

The fertility puzzle

Trends and patterns of male and female fertility



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This thesis is dedicated to
my mum, my dad, my brother David and Clara
for their unconditional support and love.

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Abstract

Human fertility is a complex and multifaceted phenomenon that has been studied extensively in demography. Despite its importance for population growth and structures, fertility remains a poorly understood aspect of human behavior, with many factors influencing whether and how many children an individual may have. Therefore, this thesis aims to shed light on the factors affecting fertility trends and patterns, with a focus on the interplay of social, cultural, economic, structural, and biological factors that influence human fertility. By considering the contributions of both men and women, and employing subnational designs to address the limitations of cross-country comparisons, this thesis aims to provide a nuanced understanding of the factors affecting fertility trends and patterns. The noteworthy decline in TFRs in the Nordic and Anglo-Saxon countries provides a timely motivation for this study, highlighting the need for a comprehensive analysis of the complex factors driving fertility changes. In **Chapter 1**, I describe the fertility trends across countries in the recent period and introduce the most important theories of fertility. In **Part I**, I focus on predictors of fertility at the macro-level. **Chapter 2** describes the relationship between economic development and fertility in the United States using longitudinal data. Here, the fertility decline reversal as well as the fading relationship in the 2010s are particularly noteworthy. **Chapter 3** uses Finnish register data to discern the contribution of accelerated secularization to the recent declines in fertility. This chapter advances also a sociological mechanism, the self-reinforcing effect of secularization on fertility, which rests on the interaction of religious affiliation, partnership formation and couple fertility. **Chapter 4** of the thesis quantifies couples' fecundity, an often overlooked but potentially relevant factor in childbearing. By combining data from the Norwegian Mother and Child Cohort Study (MoBa) with Norwegian register data, I predict couple's sub-fecundity using modern machine-learning tools. **Part II** focuses on gender differences in fertility. **Chapter 5** investigates male-female differences in subnational fertility rates across eight middle- and high-income countries. This chapter highlights the relevance of regional population imbalances on gender differences in fertility quantum. Moreover, it describes factors that lead to these gender differences and proposes four approaches to classify pronounced differences, e.g. *birth squeezes*. **Chapter 6** harnesses individual-level Finnish register data to assess the relationship between life-time exposure to unbalanced regional partner markets and the probability of remaining childless among men. This chapter proposes partner markets as a potential driver for fertility trends, as men's childlessness has been rapidly increasing, particularly among lower educated men. The thesis concludes in **Chapter 7** with a discussion of the importance of fertility for society, potential policy suggestions, and provides a glimpse at the future of fertility.

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List of Abbreviations

ASFR	Age-specific fertility rate
AUC	Area-under-the curve
AR	Availability ratio
CDC	Centers for Disease Control
DNBC	Danish National Birth Cohort Study
e_0	Life expectancy at birth
FE	Fixed-effects
FEISR	Fixed-effects individual slope regression
GAM	Generalized additive model
GDP	Gross domestic product
HDI	Human Development Index
HLI	Human Life Indicator
LOESS	Locally-weighted scatterplot smoothing
PR	Preference ratio
MoBa	Norwegian Mother, Father, and Child Cohort Study
ROC	Receiver operating characteristic
SR	Sex ratio
SRB	Sex ratio at birth
TFR	Total fertility rate
TTP	Time-to-pregnancy

UN United Nations

US The United States of America

*The fox knows many things,
but the hedgehog knows one big
thing.*

Archilochus

1

Introduction

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Human fertility is a complex and multifaceted phenomenon that has been studied extensively in demography. Despite its importance for population growth and structures, fertility remains a poorly understood aspect of human behavior, with many factors influencing whether and how many children an individual may have. The recent fertility decline in the 2010s in many high-income countries, including the United States (Chapter 2) and the Nordic countries (Chapter 5), has

highlighted the limitations of our current understanding of fertility. The fertility decline was particularly unexpected in the Nordic countries, where generous family policies and progress in gender equity had been assumed to consolidate fertility rates at around the replacement level (Esping-Andersen & Billari, 2015; Goldstein et al., 2009; Myrskylä et al., 2009). Therefore, this dissertation sheds light on the drivers and patterns of fertility. I examine the factors that influence human fertility, with a focus on the fertility of women and men at the subnational level using full population administrative register data. The thesis concentrates on the United States, Norway, and Finland, but also looks at other countries.

This thesis contends that fertility is the result of a complex interplay of biological, social, structural, and economic factors, and thus cannot be explained by a single cause. Demographers, sociologists, and economists proposed several explanations for fertility trends and the recent fertility decline particularly (Comolli, 2021; Hellstrand et al., 2024; Schneider & Gemmill, 2016; Vignoli et al., 2020). However, they neither anticipated the decline nor were able to fully explain it. Scholars tend to point at one central explanation for the decline, but such simplistic approaches are destined to fail because fertility is a complex multifactorial outcome. I will therefore adopt a more nuanced approach that acknowledges the complexity of the issue. This perspective is in line with Isaiah Berlin's (1953) argument that a "fox" approach, which involves considering multiple perspectives and explanations, is more scholarly and scientific than a "hedgehog" approach, which seeks to fit all evidence into a single, overarching theory. Hedgehogs "relate everything to a single central vision, one system less or more coherent or articulate, in terms of which they understand, think and feel—a single, universal, organizing principle" (Berlin, 1953, p. 2). In other words, hedgehogs possess a theory and fit the evidence to the theory. By contrast, foxes accept many contradictory facts at different levels "without, consciously or unconsciously, seeking to fit them into, or exclude them from, anyone unchanging, all-embracing, sometimes self-contradictory and incomplete, at times

fanatical, unitary inner vision” (Berlin, 1953, p. 2). Foxes draw on a wide array of perspectives to explain and predict a phenomenon. Evidence has shown that foxes are the better forecasters because they remain humble about their knowledge gaps, while hedgehogs are overconfident in their knowledge (Tetlock, 2006). In a similar vein, I contend, foxes are better able to comprehend the recent fertility decline.

Taking the fox’s position has significant epistemological implications. First, the fox employs a diverse range of theoretical perspectives to explain complex phenomena, unlike the hedgehog, who relies on a single, overarching theory. In this thesis, I adopt a similar approach, investigating multiple factors that contribute to the fertility decline, including human development (Chapter 2), secularisation (Chapter 3), fecundity (Chapter 4), and partner markets (Chapter 6). These factors may be classified as social, economic, cultural, structural, and biological drivers, which is already an indication of the diversity of factors influencing fertility. Second, all theories and hypotheses are subject to rigorous examination. The fox investigates the same hypothesis in different settings, models, data sets, and operationalisation, while the hedgehog may stop upon finding the first confirming result. Therefore, I use multiverse analysis throughout the different empirical chapters in the thesis. Multiverse analysis involves the use of a variety of operationalisation, specifications, models, and designs to substantiate the findings. This approach has been successfully applied in other fields, such as the study of social mobility in Sweden (Engzell & Mood, 2023). Finally, I expand the current understanding of fertility and its underlying causes by relating my findings back to the initial research question and quantifying its contribution to changes in overall fertility. Specifically, I use population-level effects and counterfactual simulations to quantify the contribution of each factor to the fertility decline. Decomposing the fertility decline into its components and quantifying the size of each contribution sheds light on its relative importance.

Understanding human fertility is crucial for both academics and policymakers for several reasons. First, fertility is a key demographic process that shapes population structures, and policy-makers need to plan for future changes in these structures. Population structures are relevant for labour market, health care, and education policies. As Keyfitz (1975) and Lee et al. (2017) have demonstrated, the impact of fertility decline on population ageing is stronger than the corresponding effect of mortality decline. Therefore, understanding fertility is essential for forecasting the structure of populations in the future. Second, childbearing is an important life goal for individuals, and fertility affects their happiness and well-being (Baetschmann et al., 2016), although the duration of these effects is controversial (Aassve et al., 2021). Research has shown that having up to two children can increase happiness, particularly for those who have postponed childbearing (Myrskylä et al., 2014). When structural constraints prevent individuals from fulfilling their childbearing intentions, their quality of life and life satisfaction may be negatively affected. This is important to bear in mind because there is a gap between the ideal number of children and realized fertility in many countries (Harknett et al., 2014). Furthermore, in many countries, care and social support structures for individuals are largely organized around family relationships (Deindl & Brandt, 2017; Suanet et al., 2012). If more individuals remain childless, their social and care safety nets may deteriorate, leading to loneliness and a lack of elderly care, particularly among the less affluent. These changes may be detrimental to individuals' well-being and health in old age (Einiö et al., 2016; Elenkov et al., 2020).

It is essential to note that low fertility is not a problem *per se*, and comes with several positive side effects. Over the long term, declining cohorts may reduce the impact of humans on the climate, provide governments and parents with the opportunity to invest more in individual children, and ease the competition on housing markets (Skirbekk, 2022). For instance, research has shown that the impact of declining cohort sizes on economic growth and pension systems can be mitigated

by investments in the human capital of the upcoming cohorts (Myrskylä et al., 2024). Thus, it highlights the importance to consider the potential benefits of low fertility when developing policies to address its challenges.

1.1 The recent fertility trends

Fertility is defined as the reproductive behaviour of a population. Fertility can be measured for cohorts or for periods. The latter is usually measured by the total fertility rate, which indicates the average number of children a woman would bear over her entire reproductive period if she was subject to the fertility regime of a given year (Preston et al., 2008). Although the measure has been criticised for several reasons, including because it may be affected by parity-tempo distortions (Bongaarts & Watkins, 1996; Kohler & Philipov, 2001; Sobotka & Lutz, 2010), it remains a widely used metric in demography. Figure 1.1 illustrates the trend in the total fertility rate for the largest countries in the Human Fertility Database (Max Planck Institute for Demographic Research & Vienna Institute of Demography, 2025), and highlights with colour the countries under investigation in this thesis. Countries are split over several panels according to their geographic (Mediterranean) or cultural (Anglo-Saxon) positions. Trends and levels within country groups are remarkably similar, with the lines within a panel following similar paths and being relatively close together. The only exception is that of France, which stands out from the other Mediterranean countries.¹ Moreover, countries with similarly high fertility around 2008, which is indicated by the vertical red line, experienced declining fertility in the subsequent decade. This pattern is observable in the Anglo-Saxon countries, France, and the Nordics. The TFR declined most strongly in Norway, where it fell by 0.48 points (see Chapter 4); in Finland, where it

¹France is therefore sometimes grouped with the German-speaking countries as a continental country group.

decreased by 0.477 points (see Chapter 3); Iceland, where it declined by 0.436 points; and in the United States, where it decreased by 0.335 points (see Chapter 2). Importantly, the TFR declines in the Nordic countries will likely lead to declines in cohort fertility, as complete recuperation at older ages is unlikely (Hellstrand et al., 2021). In contrast, fertility decreased less in the East Asian and Mediterranean countries, where fertility had already been low. Moreover, the Eastern European and German-speaking countries showed a divergent trend in the last decade (see second next paragraph). In these countries, fertility actually remained stable or even increased in the period between 2010 and 2020. This pattern might have been driven by cohort fertility recuperation or a fertility rebound. Potential explanations for fertility decline reversals are discussed in Chapter 2. However, these increases were not long-lasting, at least in Germany, where the TFR dropped to 1.34 in 2022, according Bujard and Andersson (2024).

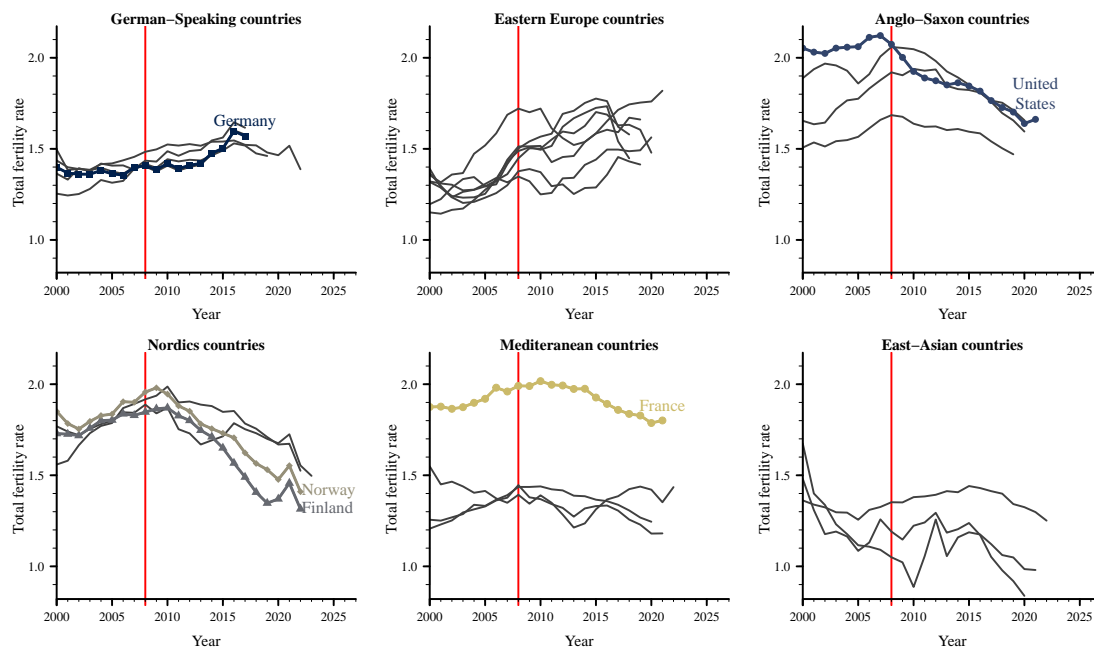


Figure 1.1: Time trend of the total fertility rate across countries grouped by geographic-cultural similarities in the 2000-2020 period. **Source:** Data were obtained from the Human Fertility Database (Max Planck Institute for Demographic Research & Vienna Institute of Demography, 2025).

