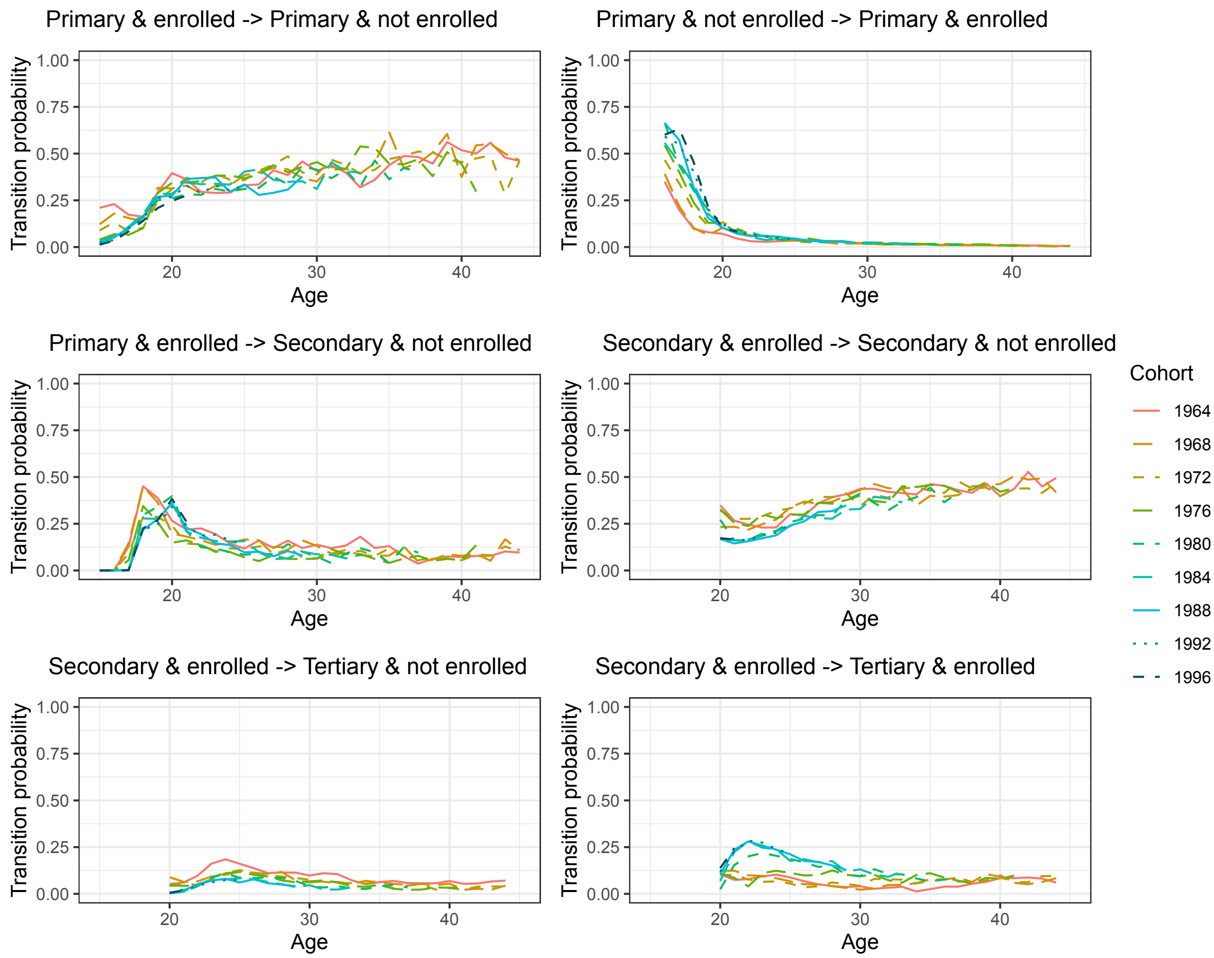

Figure B1. Age-specific transition probabilities between education states across cohorts, men.

Appendix C

Age-Specific Fertility Rates

Figure C1 provides the smoothed age-specific first birth rate by educational state for men and women across cohorts born between 1964 and 1988. For both men and women, we see a clear decline in first birth rates across cohorts for those not enrolled with a primary education. For men, there also is a decline in first birth rates for men not enrolled with a tertiary degree as well, while for women this is only clear for the most recent cohort. First birth rates for both men and women enrolled in education, regardless of educational attainment, appear to be relatively stable across cohorts.