The fertility decline is visible in the period rates for the years between 2007/08

and 2022. Over this period, fertility was increasingly postponed to later ages (Hellstrand et al., 2020; Kearney et al., 2022), which may have deflated the total fertility rates to some degree. Regardless, the fertility decline is certainly affecting cohort fertility, as complete recuperation after postponement is unlikely to offset the impact of the 12-year decline (Hellstrand et al., 2020). Thus, the fertility decline is not just a temporal postponement, as individuals appear to be having fewer children or forgoing childbearing altogether. While the fertility declines during the first demographic transition were mainly driven by reductions of higher parity births (Zeman et al., 2018), the patterns for the recent declines have been different, as reductions in first births contributed the most to these declines (Comolli, 2021; Hellstrand et al., 2021; Kearney et al., 2022; Ohlsson-Wijk & Andersson, 2022). Thus, individuals tend to enter parenthood later and remain childless more often. Evidence for Finland shows that delayed and reduced childbearing within unions account for the major share (three-quarters) of the recent decline in first births, while changing union dynamics account for only a small share (one-quarter) of this decline. While the decline has occurred across all social groups in the Nordics and the United States, it has been more accentuated in disadvantaged groups (Hellstrand et al., 2024; Jalovaara et al., 2019, 2022; Kearney et al., 2022; Ohlsson-Wijk & Andersson, 2022). In the United States, Hispanic, younger (aged 15–29), unmarried, and lower educated individuals have experienced more pronounced fertility declines (Kearney et al., 2022; Schneider & Hastings, 2015). In Sweden, the largest declines have been observed among low-income groups and students (Ohlsson-Wijk & Andersson, 2022). In Finland, the declines have been greatest among lower educated individuals and those in educational fields exposed to increasing economic uncertainty (Hellstrand et al., 2024; Jalovaara et al., 2019).

The Eastern- and German-speaking countries exhibit a divergent fertility trend, as the TFR remained stable or even increased in the 2010s (see Figure 1.1). The Eastern European countries have historically had a distinct fertility pattern, marked

by a sudden decline in the TFR in the 1990s and a gradual recovery afterwards, which has been related to the transformation from a state-socialist to a market-based democratic system (Sobotka & Fürnkranz-Prskawetz, 2020). The legacy of the state-socialist period continues to influence cultural norms, making first births relatively common among women, while childlessness and higher-order parities are less common (Billingsley, 2010; Sobotka, 2017a). In contrast, the German-speaking countries have a remarkably stable level of low fertility, as indicated by the TFR (Sobotka, 2011a), and high levels of childlessness (Sobotka, 2017a). The divergent trend in these country groups can likely be attributed to differences in historical, cultural, and structural characteristics (Németh et al., 2025). Historical differences are particularly relevant for Eastern European countries and East Germany, where the societal transformation from a state-socialist to a market-based democratic system led to temporary fertility postponement in the 1990s (Sobotka, 2011b). This temporary fertility postponement was followed by a gradual fertility recovery in the 21st century, likely driven by fertility postponement recuperation (Sobotka, 2011b). Regarding cultural and institutional differences, the welfare state in German-speaking countries is more conservative and family-oriented, which may result in a lower degree of pro-cyclical fertility compared to Nordic and Anglo-Saxon countries, where generous family policies or flexible labor markets reinforce the impact of economic conditions on childbearing (Andersson et al., 2009). Furthermore, fertility intentions are lower and below the replacement level in German-speaking countries (Beaujouan & Berghammer, 2019).

1.2 Classical theories of fertility

Various theories have been developed to explain fertility behaviour in a logical and coherent way. These theoretical contributions come from sociology, demography, economics, and biology. Each of these disciplines employs a distinct lens for understanding the complex phenomenon of fertility. For instance, sociological

theories emphasise the role of norms and values in shaping fertility behaviour, as exemplified by the fertility diffusion theory or the second demographic transition theory. Demography, by contrast, contributes the theory of the first demographic transition, which describes the transition from high to low levels of mortality and birth rates. Economic theories assume that individuals and households behave rationally, and thus strive to maximise their utility. Meanwhile, biological theories focus on the fitness of a population and highlight the trade-off between reproduction and survival. All of these theories remain important in the ongoing debate on fertility trends, as they have been employed to explain the recent fertility declines. In this section, I will briefly introduce the most important theories of fertility and connect them to the recent fertility trends. I provide references for readers who wish to explore these topics in greater depth.

1.2.1 The demographic transition

The demographic transition theory remains relevant today, as it is used for fertility forecasts by the United Nations population division of countries that have above replacement level fertility (Alkema et al., 2011). However, as this theory does not provide conclusive predictions regarding fertility trends after the completion of the fertility transition, it is not very useful for understanding fertility declines in low fertility contexts, except for emphasising the structural factors of fertility. The demographic transition theory, which is rather a descriptive framework than a theory, describes the transition from a demographic regime of high mortality and fertility to a regime of low fertility and mortality (for a review, see Kirk, 1996). The theory contends that the transition unfolds over several stages, although its proponents differ on the number of stages. It asserts that modernisation, the associated increases in wealth and spread of education, and improvements in survival, are linked to fertility reductions (Bryant, 2007; Davis, 1945; Notestein, 1945). Once the demographic transition is completed, fertility stabilises in a long-term equilibrium, with fertility

around replacement level (Casterline, 2003, p. 2011). Most researchers assumed that fertility will fluctuate when it has reached the lowest low (Sobotka, 2021).

1.2.2 Fertility diffusion

The fertility diffusion theory emphasises the role of cultural diffusion in fertility behaviour (Coale & Watkins, 1986). The theory originates from the Princeton fertility project, which showed that fertility declines in the 19th and 20th centuries diffused from regions where fertility declined earlier to neighbouring regions, independent of structural developments. These observations provided evidence for the social contagion and diffusion of fertility behaviour. The fertility diffusion theory contends that norms and ideas about family size, contraceptive practice and fertility are communicated, which affects fertility (Casterline, 2001; Rosero-Bixby & Casterline, 1993). Subsequently, Hammel (1990) argued that culture should be a central concept in demographic explanations, and also used for explaining fertility patterns. Recent research has confirmed that fertility spreads within friendship networks, providing a micro-level foundation for fertility diffusion processes (Balbo & Barban, 2014). Additional evidence for the role of diffusion processes in fertility declines has come from spatial models that quantify the effects of spatial autocorrelation (Goldstein & Cassidy, 2014; Klüsener et al., 2019; Montgomery & Casterline, 1998; Rosero-Bixby & Casterline, 1993). For instance, Campisi et al. (2022) showed that the recent fertility declines in the Nordic countries had a strong spatial component. Specifically, they found that fertility declined in regions if the neighbouring regions experienced fertility declines in the preceding year. According to this theory, recent fertility declines are only partially attributable to structural factors.

1.2.3 Wealth flow theory

Caldwell (1982) developed the wealth flow theory partly in response to the shortcomings of the demographic transition theory, criticising in particular its notion

of high fertility as irrational behaviour, and suggesting that fertility behaviour is always rational within the social and cultural context (Caldwell, 1976). The theory argues that fertility is a rational behaviour that maximises wealth and other forms of pleasure. The key determinant of fertility is “*the direction and magnitude of intergenerational flows of wealth [...] over the period from when people become parents until they die*” (p.344, Caldwell, 1976). In pre-transitional societies, wealth flows mainly from children to parents. Caldwell (1976) identified six benefits that children provide to adults, such that adults benefit economically and emotionally from larger families. These benefits are related to the family production system. Therefore, in certain contexts, having a large number of children is a rational decision rather than an accidental or forced outcome. However, as production is increasingly transferred from the family to the labour market and education expands, children become more costly. Under these circumstances, the flow of wealth reverses and goes in the opposite direction, discouraging childbearing. This view regarding the intergenerational wealth flow was brought into the debate about recent fertility declines by Vanhuysse et al. (2023). He argued that fertility may be low and declining in European countries because parents face higher intergenerational costs than other groups, which may discourage childbearing.

1.2.4 The second-demographic transition

Lesthaeghe (1986) and van de Kaa (1987) suggested that the first demographic transition is followed by a second demographic transition, which is characterised by increasing non-marital cohabitation and the emergence of lowest-low fertility. The underlying driver of the second demographic transition is individualisation, which is the result of increasing wealth and material security (Inglehart, 1997). Increases in wealth and changes in the occupational structure are assumed to spur value change (Beck, 1992; Inglehart, 1977). Individualisation leads to the emergence of competing life goals and the weakening of traditional institutions, which, in

turn, leads to non-marital cohabitation, reductions in fertility and high levels of childlessness. In its original formulation, the theory predicts that individualisation entrenches fertility at low levels (Lesthaeghe & Van de Kaa, 1986; van de Kaa, 1987). The second demographic transition theory has recently been used to explain the current fertility declines in the Nordics and the United States, given that no direct structural explanation for these declines could be found (Kearney et al., 2022; Lesthaeghe & Kryštof Zeman, 2024).

1.2.5 The new household economics

Beyond the macro-level theories, the household economics framework by Gary S. Becker (1981) provides a micro-level foundation that offers an explanation for declining fertility. As in all economic theories, units are assumed to maximise their individual utility. The new household economic theory introduces economic models to the realm of family by assuming that households are the primary units of action and that children are regarded as goods. This perspective further assumes that economic development changes the structure of society by expanding educational participation and increasing wages. In response to increasing educational and wage levels, the orientation shifts from the quantity of children to the quality of children, as parents are able to invest more in each child (Becker & Lewis, 1973; Becker & Tomes, 1976). Thus, women are inclined to have fewer children, because of monetary constraints. Beyond describing the quality-quantity trade-off, Becker (1981) showed that as the educational and employment levels of women increase, elevated opportunity costs reduce their fertility. Opportunity costs, in this context, refer to foregone incomes due to child-related employment interruptions. For example, women with good earnings may expect to experience larger income losses as a consequence of child-related career interruptions than their lower earning counterparts. Therefore, increasing income and educational levels incentivise individuals to opt out of forming a family or of having children altogether. This

theory remains popular in economics and beyond for explaining fertility behaviour in general (for a recent review, see Doepke et al., 2023) and the recent fertility declines in particular (Kearney & Levine, 2023; Schneider & Hastings, 2015).

1.2.6 The low fertility trap

Wolfgang Lutz and colleagues (2006) proposed the fertility trap hypothesis, which states that once the fertility has fallen to lowest-low levels, it remains entrenched at low levels. The key mechanism of this trap is the decreasing cohort size; i.e., if individuals grow up in an environment with low fertility and relatively few children, their fertility aspirations will decline. Moreover, low fertility can put pressure on welfare states through the accelerated ageing of the population. As an ageing population demands more spending on health and pension systems, welfare states may distribute a smaller share of the budget to young people. As the income levels and welfare protections of younger cohorts decrease, fertility may become entrenched at low levels. In addition, the authors argued that the detrimental effects of decreasing net income on fertility are reinforced by increasing economic aspirations, which result from past economic growth, as well as from small sibling numbers, as siblings can limit the amount of attention and resources each child receives (Blake, 1989). It has been pointed out that this mechanism, among others, may counteract pronatalist policies in Hungary, South Korea, and China, and keep fertility at low levels (Hwang, 2023).

1.2.7 Gender equity and fertility

McDonald (2000), Goldscheider (2015), and Esping-Andersen (2015) argued that progress in gender equity may lead to increases in fertility, observing that the gender revolution may offset the suppressing effect of work-family conflicts, thereby removing one of the barriers to childbearing among highly educated women (Goldin, 2021). In the first stage of the gender revolution, progress in gender equity suppresses

fertility. The increasing participation of women in education and paid work reinforces the demographic transition because it empowers women to make individual fertility decisions, while intensifying the conflict between career and family (Goldin, 2004). In other words, the conflict between career and family intensifies because employment adds another burden for women on top of the household workload. In the second stage of the gender revolution, however, gender equity spreads to the household sphere, which leads to a more equal distribution of power and of roles within the household, and facilitates the reconciliation of work and family. In addition, the state develops support infrastructures for working families, such as childcare and parental leave legislations. Thus, as male partners and public institutions increasingly take on household chores and childcare, the workload in the household declines for women, easing their work-family conflict to some degree. This framework essentially uses the opportunity cost argument proposed by Becker (1981) to explain the first stage, and argue that these constraints could be mitigated by the institutional context. While the gender equity perspective in family research received global attention in 2022, when Claudia Goldin won the Nobel Prize in Economics, and when it was shown to be able to explain current fertility trends in low fertility countries (Han & Qian, 2022), it has been recently been challenged by declining fertility in the gender-progressive Nordic countries (Kolk, 2019).