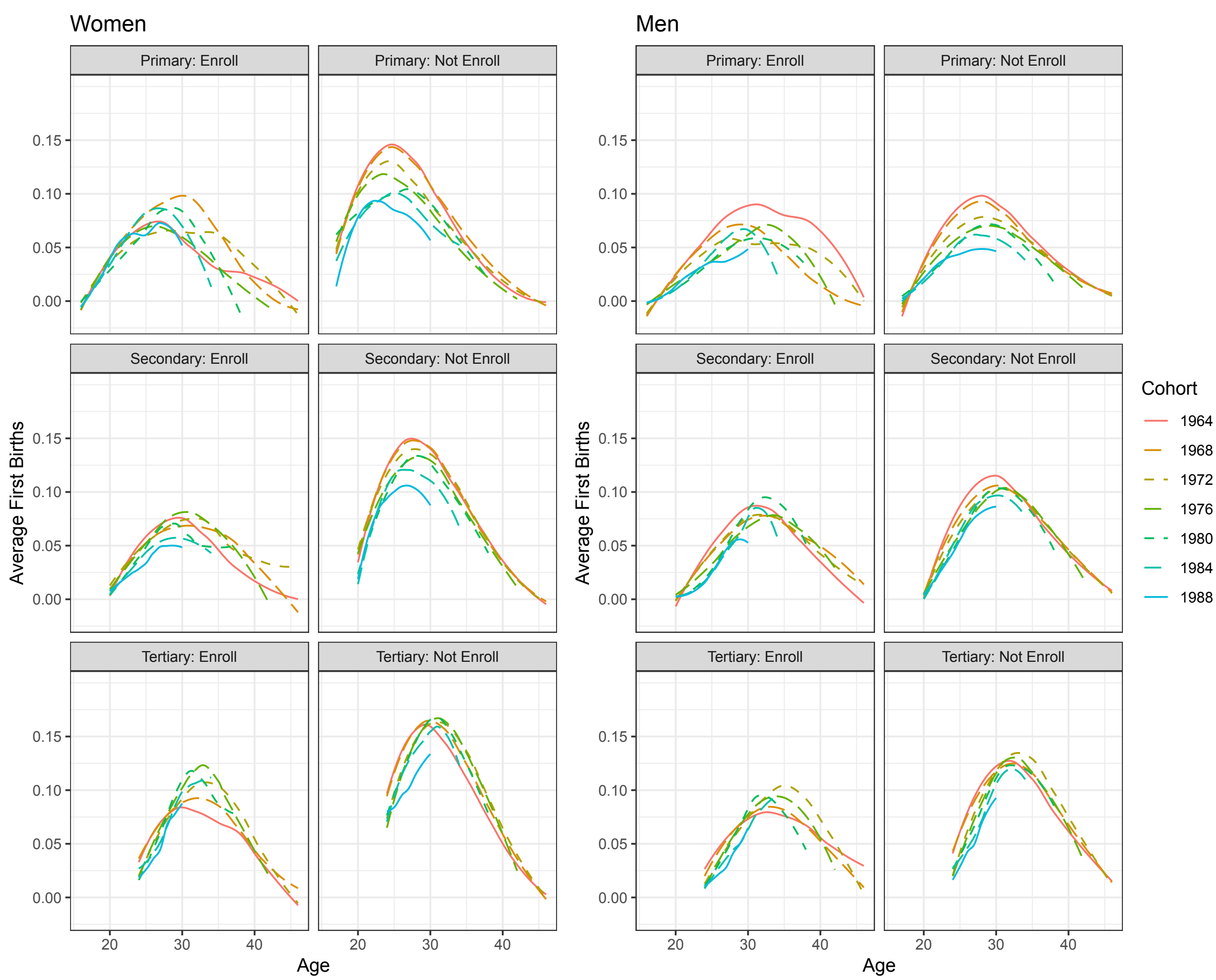

Figure C1. Age-specific first birth rate by education state and cohort, women and men. *Note.* Rates at older ages for those enrolled in education should be read with caution do to the small numbers of individuals in these groups. Loess smoothed rates.

Figure C2 provides the loess-smoothed age-specific birth rates by education state for men and women across cohorts born between 1964 and 1988.