1.3 Explanations for the fertility declines

The recent fertility declines challenged existing fertility theories, which were largely developed before the onset of this trend. Many scholars and researchers were caught off guard by the declines and especially the falling fertility rates in the Nordic countries. In response, new approaches and perspectives have been proposed to explain this phenomenon. Three main explanations for the fertility declines of the 2010s have emerged: economic shocks, global uncertainty, and the second demographic transition. In this section, the arguments of these perspectives and their respective strengths and weaknesses will be discussed.

Economic shocks

The first explanation relates to macroeconomic trends. The economic downturn following the Great Recession of 2007/08 may have triggered the initial fertility decline (Cherlin et al., 2013; Goldstein et al., 2013; Hellstrand et al., 2024; Matysiak et al., 2021; Schneider & Gemmill, 2016; Sobotka et al., 2011). The coincidence of the fertility and economic downturns at least suggests that they are connected. This argument largely follows the reasoning of the household economic approach outlined in Section 1.2. Based on the economic framework (Doepke et al., 2023), proponents of this perspective argued that rising unemployment and falling incomes affected couples' decisions to have children, simply because children are an expansive good. Thus, the Great Recession mainly affected young adults who did not have enough income to provide for children in the way they intended, and who responded to this shortfall by postponing childbearing (Cherlin et al., 2013). In other words, individuals postponed childbearing or did not have children at all. However, some features of the decline cannot be explained by macroeconomic developments. Three features in particular challenge the explanation that the decline was solely caused by the economic shock: 1) the persistence of the decline, as fertility continued to fall even after economic indicators recovered (Vignoli et al., 2020), 2) the ubiquity of the decline, given that it occurred in very different contexts, some of which may have mitigated the impact of the economic recession on fertility through generous family policies (Kearney et al., 2022; Ohlsson-Wijk & Andersson, 2022), and 3) the indistinctness of the decline, as the decline affected very different social groups, some of whom might have been in a position to mitigate the impact of the economic shock (Hellstrand et al., 2024).

Global uncertainty

The second explanation relates to global and economic uncertainty (Comolli, 2017; Kreyenfeld, 2010; Kreyenfeld et al., 2023; Van Wijk, 2024). This explanation is

theoretically embedded in the of conjunctural action by Johnson-Hanks et al. (2011) and the narrative framework by Vignoli et al. (2020), which emerged as a response to the failure of economic explanations to fully explain the fertility decline, as the decline affected different contexts and groups in similar ways and persisted even after the economy recovered (Kearney et al., 2022; Ohlsson-Wijk & Andersson, 2022). Those theories acknowledge the impact of economic trends and circumstances on fertility, but emphasises that this impact is mediated by subjective perceptions and social schemas. As a result, fertility may continue to decline despite a recovery in objective economic circumstances. This is because economic circumstances may be decoupled from fertility, as couples' decisions may be influenced by past economic shocks that cast long shadows of economic uncertainty. This argument is consistent with findings from psycho-economic research showing that income gains and losses are perceived asymmetrically (Tversky & Kahneman, 1992). Income losses are perceived as greater than income gains of the same magnitude. Moreover, Caldwell (2004) has demonstrated social upheavals have long lasting impacts on fertility behaviour. However, the narrative framework has several weaknesses. First, it is a non-testable hypothesis, as it predicts that similar objective circumstances can lead to different empirical patterns of fertility due to subjective perceptions. In addition, uncertainty and fertility intentions are often linked in surveys, which may provide evidence of the impact of uncertainty on fertility. However, as both concepts are subjective, it is difficult to identify the causal effect, given that both factors could simultaneously arise from either personality or general survey response patterns. Second, the narrative framework rests on a weak foundation, as scholars turned to it only after finding that none of the objective explanations could account for the overall trend. This approach follows Occam's razor, which suggests that the simplest explanation is often the most likely. However, the list of possible alternative explanations is long and not exhaustive. It is, for example, possible that secularisation, partner markets, and declining fecundity could produce similar

fertility patterns. Indeed, Chapter 3, 4, and 6 show that structural and biological factors can have a significant impact on fertility rates, and it is possible that these factors have contributed to the fertility decline in the Nordic countries. Therefore, it is not clear that the narrative framework is the most likely explanation for the fertility decline. Finally, Hellstrand et al. (2024) showed that the fertility decline was stronger among individuals in occupations with objectively worse economic characteristics and lower earnings than in occupations with employment uncertainty. This finding contradicts the uncertainty hypothesis and casts doubt on its validity.

Second demographic transition

The second demographic transition theory has been proposed to explain the recent fertility declines (Kearney et al., 2022). The theory suggests that individualisation leads to changes in partnership formation, life goals and childbearing, as individuals place greater emphasis on self-realisation or self-expression than on established social norms (Lesthaeghe, 2020; Lesthaeghe & Van de Kaa, 1986; Lesthaeghe & Neidert, 2006). Childbearing may be postponed or ultimately foregone because it conflicts with other life goals. However, the second demographic transition theory is not without limitations. First, although the theory was developed in the 1980s, the empirical patterns did not match the theoretical predictions for long. The leaders in individualisation, the Anglo-Saxon and Nordic countries, had higher fertility than more traditional countries such as Italy and Germany. Similarly, highly educated people in the Nordic countries have higher average fertility and are less likely to remain childless compared to lower educated groups (Jalovaara et al., 2019). Second, while individualisation and increasing concern with self-realisation are normative changes, they do not necessarily imply that fertility will be affected. This is because individualisation must be accompanied by a change in life goals away from having children to valuing other things. Thus, if an individual lists having children as a life goal, self-realisation actually encourages childbearing. Third, the

change in values is a long-term trend, the full effects of which are unlikely to unfold within a few years, as they have in the Nordic countries, for example (Vignoli et al., 2020). Finally, Han and Qian (2022) tested the second demographic transition theories against data between 1990 and 2018 and found that the gender equity theory is better able to explain fertility trends.

1.4 The perspective of the thesis

The theories discussed in Sections 1.2 and 1.3 have some explanatory power and have been valuable for understanding past fertility trends and patterns. However, I will show throughout the thesis that the list presented above is not complete. In particular, I will demonstrate the power of structural and biological factors in explaining childbearing and fertility trends. Structural factors are conceptualised largely as partner markets. For instance, I show in Chapter 3 that secularization changes the composition of the population and of partner markets, which leads the couple composition to become more religiously unaffiliated. As the couple composition with respect to religious affiliation determines childbearing, fertility declines. In Chapters 5 and 6, I examine the impact of subnational population structures on fertility, which are increasingly skewed by gender, with urban areas becoming female-dominated and rural areas becoming male-dominated (Gulczynski, 2023). Moreover, I demonstrate the role of biological factors in childbearing. Chapter 4 shows the variation in fecundity across couples in Norway, and highlight the impact of age and BMI on fecundity. As both BMI in the population at reproductive age and age at childbearing are increasing, fecundity might be an underlying factor in fertility trends. Besides the main theme, three perspectives underlie the empirical chapters throughout the thesis. Specifically, the five chapters examine the contributions of both women and men, perform subnational analysis, and utilise administrative register data.

1.4.1 Men and women in fertility research

This thesis looks at the roles of both men and women in childbearing, recognising that fertility is a phenomenon that involves the contributions of both genders. While the demographic literature often focuses on the female perspective, this approach can overlook the important role of men. Ignoring the male factor not only provides an incomplete account of fertility, but can also introduce bias. For instance, the age-related decline in fecundity in women has been overestimated due to the fact that fecundity in men also declines with age, and partners' ages are strongly associated (Committee on Clinical Consensus–Obstetrics, 2022; Hassan & Killick, 2003). This example illustrates the limitations of a mono-sexual perspective, which my dissertation aims to overcome. For instance, I take a dyadic perspective looking at both the male and the female partner to examine the impact of the couple's religious composition on childbearing in Chapter 3. Moreover, as the determinants of male fertility differ from those of female fertility, it is a topic worthy of investigation in its own right (Zhang, 2011).

Gender differences in fertility

Male fertility refers to the childbearing behaviour and outcomes of men. Research has shown that the average number of children for men can differ from that for women in the same population (Brouard, 1977; Dudel & Klüsener, 2021; Schoumaker, 2017, 2019). This difference can be substantial. The TFR for men ranges from half to two times the TFR for women in the same region in the same year (Schoumaker, 2019). The gender gap in fertility diminishes with female fertility, which is related to the shifting age distribution of the population (Schoumaker, 2019) and the trend towards fertility postponement among women (Dudel & Klüsener, 2021). Schoumaker (2019) proposed a stable-population approximation of the male-to-female TFR ratio,

$$\frac{TFR_m}{TFR_f} = \frac{1}{SRB} \cdot \frac{p(MAF)}{p(MAC)} \cdot \exp(r \cdot (MAF - MAC)) \quad (1.1)$$

where SRB is the sex ratio at birth, $p(MAF)$ is the probability of surviving to the mean age of fatherhood, $p(MAC)$ is the probability of surviving until the mean age of childbearing, r is the stable population growth rate (for details, see Keyfitz & Caswell, 2005), MAF is the mean age of fatherhood and MAC is the mean age of childbearing. The ratio of the male to the female TFR is driven by the population structure, e.g. the sex ratio at birth, the survival ratio and the growth rate, and fertility timing. Therefore, as the survival differences between men and women and the stable population growth rate diminish over the course of the demographic transition, the fertility differences are declining. I show in Chapter 5 that this relationship holds at the subnational level as well.

Intriguingly, while the TFRs for men and women tend to converge over the demographic transition, levels of childlessness are diverging between men and women. Men are more likely to remain childless than women in most countries, and this gap has been widening in countries with time-series data (Klein, 2003; Kravdal, 2021; Sobotka, 2017b; Tanturri et al., 2015). One exception to this pattern is Georgia, where the population structure is female skewed due to the high levels of emigration and mortality among men during the military conflict with Russia (Tanturri et al., 2015). In Chapter 5, I show a similar impact of military conflict on gender differences in fertility in Colombia and Mexico. During the military conflicts in these countries, male fertility rates increased relative to female fertility rates. The main explanation for this pattern has been that the male exposures shrank relative to the female exposures, which inflated the male fertility rates. Kravdal (2021) and Chudnovskaya (2021) demonstrated the impact of sex imbalances in the population on the sex gap in childlessness. Building on their findings, I study the relationship between population imbalances and male childlessness at the subnational level in Chapter 6.

Moreover, the predictors of childbearing also differ in magnitude, direction, and ordering between men and women. The most commonly observed difference pertains to age. Men are on average 2–3 years older than women when they have

children, which may be attributable to the average age gap in partnerships and the wider reproductive window among men (Dudel & Klüsener, 2021; Dudel et al., 2023; Schoumaker, 2019). On the one hand, men tend to partner with younger women, which translates into age differences in childbearing unions (Dudel et al., 2023; Rotering & Bras, 2019). On the other hand, men may get children after age 50, even though it is rare for them to do so, whereas women's reproductive window is shorter and more clearly defined by age at menarche and menopause (Dudel et al., 2023). This leads to a different shape of age-specific fertility rates, as men's age-specific fertility rates are shifted to older ages and decline more gradually after the peak age (Paget & Timæus, 1994). Dudel et al. (2023) reported some additional robust pattern regarding maternal and paternal ages. For instance, the age gap between childbearing partners relates to the timing of birth, as wider age gaps are more frequent among young women. However, age gaps narrow with the age of childbearing. This polarisation between young mothers with large age gaps and late mothers with smaller age gaps has been observed across 17 high-income countries (Dudel et al., 2023).

Moreover, a positive socio-economic gradient in childbearing is consistently found for men, whereas a changing and often negative gradient is observed for women (Bratsberg & Rogeberg, 2023; Jalovaara et al., 2019, 2022; Parr, 2010; Skirbekk, 2008). Among women, the socio-economic gradient in childbearing is negative in most contexts, except in the Nordic countries in recent years (Bratsberg & Rogeberg, 2023; Jalovaara et al., 2019, 2022; Kravdal & Rindfuss, 2008; Skirbekk, 2008). The reasons for the changing socio-economic gradient in childbearing among women have been well described by Nobel laureate Claudia Goldin (2021) in her book *Career and Family. Family policies* (Duvander et al., 2010; Kravdal & Rindfuss, 2008), changing role distribution within the household (Goldscheider et al., 2010; Neyer et al., 2013), and changing economic structures of employment may have removed barriers to childbearing among highly educated women (Adserà, 2004).

Among men, more education and income are positively associated with childbearing (Bratsberg & Rogeberg, 2023; Kravdal & Rindfuss, 2008; Parr, 2010), which may be related to several different mechanisms (Lappegård & Rønsen, 2011). On the one hand, men are positively selected regarding income and education into partnerships, which increases their propensity to have children (Chudnovskaya, 2019; Jalovaara & Andersson, 2023; Saarela & Skirbekk, 2020). On the other hand, union dissolution may play also a role (Hart, 2019; Jalovaara & Fasang, 2015; Jalovaara & Miettinen, 2013; Lyngstad & Jalovaara, 2010; Perelli-Harris et al., 2010). Using multiprocess event-history models, Trimarchi and Van Bavel (2017) showed for 10 European countries that the transition into a union may be more relevant for the socio-economic gradient in fatherhood among men. Therefore, I study the impact of partner markets on male childlessness and the socio-economic gradient in male childlessness in Chapter 6. In addition, socio-economic differences in fatherhood may also be related to fecundity. Fecundity is understood as the biological capacity to conceive. Lifestyle factors such as smoking, exercise, nutrition, and environmental toxins are strong predictors of sperm characteristics (Eisenberg et al., 2023; Hernaez, 2021; Jensen et al., 2004; Kumar & Singh, 2022; Wootton et al., 2022). Hence, a socio-economic gradient in fertility may arise as a consequence of socially patterned lifestyles that affect fecundity. Therefore, Chapter 4 investigates social and biological predictors of time-to-pregnancy in partnered unions.

1.4.2 Subnational analysis

This thesis employs subnational analysis to capitalise on the variation in partner markets, living standards, and well-being within countries. Examining subnational data enables me to gain a more nuanced understanding of the factors that influence fertility. This approach is robust to institutional and cultural differences, which are relatively stable within countries. For instance, Chapter 2 exploits the spatial and temporal variation of human development in the United States to identify the impact of progress in development on fertility.

Background on subnational fertility research

While demography has long been primarily concerned with national fertility and mortality trends, subnational analysis has gradually established itself within the discipline. Among the first studies on subnational fertility was the *Princeton European Fertility Project* in the 1970s. The objectives of this project were twofold: 1) to provide a quantitative description of the European fertility transition; and 2) to describe the social, economic and institutional circumstances at the time of the onset of this transition (Coale & Watkins, 1986). The project revealed that the fertility decline unfolded spatially across neighbouring regions. This evidence of spatial contagion demonstrated that culture, in addition to structural characteristics, played an important role in the historical fertility declines. These findings were reinforced by new data (Blanc, 2024; Goldstein & Cassidy, 2014; Vitali & Billari, 2017) and innovative models (Myrskylä et al., 2013). About 40 years after the Princeton European Fertility Project, Campisi et al. (2020) used fine-grained subnational data on 21 European countries to disentangle the impacts of economic, sociocultural and spatial factors on fertility, and showed that all of them play a role. In particular, he found that gross domestic product, as a marker for socio-economic development, explains modern fertility variation. This finding relates to my analysis in Chapter 2, in which I investigate the relationship between human development and fertility in the United States over time. I show that the impact of progress in development on fertility has changed over time and by development level, which supports the results reported by Myrskylä et al. (2009) and Fox et al. (2019).

The growing availability of subnational data has opened up new pathways for fertility research. Shifting the focus to more granular units brings new dimensions to the surface. For instance, settlement type and fertility are associated. Fertility is higher in semi-urban areas than in urban and rural areas (Kulu, 2008; Kulu & González-Ferrer, 2014; Kulu & Steele, 2013). This association is bidirectional. Settlement structure may encourage or suppress fertility, as it relates to different

lifestyles and to different contexts for family formation. However, childbearing may also encourage movement, such a move to an area more suitable for raising a family (Kulu, 2008).

Regional characteristics also affect the spatial pattern of fertility (Campisi et al., 2020, 2024). For instance, fertility may be affected by regional partner markets. In Chapter 6, I examine the impact of regional partner markets on male childlessness. Beyond partner markets, other regional characteristics may also be important determinants of fertility. For instance, fertility may be increasingly related to housing availability and prices because family formation is interconnected with housing in some countries (Mulder, 2013). For instance, housing tenure is a strong predictor of childbearing in Britain (Murphy & Sullivan, 1985). The strong link between house purchases and childbearing depresses fertility in Spain and Italy (Kohler et al., 2002; Simon & Tamura, 2009). However, a recent study by Van Wijk (2024) on this potential association in the Netherlands found inconclusive results, showing that the impact of housing prices on the total fertility rate was positive in the pre-2010 period, while the direction of the association reversed and became negative in the post-2010 period.

The recent fertility declines in the Nordics and the United States followed a clear spatial pattern (Campisi et al., 2022; Seltzer, 2019). For instance, in the Nordic countries, the fertility declines were associated with urbanisation (Campisi et al., 2022). Moreover, unemployment and union stability were associated with lower levels of fertility. Similar findings have been reported for the United States, where the regional economic structure is associated with fertility declines (Seltzer, 2019). Seltzer (2019) showed that changes in industry composition, and especially the loss of manufacturing and goods-producing businesses, are related to fertility declines. Therefore, I also include indicators for the labour market situation and the sectoral composition in Chapter 2 on human development and fertility.

1.4.3 Administrative register data

The empirical investigations in the thesis draw on administrative register data from high-income countries. The use of register data is motivated by the need to accurately capture fertility information for men, which is often biased in surveys (Joyner et al., 2012). Register data offer several other advantages, including high case numbers, representativeness, and inclusion of groups that are typically underrepresented in surveys. However, administrative records also have limitations, and the merits and drawbacks of register data are discussed in Section 7.2.3 of the thesis.

Background on register-based fertility research

Register-based research on fertility has gained in popularity in recent years. Among the vanguards of this research approach was Kravdal (2002). Initially, fertility research based on register data was mainly conducted in Nordic countries in the beginning, as these countries were forerunners in making register data available for scientific use. The European Association of Population Studies founded the *Working Group Register Based Fertility Research* to encourage this type of research in other countries. In the group's 2025 meeting, research on Sweden, the Netherlands, Finland, and Belgium was presented. This shows a growing diversification of register-based fertility research.

The availability of register data has opened up new pathways for research. As the data are available at the population scale, they can be used to analyse minority groups, which are hard to sample with surveys. Moreover, weak but meaningful effects can be detected using register data, because statistical significance becomes a secondary concern with sample sizes in the millions. Moreover, register data have been instrumental for research on male fertility. Joyner et al. (2012) showed that men do not respond truthfully in surveys on childbearing, which may have implications for estimation results. Hence, Bratsberg and Rogeberg (2023) provided new insights on male fertility drawing on register data. Register data have been

used to study different determinants and facets of fertility, such as psychological determinants (Peters & Barclay, 2022); to monitor the growing use of assisted reproductive technologies (Fallesen et al., 2022); and to study fertility in same-sex couples (Ponkilainen et al., 2024). Moreover, the availability of register data pushed the boundaries of research on male fertility (Dudel & Klüsener, 2019a; Dudel et al., 2021; Jalovaara & Andersson, 2023; Jalovaara et al., 2019, 2022) and subnational analysis (Campisi et al., 2020; Miettinen, 2010).

1.5 The structure of the thesis

The thesis is structured into five empirical chapters investigating fertility, in particular the recent fertility decline in relation to structural and biological factors. Table 1.1 summarizes the chapters, whereas Figure 1.2 illustrates the connections between them.

- *Chapter 2:*² Economic and social development are closely linked with fertility. Several studies have shown that the relationship follows an inverse J-shape: at low and intermediate levels of human development, the association is negative; while at high levels of human development, the association is reversed and becomes positive. However, more recent research building on subnational and U.S. data found only mixed evidence for the inverse J-shape. In this chapter, we draw on subnational data on development and fertility in the U.S. states between 1969 and 2018 to examine the relationship between development and fertility. Using a longitudinal approach and addressing

²This chapter was published in *Demography* and written with my co-authors Christian Dudel, Marina Kolobova and Mikko Myrskylä. The publication can be found under <https://read.dukeupress.edu/demography/article/61/6/1949/393035/Revisiting-the-J-Shape-Human-Development-and>. I developed the idea and the research strategy and wrote the manuscript. My co-authors provided mainly feedback on the draft and the analytical strategy. Christian Dudel performed a code-check. Marina Kolobova assisted me with the data access. The results are reproducible using the code under https://osf.io/mrzb5/?view_only=98d4065e951d4b8bb1d03198fa12ddd8

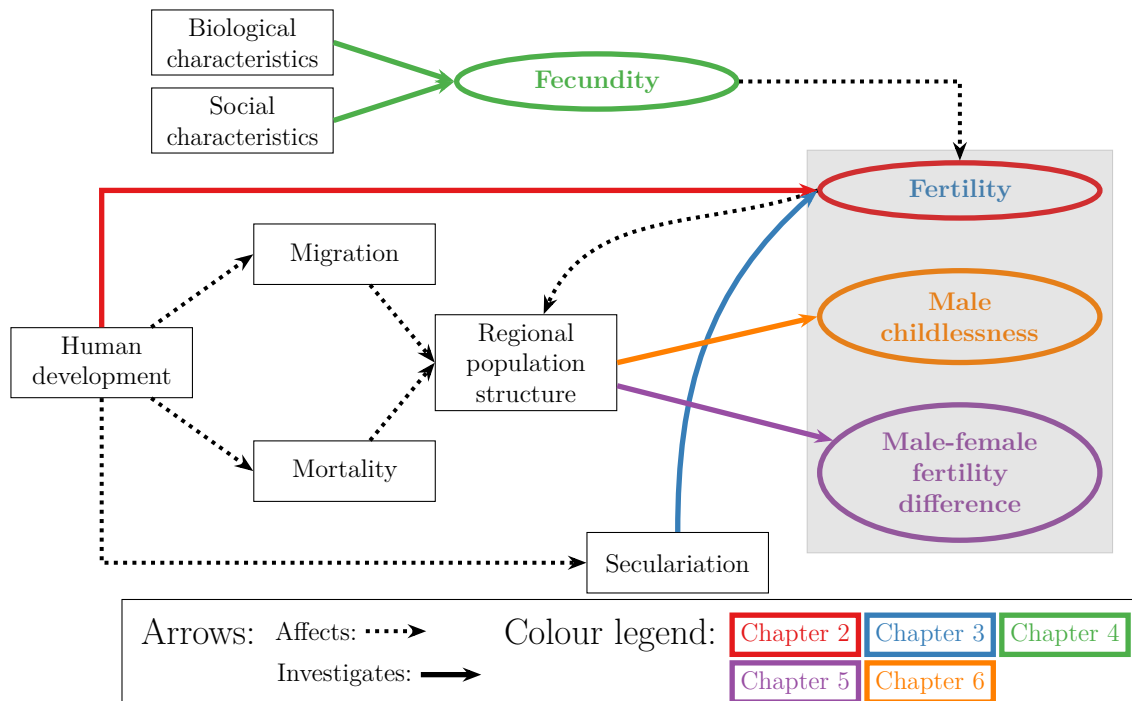


Figure 1.2: This figure illustrated the contributions of the different chapters (see colours) and the relationships between the chapters. The dotted arrows illustrate relationships between variables. The coloured lines are relationships that are investigated by the different chapters. **Chapter 2** examines the relationship between human development and fertility. **Chapter 3** investigates the individual and couple level impact of secularization on fertility. **Chapter 4** investigates the predictability of subfecundity using biological and social variables. **Chapter 5** examines male-female fertility differences at the subnational level. **Chapter 6** investigates the relationship between partner markets and childlessness among men.

several criticisms of the fertility reversal hypothesis, our results support the inverse J-shaped pattern. However, this pattern might have vanished since the financial crisis in 2007/2008. Our findings provide insights into the mechanisms that link development and fertility, showing that gender equality and economic uncertainty mediate the relationship between development and fertility.

- *Chapter 3:*³ This chapter investigates the relationship between secularisation

³This chapter is submitted to *Social Science Research*. It is work with my co-authors Vegard Skirbekk and Jessica Nisén. I developed the idea and the research strategy, performed all the analysis and wrote the manuscript. My co-authors mainly provided feedback on the draft and the analytical strategy. The code is accessible under https://osf.io/m6ydt/?view_only=

and fertility decline in Finland in a recent period from an individual and couple perspective, amid a broader trend of declining fertility in the Nordic and Anglo-Saxon countries. We argue based on Peter M. Blau’s theory of social structure that secularisation may exert a self-reinforcing negative effect on fertility through an interplay of declining church membership, changing partnership dynamics, and the fertility outcomes of mixed religious couples. Using Finnish registry data for the period between 1995 and 2018, we use church tax payments as a proxy for religious affiliation in the secularised context of Finland. The analysis unfolds in two parts: first, through a demographic examination of the fertility trends of the religiously affiliated and unaffiliated groups; and, second, through a dyadic perspective exploring the relationships between religious affiliation, partnership composition, and the probability of having a first child. We conclude that a substantial part of the recent fertility decline can be explained by the accelerated decline in church membership, and thus that religious affiliation continues to play a significant role in individuals lives and social processes, even in modern gender-equal industrialized and secularized societies.