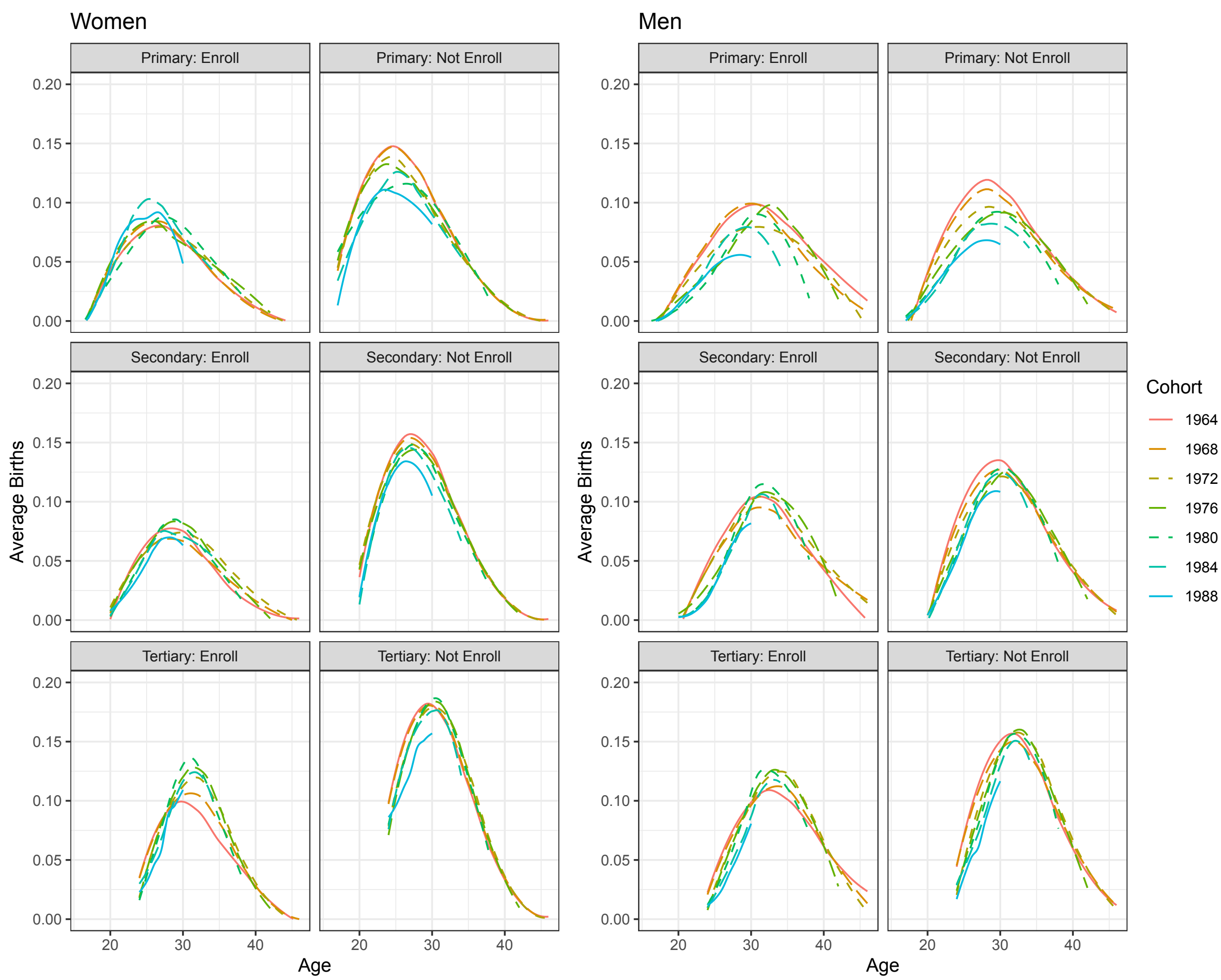

Figure C2. Age-specific fertility rate by education state and cohort, women and men. *Note.* Rates at older ages for those enrolled in education should be read with caution do to the small numbers of individuals in these groups. Loess smoothed fertility rates.

Appendix D

Contribution by Father's Education

To get some indication of future fertility patterns by education we present the observed and predicted completed cohort fertility and ultimate childlessness for women by father's education in Figure D1. Previous research has shown that early life socio-economic status is not a very good predictor of later educational attainment among men, thus the results are presented for women only (Nisén et al., 2018). We first note that the fertility patterns by father's education match relatively well the patterns observed by own education for the late 1960s cohorts (Jalovaara et al., 2019). Women with primary educated fathers experienced a declining trend in completed cohort fertility, and consequently, completed cohort fertility converged to right above 2 children per woman by the early 1970s cohorts across education levels. Nevertheless, the increasing trend in ultimate childlessness for women with primary educated fathers is somewhat less pronounced compared to the trend observed for primary educated women, who experienced levels of ultimate childlessness surpassing the higher educated counterparts by the late 1960s cohorts.

Looking at the predicted values, we observe relatively similar declines in completed cohort fertility and increases in ultimate childlessness by father's education, should future education transitions and birth rates remain stable in the future. Completed cohort fertility is predicted to decline to around 1.75 for women with primary and tertiary educated fathers, while remaining somewhat higher for women with secondary educated fathers. Ultimate childlessness is predicted to rise to 16-17% regardless of education level. Notably however, women with lower educated fathers likely had most of their children at relatively young ages, whereas women with higher educated fathers have children later, leaving more space for fertility recuperation for these cohorts. Hence, the prediction for women with lower educated fathers is likely to be more accurate than for women with higher educated fathers.

Changes in education initially contributed to both the decline in cohort fertility and the increase ultimate childlessness among women with primary and secondary educated fathers. After the 1974 cohort, the predicted changes are almost entirely driven by changes in birth rates.

Educational expansion for the older cohorts and stagnation for the younger cohorts contributed little to the fluctuation in completed fertility and ultimate childlessness across women from highly educated fathers, with changes in birth rates driving the trends in cohort fertility and ultimate childlessness.

The predicted changes in completed cohort fertility and ultimate childlessness are rather similar by father's education and did not identify diverging social gradients, should future education transitions and age-specific fertility rates remain unchanged. Nevertheless, while father's education appears to be a relatively good proxy for older cohorts, it might be less so for younger cohorts. Women experienced large increases in education as a result of educational expansion, and especially experienced large gains in tertiary education participation (Lindbekk, 2015). Therefore, women in the younger cohorts may have experienced larger relative gains in education comparatively to their parent's educational attainment. Future studies should use more sophisticated methods to forecast own education and to better take into account the different fertility timing of different education levels. It is likely that 30+ fertility recovers more among the higher educated men and women.