- *Chapter 4*:⁴ The predictability of fecundity has been constrained by computational methods and a lack of data. We address these problems by assembling a population-scale data set and analysing it with modern machine-learning methods. We assess the predictability of time-to-pregnancy in Norwegian couples who conceived in the period between 1999 and 2005 by applying modern machine learning methods to data from the Norwegian

b0d48477bdd2426abed9f9c26475766d and a previous version is available as working paper under <https://www.demogr.mpg.de/papers/working/wp-2024-040.pdf>.

⁴This chapter was written with my co-authors Siri Eldevik Håberg, Cecilia Ramlau-Hansen, Mikko Myrskylä and Yunsung Lee, who provided mainly the data access and assisted with feedback on the draft and the analytical strategy. I developed the idea, the research strategy, co-performed the analysis and wrote the manuscript. Yunsung Lee was also involved in the empirical analysis. This paper will be submitted to *Nature Communications*.

Mother and Child Birth Cohort ($N = 66,435$), which were supplemented by information from the Norwegian administrative registers. The predictors are the socioeconomic, behavioural, biological, and genetic characteristics of both partners. The results (1) show a reasonably good out-of-sample prediction performance using gradient boosting decision trees ($AUC = 0.772$); (2) that age, BMI, and health factors are the strongest predictors of time-to-pregnancy; (3) that these factors are interacting; and (4) that couples who conceive instantly are a distinct group from couples who conceive after a longer duration or have an unplanned pregnancy. The findings provide important insights for clinicians seeking to inform couples about potential fecundity issues.

- *Chapter 5*:⁵ Fertility indicators traditionally focus on women's reproductive behaviour, neglecting the nuanced contributions of men. Fertility rates based only on women may be misleading, as these fertility rates depend not just on the fertility intensity, but also on the age-sex population composition. This study quantifies this problem, which is also known as *birth squeeze*, by conducting a subnational analysis of differences in the total fertility rates between men and women, utilizing high-quality administrative registers from the United States, Australia, Colombia, Finland, France, Germany, Mexico, and Spain ($n = 5,747$). The results show that these differences are related to gender differences in population structures and age patterns of fertility, which are in turn influenced by development progress and urban-rural settlement structures. We detect regional idiosyncrasies in the United States, Colombia, Mexico, Germany, and Australia. We suggest several approaches for measuring birth squeezes and demonstrate the importance of considering both male and

⁵This chapter is submitted to *Demography* and has been published as MPIDR Working Paper under <https://dx.doi.org/10.4054/MPIDR-WP-2025-025>. The code is accessible under https://github.com/Henrik-Alexander/unveiling_disparities

female fertility indicators to gain a more nuanced understanding of population dynamics.

- *Chapter 6:*⁶ Levels of childlessness have been rising steeply in the Nordic countries (Jalovaara et al., 2019; Zeman et al., 2018), particularly among men. For instance, in Finland, childlessness among men aged 40 to 44 has been increasing continuously, rising from 19% in 1990 to 29% in 2022, and it exceeds the corresponding levels for women by about 10 percentage points. Such increases in childlessness have been a key driver of Nordic fertility decline since 2008 (Hellstrand et al., 2020, 2021; Jalovaara et al., 2019). The high fertility rates in the Nordic countries before 2008 has been attributable to the generous welfare-states in general, and family policies in particular, as well as to their progressiveness in terms of gender equality (Duvander et al., 2010). This leaves the development after 2008 largely unexplained, including trends and levels in childlessness. Therefore, this chapter examines whether regional partner markets are associated with male childlessness at the individual level in Finland. These regional partner markets are structurally determined by the regional population structure. In particular, we ask whether regional imbalances in the age-sex-education structure drive Finland's male childlessness levels, using Finnish population register data for the years 1987 to 2020. We estimate several partner market measures at the subnational level to assess the partner market opportunities over time and across regions. These metrics encompass factors such as the demographic distribution of the opposite sex, the level of competition for potential partners, and individual preferences, including age and educational preferences. In a second step, we use these

⁶This chapter is published in *Population Studies* under <https://doi.org/10.1080/00324728.2025.2534876>. The paper is written with my co-author Christian Dudel, who provided mainly feedback on the draft and the analytical strategy. I developed the idea, the research strategy, performed all the analysis and wrote the manuscript. The code is accessible under https://osf.io/4nbvg/?view_only=f56b53c5d79e4e0ea22425f9cd8370d4

measures to model the relationship between the partner market situation throughout the life course and being childless at the end of the reproductive period. The main specification regresses to being childless at age 45 on the average lifetime partner market measure. Moreover, we estimate several additional models, including sibling fixed effects and discrete time survival models, to account for potential issues such as unobserved heterogeneity and model misspecification.

Table 1.1: This table summarizes the designs and conclusions from the different empirical chapters in the thesis.

Title	Country	Years	Data	Method	Conclusion
Revisiting the J-Shape	United States	1969-2018	Vital statistics data	Panel regression models Discrete-time survival model, counterfactual simulation, demographic rates	Historical J-Shape and recent declines Secularization reduces fertility by 1) reducing individual childbearing and 2) changing couple composition
Secularization and low fertility	Finland	1996-2019	Register data	Logistic regression, elastic net regression, generalized additive models, light-GBM, Neural network	Time-to-pregnancy is predictable with biological and social variables. Male and female factors play a role.
Fecundity Score	Norway, Denmark	1998-2004	MoBa and register data		
Subnational squeezes?	Australia, Colombia, Finland, Mexico, United States	France, Germany, United States 1969-2018	Vital statistics data	Descriptive, Threshold methods	Male-fertility differences are frequent at the subnational level, indicating birth squeezes
Too many men?	Finland	1987-2018	Register data	Logistic, panel regression, matching	Population imbalances relate to individual childlessness among men

Part I

Structural and behavioural factors influencing fertility

A new scientific truth does not triumph by convincing its opponents and making them see the light, but rather because its opponents eventually die, and a new generation grows up that is familiar with it.

Max Planck

2

Human Development and Fertility in the United States

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This chapter is co-authored with Christian Dudel, Marina Kolobova and Mikko Myrskylä. Materials from this chapter are published in *Demography* under <https://read.dukeupress.edu/>

2.1 Introduction

Are economic and social development and fertility negatively or positively associated? From a theoretical perspective, proponents of the demographic transition model have long argued that development increases the costs of having children, improves the means to control childbearing, and gives rise to life goals that conflict with fertility (Davis, 1945; Lesthaeghe & Van de Kaa, 1986; Notestein, 1945; van de Kaa, 1987). Thus, fertility and development should have a negative association. This theory accurately describes the lowest-low fertility observed in high-income countries, including the drop in fertility below the replacement level in the United States (Kohler et al., 2002; Ruggles, 2015). However, this model was challenged when a study found reversals of fertility declines (Myrskylä et al., 2009). The association between fertility and development was shown to follow an inverse J-shaped pattern, with a negative association at low and medium levels of development, and a positive association at higher levels of development.

The initial evidence on the inverse J-shape and on reversals of fertility declines spawned a rich, partly critical body of literature that generated mixed evidence. Several studies replicated the original findings at the national and the subnational levels, and argued that gender attitudes, late childbearing, and family policies have been key contributors to recent fertility increases (Anderson & Kohler, 2015; Fox et al., 2019; Kolk & Barclay, 2019; Luci-Greulich & Thévenon, 2014; Mavropoulos & Panagiotidis, 2021; Myrskylä et al., 2011). However, other studies failed to find an inverse J-shaped relationship between fertility and development (Gaddy, 2021; Harknett et al., 2014; Ryabov, 2015). For instance, Ryabov, 2015 did not find a J-shaped relationship based on an analysis of cross-sectional data for the U.S. counties. One potential explanation for why the inverse J-shape could be a spurious

finding cites measurement errors. Fertility is often measured using the total fertility rate (TFR), which suffers from tempo distortions (Bongaarts & Sobotka, 2012); and development is captured through the Human Development Index (HDI), which is known to be imprecise (Ghislandi et al., 2019).

In this paper, we use data for the U.S. states and the District of Columbia covering the years 1969 to 2018 to re-examine the relationship between development and fertility. To address the criticisms raised in the literature, we use several measures of fertility and several measures of development, and we apply several different panel regression approaches. For instance, we test the inverse J-shape with three measures of fertility: the TFR, a tempo-adjusted TFR, and the TFR for men. The tempo-adjusted TFR removes distortions of fertility levels caused by postponement (Bongaarts & Watkins, 1996), while the TFR for men can differ substantially from the TFR for women because of birth squeezes caused by migration and cohort size (Dudel, 2021). We also provide insights into the potential mechanisms behind the association between development and fertility, including gender relations and economic uncertainty. The results are fully reproducible and all code is available online at https://osf.io/mrzb5/?view_only=98d4065e951d4b8bb1d03198fa12ddd8; the data can be obtained from National Bureau of Economic Research (NBER), the United States Mortality DataBase and the Global Data Lab.

Studying the relationship between development and fertility at the subnational level is crucial for the discussion of fertility decline reversals. There is considerable heterogeneity in terms of income, living standards, and well-being within countries (see for the United States, Porter & Purser, 2008; Scherbov & Gietel-Basten, 2020). Moreover, within-country research designs are promising because they are robust to some common sources of error in cross-country research. Empirical investigations at the country level can be biased by unobserved heterogeneity due to cultural and institutional differences which are difficult to control for. In addition,

cultural differences tend to be less pronounced and the institutional setup shows less variation within countries than between countries.

The United States is an interesting case for studying the relationship between development and fertility for several reasons. There is evidence that at the national level in the U.S., there has been a pronounced reversal of the fertility decline at a comparatively high level of fertility (Luci-Greulich & Thévenon, 2014), which makes the U.S. a somewhat special case among high-income countries. Furthermore, because there has been considerable variation in development and fertility trends at the subnational level and over time, it is ideally suited for conducting subnational analyses (Scherbov & Gietel-Basten, 2020). Finally, given that results from previous research on fertility decline reversals in the U.S. have been inconsistent, it is worthwhile to study the U.S. in more depth to help explain these inconsistencies (Porter, 2017; Ryabov, 2015).

This paper contributes to the literature in several ways. We provide the first longitudinal analysis of fertility decline reversals in the U.S. using data at the subnational level that cover a 50-year period and all U.S. states. Moreover, we address general criticisms of the reversal hypothesis raised in the literature by using several indicators of development and fertility, and by conducting several robustness checks. Our analyses reconcile inconsistent findings regarding fertility reversals at the subnational level, and provide new insights into potential drivers of reversals. Furthermore, we examine how the association between development and fertility has developed in recent years, and thus a period has not been covered by most existing papers. We find that there was no association between development and fertility during the post-recession period.

2.2 Background

2.2.1 Fertility and development at the national level

Several theoretical approaches argue that development and fertility are linked. In the following, development will be broadly understood as the material conditions, wealth, technological progress, social equality, and public support in a spatially bounded area that have an impact on the well-being of people (Sen, 1998). Thus, the concept highlights the importance of contextual characteristics for people's lives.

Demographic transition theory hypothesizes a negative connection between fertility and development, starting with the observation that for much of the 20th century, fertility declined with increasing development. The first demographic transition theory asserts that modernization, and associated increases in wealth, spread of education, and improved survival are linked to fertility reductions (Bryant, 2007; Davis, 1945; Notestein, 1945). Once the demographic transition is completed, fertility stabilizes in a long-term equilibrium with mortality around replacement level (Casterline, 2003, p. 2011).¹

Van de Kaa (1987) and Lesthaeghe (1986) suggested that the first demographic transition is followed by a second demographic transition, which is characterized by increasing non-marital cohabitation and the emergence of lowest-low fertility. The underlying driver of the second demographic transition is individualization, which is itself related to development, because increases in wealth and changes in the occupational structure are assumed to spur value change (Beck, 1992; Inglehart, 1977). Individualization leads to the emergence of competing life goals and the weakening of traditional institutions, which, in turn, lead to increased rates of non-marital cohabitation, reductions in fertility and high levels of childlessness.

¹It is important to note that neither Notestein nor Davis claimed that fertility will stay at around replacement level. However, the widely adapted interpretation of the framework postulates the emergence of homeostasis before and after the first demographic transition with replacement level fertility.

Whether individualization enables individuals to reach their own life goals, is a subject of discussion (Mills, 2007; Smart & Shipman, 2004; Worts et al., 2013). In its original formulation, the theory predicts that individualization entrenches fertility at low levels (Lesthaeghe & Van de Kaa, 1986; van de Kaa, 1987).

Beyond the macro-level theories, the household economics framework by Becker (1981) provides a micro-level foundation that offers an explanation for the negative relationship between development and fertility. This perspective assumes that development changes the structure of society by expanding educational participation and increasing wages. In response to increasing education and wage levels, the orientation shifts from the quantity of children to the quality of children, as they are able to invest more in each child (Becker & Lewis, 1973; Becker & Tomes, 1976). Thus, women are inclined to have fewer children, because of monetary constraints. Beyond describing the quality and quantity trade-off, Becker (1981) showed that as educational and employment levels of women increase, elevated opportunity costs reduce their fertility. Therefore, as educational levels and wages increase, growing numbers of individuals are expected to opt out of forming a family or of having children altogether.