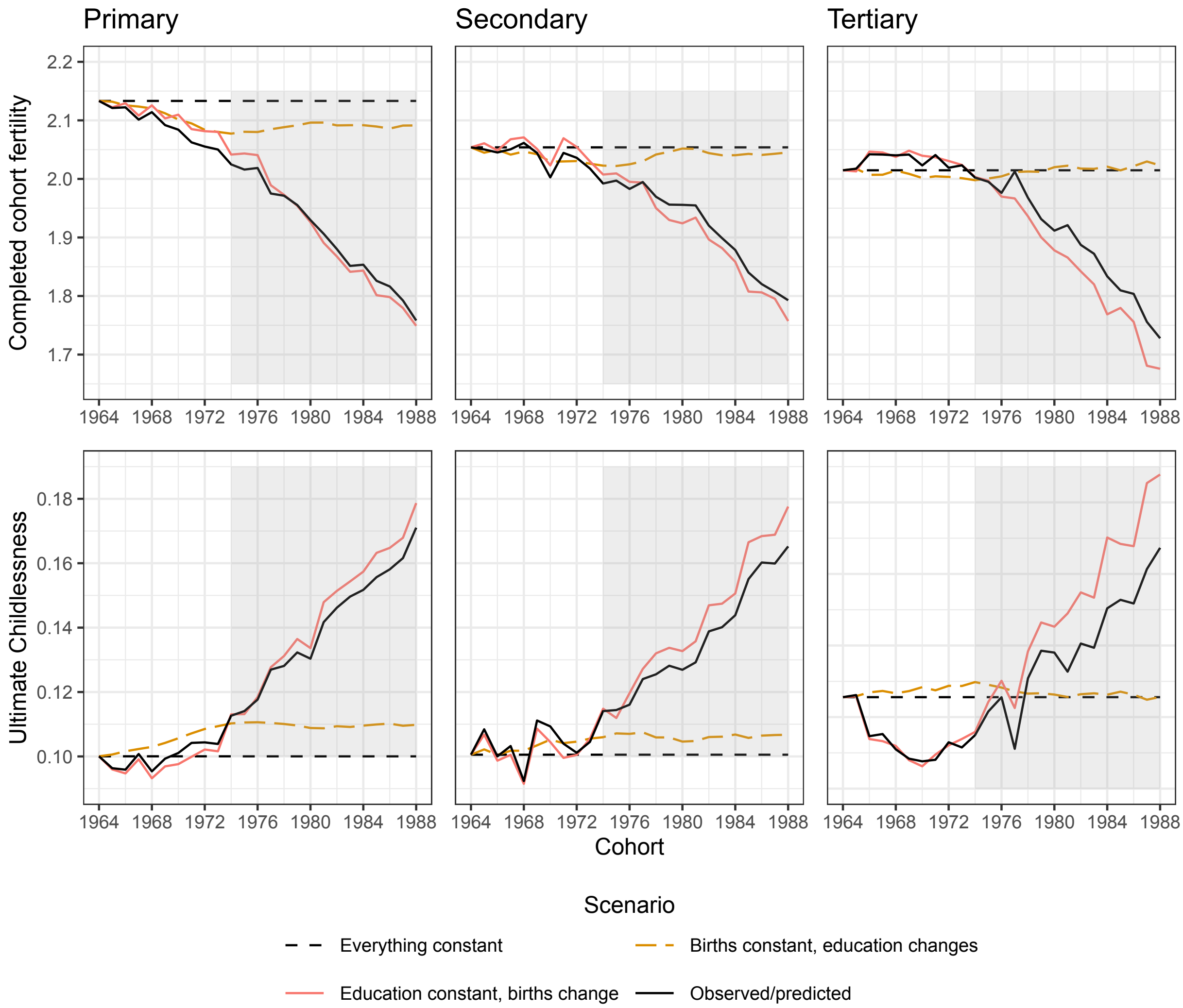

Figure D1. Observed completed cohort fertility and ultimate childlessness by father's education level for cohorts 1964–1974 and predicted completed cohort fertility and ultimate childlessness for cohorts 1975–1988 in different scenarios, women. *Note.* The grey area indicates predicted values.

Appendix E

Stable Scenario Counterfactual Results

Figure E1 provides the results for completed cohort fertility and ultimate childlessness where everything changes according to observed trends, but where educational transitions or birth rates by educational category remain stable one at a time. For female completed cohort fertility, unchanged fertility behavior reduces the predicted decline similarly across educational attainment, despite differences in relative size, resulting from the stronger fertility declines among the lower educated. For men, the contribution of some education changes becomes visible for more recent cohorts when birth rates change according to observed trends, but as shown in Figure 5, these contributions even out.

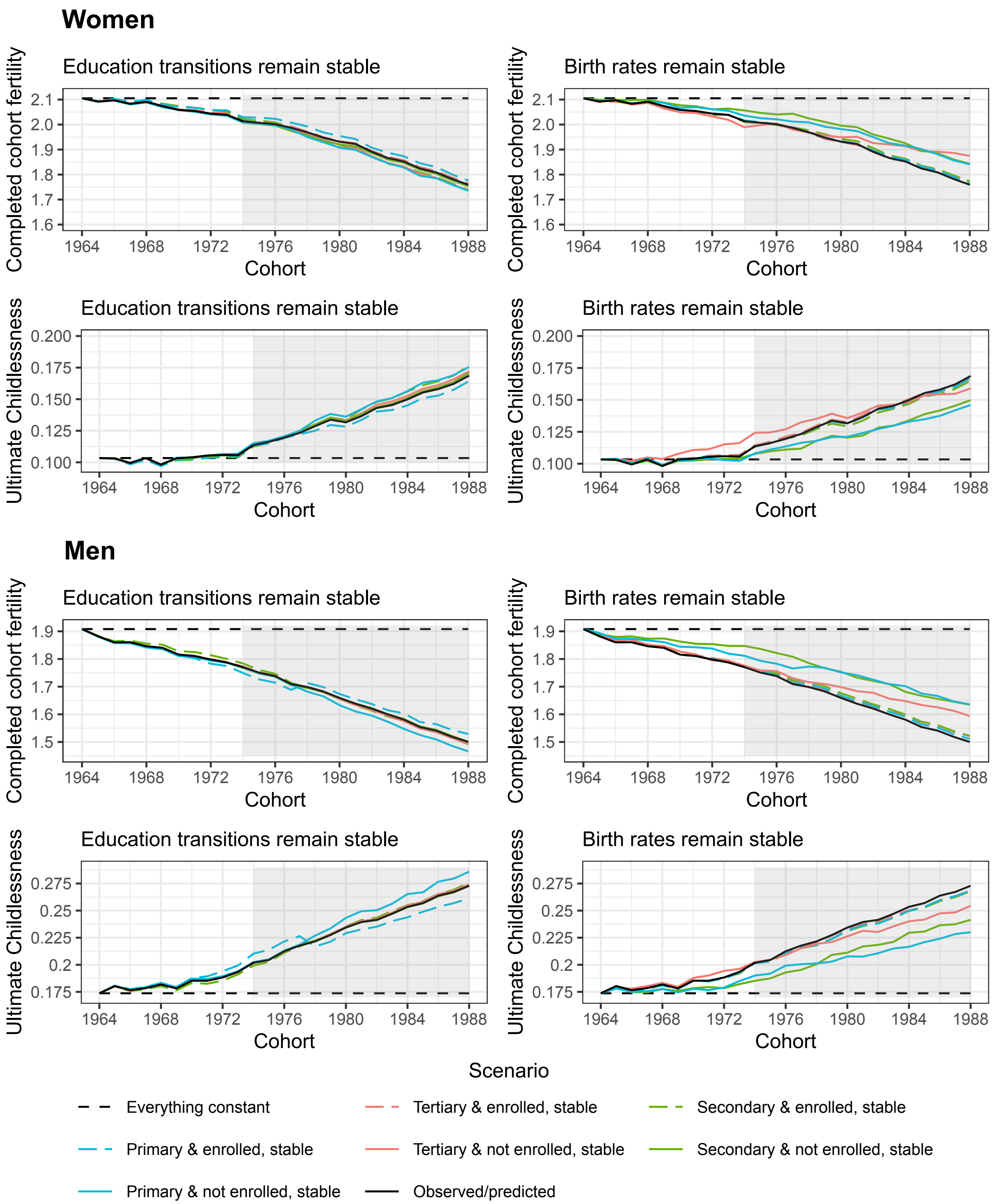

Figure E1. Observed and predicted completed cohort fertility and ultimate childlessness for men and women when everything changes according to observed trends, but education transitions are kept stable in each of the states (left), versus each of the birth rates are kept stable one at a time (right).

Appendix F

Contributions of Changes in Educational Transitions to Cohort Fertility for Men

Figure F1 provides the observed and predicted completed cohort fertility where everything remains constant but where each educational transition changes one at a time, for men. There appears to be little contribution of educational transitions to the fertility decline among men, when everything remains according to latest observed trends.