The authors of the fertility-trap hypothesis (Lutz et al., 2006) argued that once the fertility has fallen to lowest-low levels, fertility and development might be decoupled, and fertility would then remain at low levels. The key mechanism of this trap is the decreasing cohort size; i.e., if individuals grow up in an environment with low fertility and relatively few children, their fertility aspirations will be affected accordingly. Moreover, low fertility can put pressure on the welfare states through the accelerated ageing of the population. As income levels and welfare protections of younger cohorts decrease, fertility may become entrenched at low levels. In addition, the authors have argued that the detrimental effects of decreasing net income on fertility are reinforced by increasing economic aspirations, which result

from past economic growth, as well as from small sibling numbers, as siblings can limit the amount of attention and resources each child receives.

While the fertility-trap hypothesis postulated that fertility could become entrenched at low levels, McDonald (2000), Goldschneider (2015) and Esping-Andersen (2015) argued that progress in gender development may lead to increases in fertility, observing that the later stages of the gender revolution may offset the suppressing effect of work-family conflicts, thereby removing one of the mechanisms underlying the negative association between development and fertility. In the first stage of the gender revolution, the increasing participation of women in education and paid work reinforced the demographic transition, because it empowered women to make individual fertility decisions, while intensifying the conflict between career and family. However, in the second stage of the gender revolution, gender equity spread to the individual sphere, which led to a more equal distribution of power and of roles within the household, and facilitated the reconciliation of work and family. This framework essentially used the opportunity cost argument proposed by Becker (1981) to explain the first stage, and argued that these constraints could be mitigated by the institutional context.

Beyond the institutional context, development may spur fertility increases by transforming the economy into a more childbearing friendly environment. First, the modernization of the economy shifts employment away from routine and manual tasks and towards service jobs, which may provide more flexible work arrangements that can help to ease the aforementioned work-family conflicts. For instance, having flexible working hours may enable parents to align their working schedule with childcare opening hours, while having the option to work from home may save parents commuting time (Fox et al., 2019). Second, economic development plays a crucial role in the globalized market as it improves the competitive position of individuals, and thus their future prospects (Mills et al., 2006). Working in a competitive sector may provide individuals with the economic stability they

require for making long-term commitments, such as raising children (Adserà, 2004; Hofmann & Hohmeyer, 2013). However, the claim that economic restructuring and flexibility have positive effects on fertility has been contested. Labour market flexibility may lead to higher levels of employment uncertainty, which can inhibit childbearing as couples could be inclined to postpone life-changing commitments if they see the future as unpredictable (Comolli, 2017, 2021; Vignoli et al., 2020). Moreover, the positive effects of globalized markets have been called into question, as the decline in manufacturing jobs has been associated with decreases in fertility in the U.S. (Seltzer, 2019).

Empirical evidence on the reversal of this association was provided by Myrskylä et al. (2009), who found that fertility declines reverse at high levels of development. They examined the relationship between fertility and development using data from 140 countries on the TFR and the Human Development Index and uncovered an inverted J-shaped relationship between development and fertility. In line with the theoretical perspectives discussed above, they observed that fertility fell steadily from high levels at low development stages to historical lows. However, they also observed that recent increases in development have been accompanied by increases in fertility. In line with the gender revolution theory (Esping-Andersen & Billari, 2015; Goldscheider et al., 2015; McDonald, 2000), they argued that this reversal is attributable to gender and social equality, to the introduction of more effective family policies, and to increases in living standards and labor market flexibility. These trends, which are associated with economic and societal development, have facilitated childbearing, and have thus made it easier for couples to achieve their childbearing intentions.

The findings of Myrskylä et al. (2009) were reproduced by several studies, which further examined the mechanisms behind the reversal of fertility declines (Luci-Greulich & Thévenon, 2014; Mavropoulos & Panagiotidis, 2021; Myrskylä et al., 2011). These studies found that changes in gender attitudes and family

policies can indeed lead to higher fertility at highest-high levels of development (Myrskylä et al., 2011). However, they also showed that whether fertility declines are reversed depends on the labor market participation of women, which points to the importance of policies that support the reconciliation of work and family (Luci-Greulich & Thévenon, 2014). A recent study found that the existence of fertility decline reversals, as well as the conditions under which reversals occur, vary across countries, and thus highlighted the role of contextual factors in fertility, including women's employment and culture (Lacalle-Calderon et al., 2017).

2.2.2 Fertility and development at the subnational level in the United States

The research findings on fertility decline reversals spurred a debate about the mechanisms that have contributed to recent fertility increases, and whether they are limited to nation states. It has, for example, been observed that development levels can vary considerably within countries, which may affect subnational fertility levels (for the United States, see Porter & Purser, 2008; Scherbov & Gietel-Basten, 2020). We discuss several mechanisms that might cause fertility levels to increase at high development levels in some subnational units, while remaining low in others. Given that regional differences in development levels can be large, this relationship is likely to be of interest to both policy-makers and academics.

In regions with lower levels of development, relatively large shares of the population are still employed in routine task-intensive activities, which face pressure from globalization forces and technological change (Acemoglu & Autor, 2010; Mills et al., 2006). As a consequence, the working population may experience economic uncertainty, which could lead people to postpone or forego childbearing, as economic uncertainty is negatively related to fertility (Adserà, 2004; Hofmann & Hohmeyer, 2013). For instance, in the United States, state-level economic performance, as measured by the unemployment rate, is negatively related to non-marital childbearing among low-socioeconomic groups (Schneider & Hastings, 2015).

The aforementioned unequal spatial distribution of industries may contribute to fertility increases in highly developed regions dependent on the extent to which these industries allow to reconcile family and employment. Althoff et al. (2022) showed that in the U.S., the progress in workplace flexibility is not universal. Instead, they found that the share of remote work in each region depends on the region's economic structure and population density, and is particularly high in urban regions with a high proportion of jobs in the service sector. Workplace arrangements play an important role in fertility in the U.S., since having flexible working hours and the option to work from home may facilitate childbearing among working women, given the high costs of childcare (Fox et al., 2019). It thus appears that in contexts with high levels of development, eliminating an obstacle to childbearing has the potential to increase fertility.

Beyond these direct mechanisms, development may interact with migration in producing fertility increases. More developed areas are often urban and technological centres that attract large numbers of international migrants seeking employment opportunities (De Haas et al., 2020). For instance, in the U.S., states along the East and West coasts, and in the South - which are also among the leaders in terms of development levels - have larger shares of migrants than other states (Alexander & Root, 2022). In the period immediately after their arrival, the fertility of international migrants tends to be higher if they are from a high-fertility sending country. Moreover, migrants often postpone childbearing until they have settled in the host country (Lichter et al., 2012; Milewski, 2010). Thus, the arrival of migrants may boost fertility levels in more developed areas.

There is empirical evidence of fertility decline reversals at the subnational level in Europe and the United States. Fox et al. (2019) analyzed data at the NUTS-2 level for 20 European countries subdivided into 256 regions for the 1990-2012 period. They measured development using employee compensation, which is an indicator of household income; and they measured fertility using the TFR and the

tempo-adjusted TFR. Based on these data, they concluded that fertility declines have reversed at the subnational level. Specifically, they found that between 1990 and 2012, the relationship between fertility and development became less negative or even positive in most of the 20 countries studied; except in Finland, West Germany, the United Kingdom, and France, where the relationship became more negative. These findings held even after accounting for tempo distortions by using the tempo-adjusted fertility rate.

For the U.S., empirical studies that investigated this relationship at the subnational level produced mixed results, which might be attributable to the cross-sectional approaches. Ryabov, 2015 found no evidence of a fertility reversal among counties in the United States with very high development levels, and thus concluded that the combination of the second demographic transition and high levels of human development has resulted in persistent low fertility. By contrast, a study by Porter, 2017 also using county-level data reproduced the inverse J-shaped association. A potential explanation for these discrepancies is that they measured fertility and development with different measures and different models. Moreover, the cross-sectional approaches applied in these two studies relied on strong assumptions for assessing the causal relationship related to unobserved heterogeneity (Firebaugh, 2018; Wooldridge, 2010). Hence, the use of longitudinal data may help to resolve the inconsistencies in earlier research findings.

2.2.3 Critiques

The reversal hypothesis has stimulated a debate among scholars, some of whom have criticized its claims. In particular, the impact of tempo effects on fertility decline reversal has been raised. Bongaarts and Sobotka, 2012 suggested that recent increases in fertility are attributable to cohort tempo fertility recuperation, rather than to an increase in the quantum of fertility caused by increasing development. Empirical support for this critique comes from two recent papers, which aimed to

replicate the inverse J-shaped relationship, but found no evidence of fertility decline reversal in contexts with highest-high levels of development (Gaddy, 2021; Harttgen & Vollmer, 2014). Therefore, it was argued that the J-shape hypothesis held only for a short period of time when fertility postponement came to an end.

Another critique of the reversal hypothesis has related the fertility decline reversals to Simpson's paradox (Lesthaeghe, 2020). Several studies have shown that even when an inverse J-shaped relationship between fertility and development is observed at the national level it might vanish when studied within country groups (Lesthaeghe, 2020; Lesthaeghe & Permanyer, 2014; Rindfuss et al., 2016). These authors suggested that national idiosyncrasies of the Nordic and the Anglo-Saxon countries - with the former having supportive social policies and the latter having flexible labor markets - entirely explain the inverse J-shaped relationship, and thus that the positive association is a data artefact rather than a causal relationship.

Moreover, the Human Development Index, which was used in several studies as the indicator measuring development, has been criticized. The HDI is provided by the United Nations, and is itself based on four indicators: mean years of schooling, expected years of schooling, life expectancy at birth, and gross national income per capita. The main criticisms of the HDI are that it is only a crude indicator of development, and thus ignores many aspects relevant for development; that its components suffer from measurement error; that the estimation method has been revised repetitively; and that how the HDI combines the components is not well justified (Gaddy, 2021; Ghislandi et al., 2019; Harttgen & Vollmer, 2014; Scherbov & Gietel-Basten, 2020).

2.3 Data and methods

2.3.1 Overview

In this study, we aim to test the J-shape hypothesis in the U.S. states for the years 1969 to 2018. We examine the relationship between development and fertility using

longitudinal data. As we seek to contribute to the ongoing debate, we take the critiques outlined above into account and run several robustness checks. We control for tempo distortions. Moreover, we account for measurement error by running several analyses using alternative indicators of fertility and of development. The indicators, their annual coverage, and their data sources are summarized in Table 2.1. Moreover, we apply several different regression techniques in our robustness checks to assess the model dependency of the findings.

2.3.2 Fertility indicators

As our main fertility indicator, we use the total fertility rate (TFR) for the 1969-2018 period for all 50 U.S. states and the District of Columbia. For the 1969-2004 period, the state-level TFR is calculated from vital statistics data provided by the National Bureau of Economic Research (NBER, 2022), and from population counts provided by the NBER (2023). For the 2005-2018 period, we derive the state-level TFR from the annual birth collection that is published by the Centers for Disease Control and Prevention (2023).

We perform robustness checks using two alternative fertility indicators that will show to what extent the results might depend on the measurement of fertility. First, we calculate the tempo-adjusted TFR following Bongaarts and Feeney (1998, p. 278) in order to account for fertility postponement, which could distort the results as argued in the literature (Bongaarts & Sobotka, 2012). The adjusted TFR is calculated from the female perspective for the 1969-2004 period based on the data provided by the NBER (2023). The time series is shorter, because we lack access to state-level birth counts by parity for later years. We use the female mid-year population as exposure for each parity. We combine all parities higher than five into one category. Second, we use the TFR of men. Specifically, we count births by the age of the father in the numerator, and we use the mid-year population for men instead of the exposure counterpart for women as the

denominator. While the TFR for men is closely linked to the TFR for women, it can differ from the female TFR ² (Dudel, 2021; Schoumaker, 2019). These differences may be attributable to imbalances in the size of the population of men relative to size of the population of women, which can be caused by gender-selective migration or changing cohort sizes. The male TFR is also based on the data provided by the NBER (also see Dudel & Klüsener, 2019a).

2.3.3 Development indicators

Our main indicator for human development is the Human Life Indicator (HLI) (Ghislandi et al., 2019). It captures the average length of life as well as the lifespan distribution, and it is defined by the geometric average of the-age-at-death distribution. Life expectancy is central to development, as "[...] mortality information has (1) intrinsic importance (since a longer life is valued in itself), (2) enabling significance (since being alive is a necessary condition for our capabilities), and (3) associative relevance (since many other valuable achievements relate-negatively-to mortality rates)" (p. 22, Sen, 1998). In addition, the HLI captures the inequality in the length of life, which is related to development, as it reflects how societies organize health care, insurance, pensions, and other social policies and programs (p. 1002, van Raalte et al., 2018). Furthermore, lifespan inequality has an inherent dimension of social equality. In contrast to the Human Development Index (HDI; see below), which is only available from 1990 onwards, the HLI can be calculated at the state-level from 1969 through 2018. This is the main reason why we use the HLI for our main analysis. Moreover, in contrast to the data used for the components of the HDI, the life table data used as input for the HLI is very reliable and robust (Ghislandi et al., 2019). The life tables were obtained from the United States Mortality DataBase (USMDB) (Barbieri & Wilmoth, 2022).