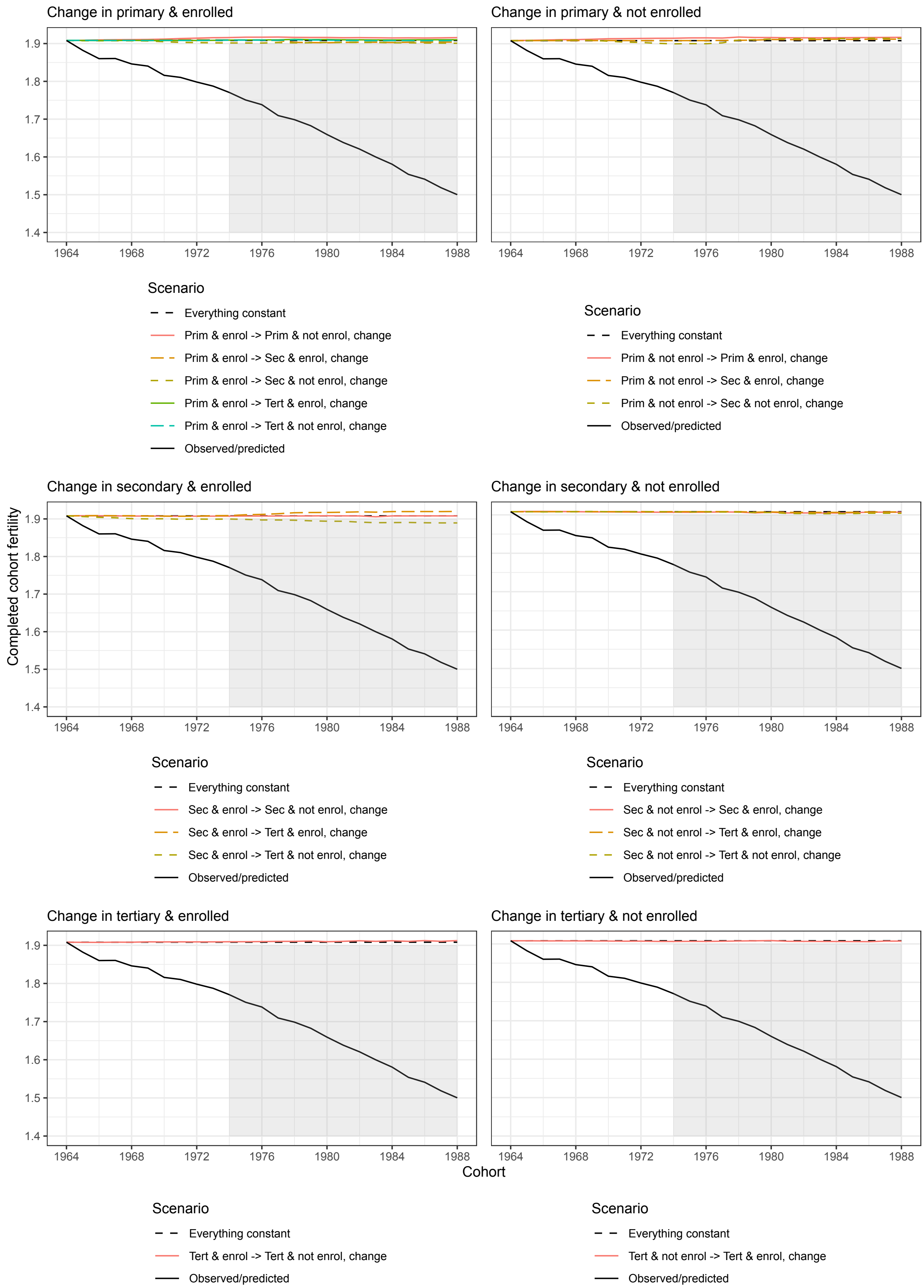

Figure F1. Observed and predicted completed cohort fertility when everything is held constant, but each of the education transitions change one at a time, men.

Appendix G

Contributions of Changes in Educational Transitions to Childlessness

Figures G1 and G2 provide the observed and predicted rates of ultimate childlessness where everything remains constant but where each educational transition changes one at a time, for women and men, respectively. For women, the lower rates of dropout across cohorts contributed slightly to the predicted increase in ultimate childlessness, as well as the increase in going back to school after leaving, both from primary and secondary education groups. For men, we see little contribution of changes in educational transitions to the rising rates of ultimate childlessness, though the lower rates of dropout positively contributed to a small extent, along with the higher rates of going back to school after dropping out (primary & not enrolled to primary & enrolled).

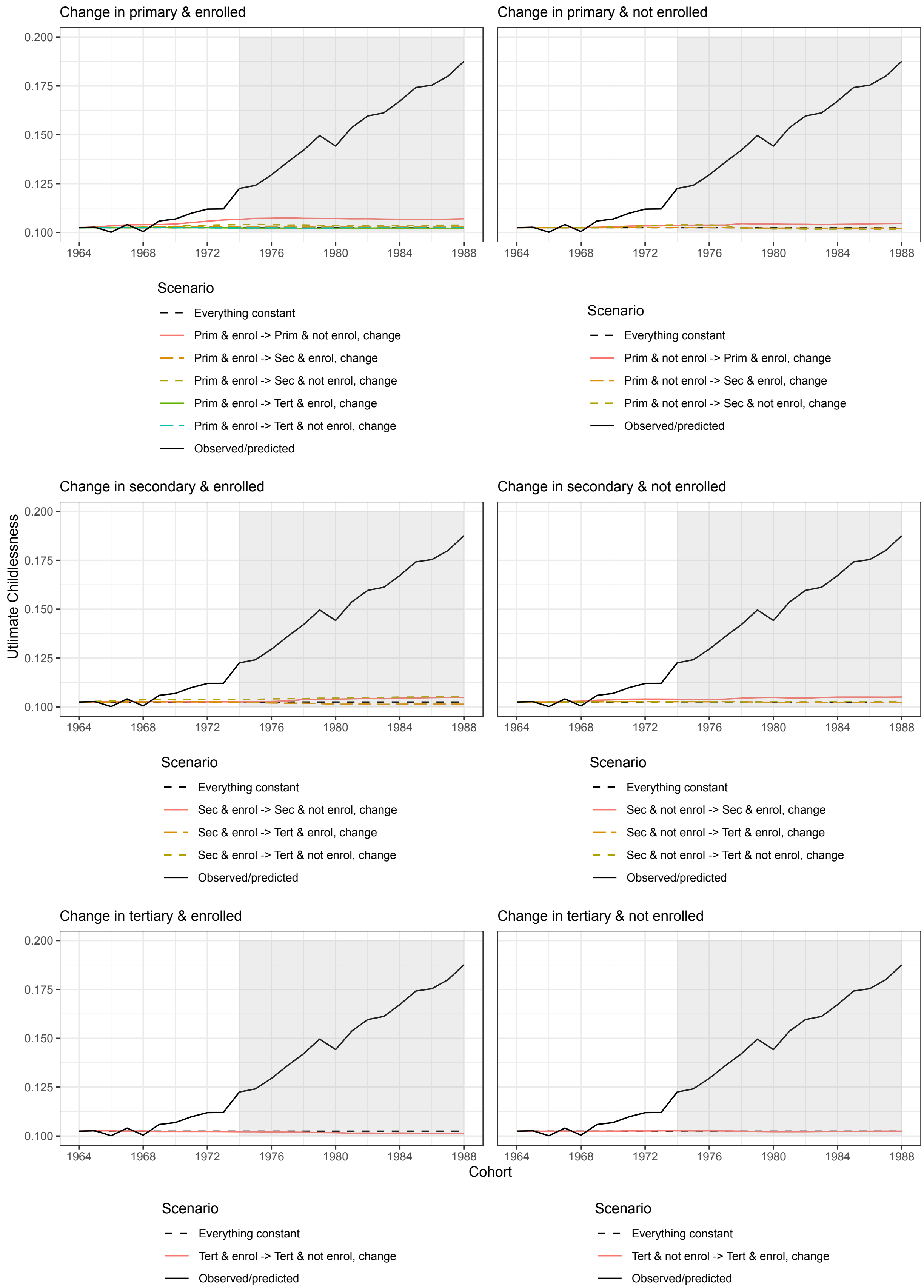

Figure G1. Observed and predicted proportion childless when everything is held constant, but each of the education transitions change one at a time, women.