²In the remainder of the paper, TFR means the TFR for women, unless it is explicitly stated that the TFR is for men.

We use three alternative measures of development: the Human Development Index (HDI), life expectancy, and the Gini coefficient for the lifespan distribution. Our motivation for doing so is to show whether the measurement of development affects the substantive findings. We present the results for the HDI and life expectancy alongside those for our main indicator. The HLI and e_0 are estimated from female life tables when the outcome is the female (tempo-adjusted) TFR, while life tables for men are used when the outcome is the male TFR. Results for the Gini coefficient are briefly covered in the discussion, and are fully reported in the supplementary materials.

2.3.4 Further control variables

In our main analysis, only development and fertility are included in the regression models. However, trends in fertility might be driven by factors other than development, or by factors that mediate the impact of development. To account for these mechanisms, we conduct robustness checks that include additional control variables. First, in some analyses we include the proportion of jobs in the service sector, which accounts for structural economic change (Ruggles, 2015; Seltzer, 2019). Furthermore, in some instances, we include the annual state unemployment rate, which accounts for economic conditions and shocks, such as the financial crisis 2007/2008, which might have driven some of the observed fertility trends (Comolli, 2021; Schneider & Hastings, 2015). The results may also be confounded by heterogeneous trends in gender equality, as suggested by the gender revolution theory, which were described in section 2.2.1 (Esping-Andersen & Billari, 2015; McDonald, 2000). Hence, we include a proxy for gender equality in norms and household roles: namely, the mean age difference between parents. The parental age difference is a good indicator for gender equality in the domestic sphere, because it affects the bargaining power within the relationship (Carmichael, 2011; Dudel et al., 2023; Presser, 1975).

Table 2.1: Summary statistics of the data. The first block contains the three fertility indicators: TFR for women, TFR for men and the tempo-adjusted TFR following Bongaarts and Feeney (1998). The second block displays the three development indicators Human Life Indicator (HLI), Human Development Index (HDI), and life expectancy at birth (e_0). The last block consists of the four control variables which are used to disentangle the mechanisms. The abbreviation of the state name is written in parentheses behind the value of the minima and maxima. **Note:** The time-series length differs across indicators due to data availability.

Statistic	Years	N	Min	Max	Source
Female TFR	1969-2018	2,550	1.346 (DC)	3.186 (UT)	NBER/CDC
Male TFR	1969-2004	1,836	1.552 (RI)	3.647 (UT)	NBER
Tempo-adjusted TFR	1969-2004	1,836	1.514 (DC)	3.513 (UT)	NBER
HLI	1969-2018	2,550	56.989 (DC)	80.548 (HI)	USMD
HDI	1990-2018	1,479	0.820 (MS)	0.955 (MA)	GDL
e_0	1969-2018	2,550	69.58 (DC)	84.47 (HI)	USMD
Unemployment rate (%)	1976-2018	2,193	2.100 (CT)	17.300 (WV)	BEA
% in service	1980-2018	2,193	0.449 (NC)	0.951 (DC)	BEA
Parental age difference	1969-2004	1,836	2.092 (NH)	4.703 (DC)	NBER
Mean age at childbearing	1969-2018	2550	24.218 (OK)	31.270 (DC)	NBER

State abbreviations: CT = Connecticut; DC = District of Columbia; HI = Hawaii; MA = Massachusetts; MS = Mississippi; NH = New Hampshire; NC = North Carolina; OK = Oklahoma; RI = Rhode Island; UT = Utah; WV = West Virginia

Source abbreviations: NBER = National Bureau of Economic Research; CDC = Centers for Disease Control; USMD = US Mortality DataBase; GDL = Global Data Lab; BEA = Bureau of Economic Analysis

As was stated in section 2.2.3 on the critiques of the reversal hypothesis, tempo-distortions of the TFR are a major threat to the identification of the effect of development on fertility. Beyond using the tempo-adjusted TFR, which is only available for the years 1969-2004, we expand the time-series to 2018 by using the mean age at childbearing as control variable in a set of further robustness checks. Guided by the models presented in the literature, we use the specification following Myrskylä et al. (2011) and include the first and second differences of the mean age at childbearing as controls. An alternative specification suggested by Luci-Greulich and Thévenon (2014) is also estimated, including the (undifferentiated) mean age at childbearing as a linear and as a squared term, as postponement might have

non-linear effects on the total fertility rate.

A description of the data is displayed in Table 2.1. For each variable, it shows the total number of state-year observations, the years covered, and the minimum and the maximum value, the latter with an indication for which state the value refers to.

2.3.5 Methods

For our main analysis, we use a fixed effects individual slope regression model (FEIS), which accounts for unobserved heterogeneous trends across states in addition to unobserved time-constant and state-specific heterogeneity (Rüttenauer & Ludwig, 2020; Wooldridge, 2010). This approach is more flexible than the FE or two-way FE approach, and makes less restrictive assumptions. However, as the model effectively reduces the number of observations, it imposes greater demands on the data and often produces larger standard errors. As our dependent variable we use the TFR in state i in year t . As our explanatory variables, we use a development indicator in state i in the previous year $t - 1$, as well as the square of the development indicator. For the HLI the regression equation looks as follows:

$$TFR_{i,t} = \beta_1 HLI_{i,t-1} + \beta_2 HLI_{i,t-1}^2 + \mu_i t + \lambda_i + \gamma_t + \epsilon_{i,t}, \quad (2.1)$$

where μ_i is the state-specific slope, λ_i is the individual fixed effect, γ_t is the year fixed effect, and $\epsilon_{i,t}$ is the idiosyncratic error. The coefficients in the equation above are estimated after taking first differences and then demeaning; because of this, μ_i , λ_i , and γ_t are not estimated explicitly, as would be the case for λ_i and γ_t in a standard one-way or two-way FE model.

For fertility decline reversals, the coefficient β_1 has to be negative, while β_2 has to be positive; if either or both coefficients have the opposite sign, the data do not follow an inverse J-shape. Furthermore, we estimate the point at which the association between the TFR and development switches from negative to positive, i.e., the inversion point I , can be calculated as $I = \frac{-\beta_1}{2\beta_2}$. The standard error

of I can be calculated from the standard errors of β_1 and β_2 (see section A in the Supplementary Materials).

Coefficient estimates consistent with the inverse J-shape are also consistent with other shapes of the empirical relationship between development and fertility, in particular an L-shape and a U-shape. If the empirical relationship has an L-shape, a quadratic model can also provide a good fit, but fertility does not increase with development; whereas if the empirical relationship has a U-shape, fertility increases much more after the turning point. However, these different shapes are not completely inconsistent; e.g., an inverse J can turn into a U over time. To distinguish between these different shapes, we conduct additional analyses. Based on the observations occurring after the turning point, we estimate TFR changes (ΔTFR) relative to development changes (ΔHLI) in the previous year. We classify the year-to-year changes as confirming a J-shape when the values are positive and as contradicting a J-shape when fertility declines following increases in development. Increasing TFR following development declines is a residual category, which we have removed from the data.

In our robustness checks, we use several other modelling approaches to account for model dependence. We apply two-way fixed effects regression, which only removes the additive contribution of state and year effects (Imai & Kim, 2021). We apply models with state fixed effects (FEs), which removes less variance from the outcome variable and which usually has lower standard errors than FEIS. In addition, we re-run the analysis using two-way random effects (RE), which is statistically more efficient, albeit at the cost of making an additional assumption, that unobserved heterogeneity is not correlated with the development indicator.

We also conducted further robustness checks. First, as was discussed earlier, these are long-term development changes, rather than short-term fluctuations, that ultimately determine fertility. To remove short-term fluctuations from the data, we smooth both the fertility and the development time-series using locally-weighted

scatterplot smoothing (LOESS). After generating the smoothed time series, we proceed as described above. Second, accounting for the spatial structure of the U.S. states, the state-level FEs are replaced by FEs structured by Census divisions. This allows us to account for the fact that states that are close to each other are often relatively similar, leading to a high spatial correlation of state-level TFRs. Finally, we have carried out a break point analysis using state-demeaned data with different *a priori* specifications of the number of break points. Although these models are less powerful than the main specification, they are less constrained in form, and can therefore better distinguish between a "U", "L" and "J" shape.

2.4 Results

2.4.1 Descriptive results

Figure 2.1 shows the TFR trends in the top left panel (blue lines) for all states (semi-transparent lines), as well as the TFR trend at the national level (thick line). Over the 1969-2018 period, the national-level TFR fell from 2.7 to a historical low of 1.8. Beyond indicating the overall trend, the graph reveals three phases: a strong decline around the year 1970 related to the baby bust that followed the baby boom, a gradual recovery between 1977 and 2008, and a strong decline following 2008. While these phases roughly apply to most states, we also see considerable heterogeneity in fertility levels. For instance, in 2018, the state-level TFR ranged from 1.3 in the District of Columbia to 2.1 in South Dakota. Moreover, we also find that the trends in some states deviated from the country-level trends.

The time-series of our three development indicators are presented in Figure 2.1 (top right and bottom panels), and show clear improvement in development in the United States over the analyzed period, with all development measures increasing between 1969 and 2018. However, we also find that this trend stalled somewhat in the most recent years, as in the 2010s, both e_0 and the HLI decreased, and the HDI increased at a slower pace. The decline in e_0 and the HLI, which are

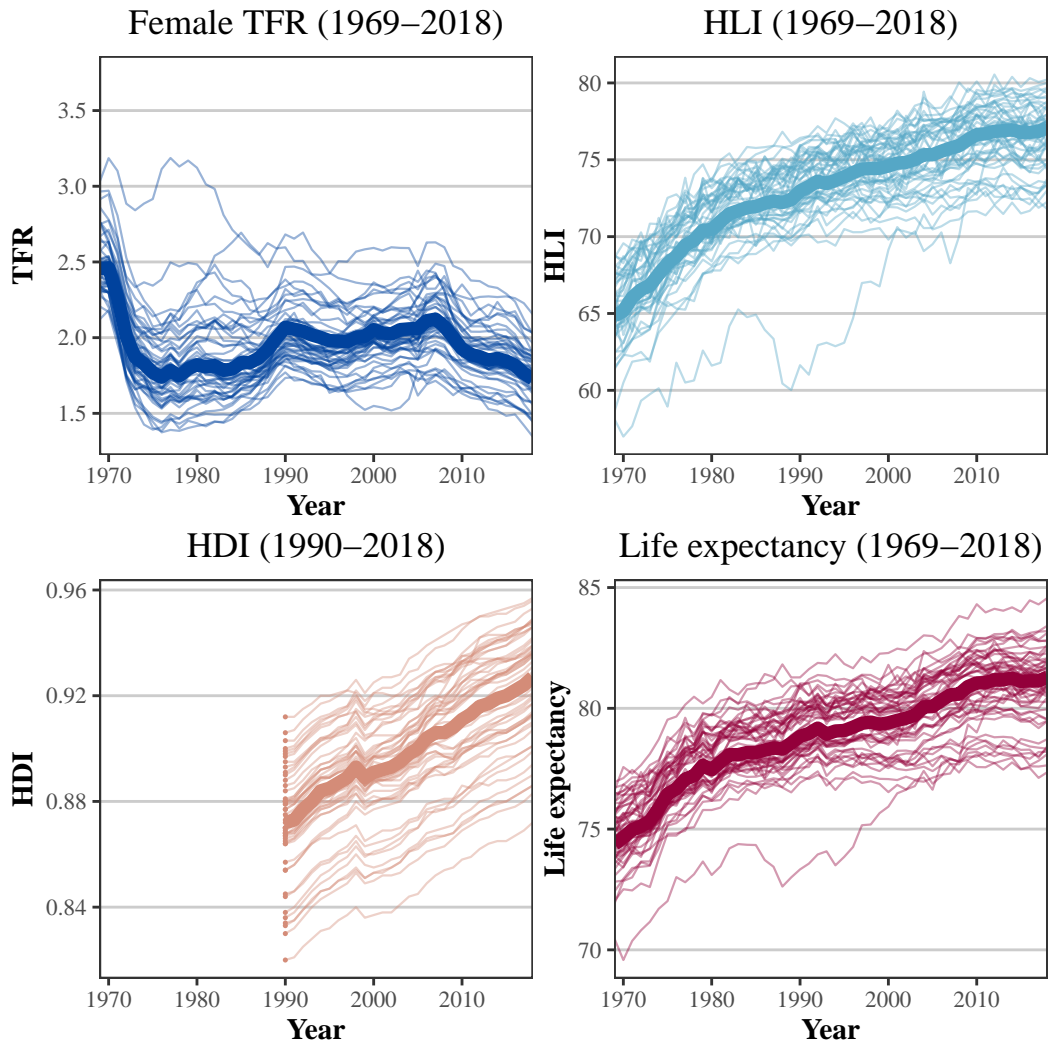


Figure 2.1: Time-series of fertility and the three development variables. The semi-transparent lines represent the data values for the states. The thick lines are the values of the indicator at the country level for the US.

measures based on life tables, reflects either stagnating or even increasing mortality, which has been attributed to the drug overdose crises and to cardiovascular diseases (Jalal et al., 2018; Mehta et al., 2020).