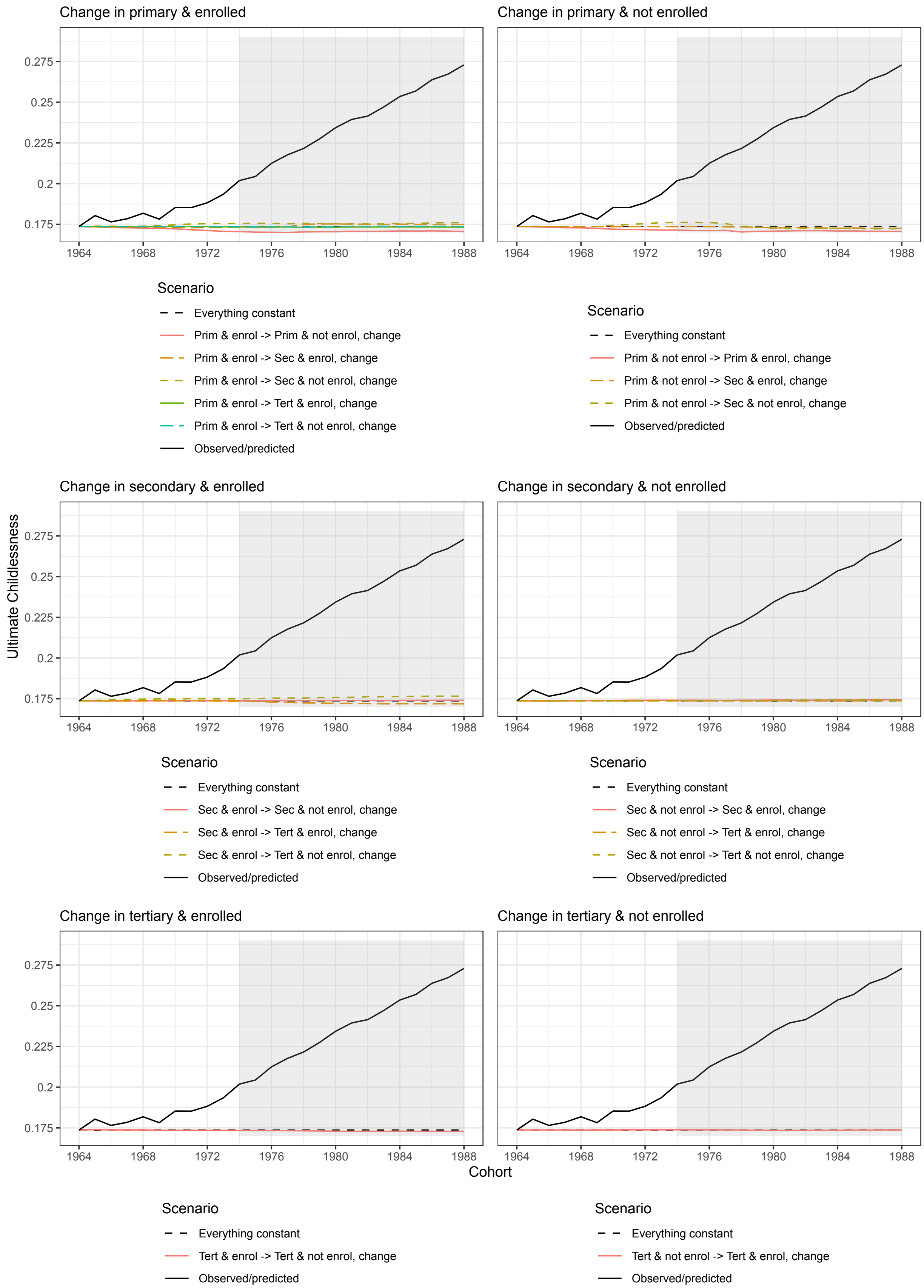

Figure G2. Observed and predicted proportion childless when everything is held constant, but each of the education transitions change one at a time, men.

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