Figure 2.2 provides a first look at the association between development and fertility. Each line represents one of the states, while each point indicates the average level of the development indicator and the average TFR during each decade (1960s, 1970s, ...). HLI and e_0 show a similar pattern, which resembles a J-shape, with fertility decreasing at lower values, and increasing again at a life expectancy

of 75. Yet, the middle panel presents a different pattern, with the relationship between the HDI and the TFR showing increases and decreases at different times and at different levels across regions.

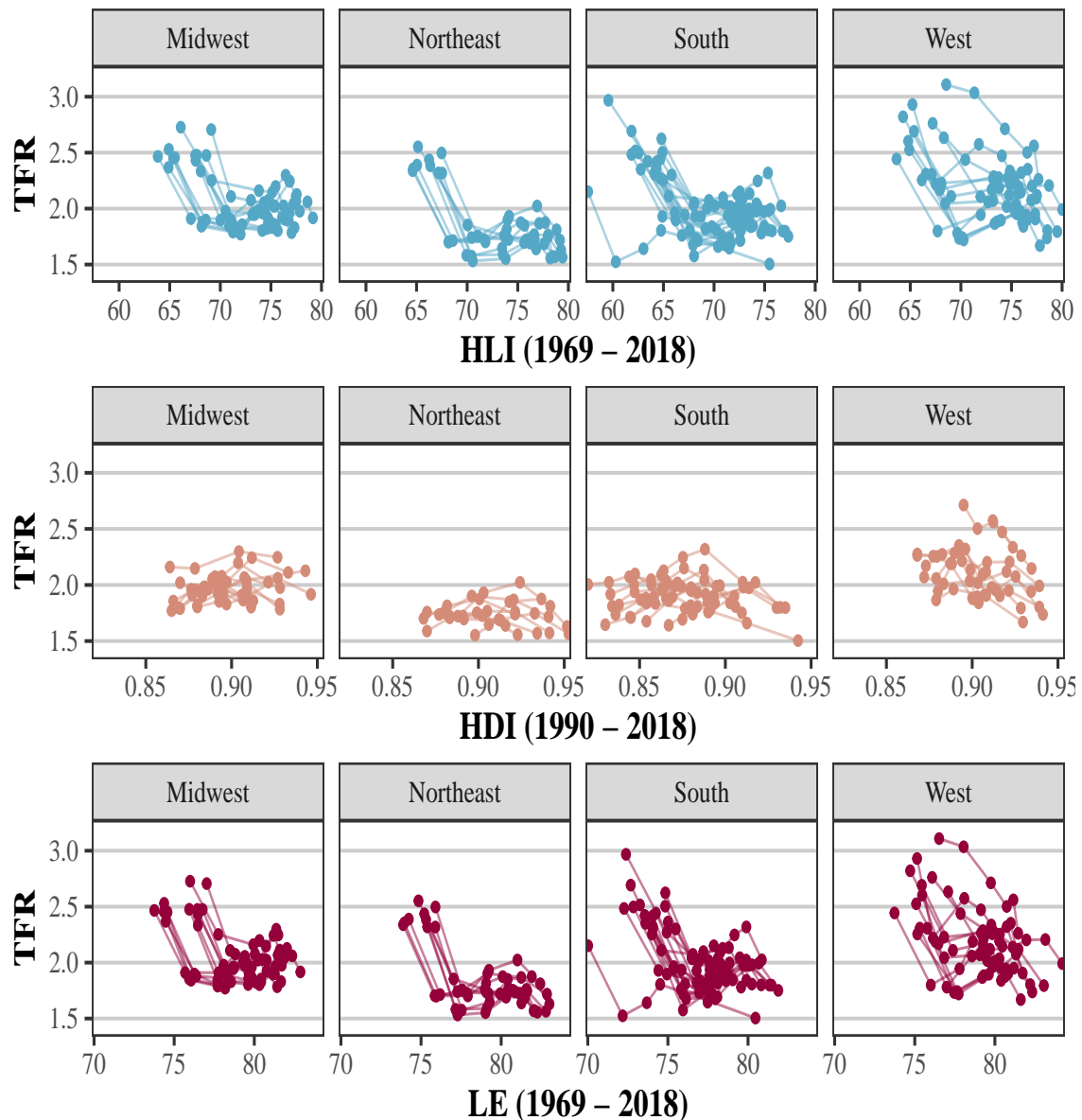


Figure 2.2: The relationship between development indicators (x-axis) and female TFR (y-axis) using decade averages. The vertical grid dimensions reflect the different development indicators. The horizontal grid dimensions represent different census divisions in order to improve readability. **Note:** The x-axis and the y-axis differ between the rows, because of different data lengths.

2.4.2 Main results

The results of the main model using the TFR as the fertility measure are shown for different development indicators in the columns in Table 2.2. The signs of the coefficients for the HLI and e_0 are in line with the fertility decline reversal hypothesis, while the results for the HDI (discussed below) contradict it. For the HLI and e_0 , the association between development and fertility is negative at lower levels of development, as the linear term has a negative sign; and the association becomes positive at higher levels of development, as the positive coefficient of the quadratic term starts to dominate. Based on these coefficients, we calculate that the female TFR starts to increase when a state has reached a HLI value above 74.2 (95% confidence interval 72.9 - 75.5) or a e_0 of 116.71 years or higher (95% confidence interval 104.02 - 129.4). The turning point for the HLI lies within the observed value range, while the turning point for e_0 exceeds the maximal observed value, which contradicts the J-shape hypothesis.

Table 2.2: Fixed effects individual slope regression (FEIS) on TFR of females.

	lag.HLI	lag.HDI	lag. e_0
Linear	-0.033* (0.017)	4.415 (21.352)	-0.036 (0.080)
Squared	0.0002* (0.0001)	0.246 (11.778)	0.0002 (0.001)
State fixed effects	Yes	Yes	Yes
Year fixed effects	Yes	Yes	Yes
Years	1969 - 2018	1990 - 2018	1969 - 2018
Observations	2,499	1,377	2,499
Adjusted R^2	0.706	0.471	0.708
Within R^2	0.001	0.019	0.003
J shape	Yes	No	Yes
Turning point	76.82	-0.5	116.71
Confidence interval	(75.4, 78.24)	(-0.93, -0.08)	(104.02, 129.4)

Note:

* $p < 0.1$; ** $p < 0.05$; *** $p < 0.01$

The results based on the HDI as a development indicator, which are also shown in Table 2.2, do not provide evidence for fertility reversals. The linear and squared terms are positive, indicating a positive impact of development that is reinforced at higher levels. These findings not only contradict the J-shape hypothesis, they also do not match demographic transition theory. The descriptive results presented in Figure 2.2 point to some potential explanation for these results. The time-series is shorter than that for the HLI and e_0 , and is only observed for relatively high values of development, with little variance. In line with this explanation are findings from our robustness checks for the HLI and e_0 , which suggest that omitting several years at the beginning of the time series changes the results drastically. More generally, the results obtained using the HDI indicate that the conclusions are sensitive to the choice of development indicator and its availability over time; the robustness checks discussed below confirm this conclusion.

In order to evaluate the effect size of development on fertility, we estimate the marginal effect of a one-point increase in the HLI on the female TFR from the model parameters at the 25% quantiles (HLI = 56.99, 70.76, 75.79, 80.73). At the lowest value of human development that is, a HLI of 56.99, a one unit increase in the HLI is expected to reduce the TFR by 0.0084 (CI: -0.0016 and -0.0152). This value corresponds to a decrease of 0.8% in the TFR sample mean. While an increase at the maximum value of the HLI, which is 80.73, corresponds to an increase of 0.0016 (CI: -0.003 and 0.006) in the TFR, which is equivalent to 0.16% of the total mean TFR of the sample. Overall, the pattern of the marginal effects is in line with the J-shape hypothesis.

Moreover, the observed data corresponds with the fertility reversal hypothesis, which is evaluated using TFR-HLI slopes after the estimated turning point. 52.15% of the slopes are in line with the J-shape hypothesis, as they are positive or show at least fertility increases, while only 47.85% show negative slopes with fertility declines. Restricting the time-series further to the pre-recession period before 2008,

the share of confirmatory results increases to 72.45%, while after the economic recession the share shrinks substantially to 44.22%.

2.4.3 Robustness checks

Our results are summarized in Figure 2.3, which displays the turning points across indicators and model specifications. Overall, the graph shows that the majority of points lie in the observed value range of the development indicator (shaded area), which supports the hypothesis that there have been fertility decline reversals in the United States. However, some results contradict the hypothesis. There is variation across model specifications displayed on the y-axis, whereas the two-way fixed effects and random effects models contradict the J-shape hypothesis, as the turning points lie outside of the observed value range. Moreover, the middle column shows fewer points than the other columns, which is due to different signs in the regression coefficients for the HDI indicator, and thus contradicts the J-shape hypothesis. Overall, fertility declines in the last decade are shifting the model-based turning points to higher values.

Fertility indicators

To account for potential tempo distortions of the TFR, we use the tempo-adjusted TFR (Bongaarts & Feeney, 1998, p. 278). The results are displayed in Tables A.1 and A.2 in the supplementary materials. The coefficients have the same signs as in the the analysis with the unadjusted TFR, and they are consistent with the J-shaped association and the fertility decline reversals. These findings give us further confidence to conclude that the J-shaped pattern was not caused by fertility recuperation, as was argued by Bongaarts and Sobotka (2012).

Table A.3 presents the results based on the male TFR, which lead to very similar conclusions, and have turning points similar to that in the main model. According to the fixed effects individual slope regression, the male TFR starts increasing at a male HLI of 68.86 (CI: 68.09 and 69.64) or, respectively, at a male

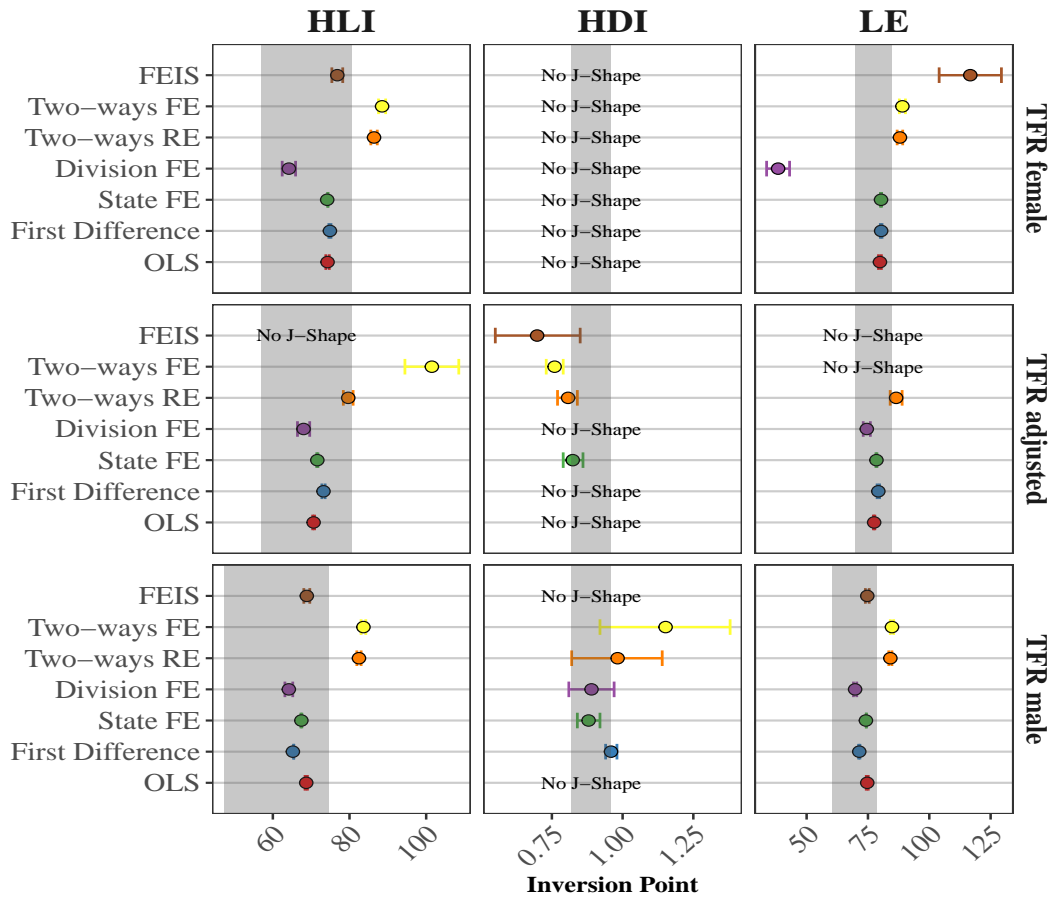


Figure 2.3: The sensitivity of the turning point in relation to the model selection and the selected variables. The shaded area indicates the observed value range over the entire observation period. If a line shows "No J-Shape", then the relationship was not convex but concave. The numbers inside the plot indicate the value of the turning point for the model. All turning points are accompanied by a 95% confidence interval, but smaller intervals are hidden behind the turning-points.

life expectancy of 74.72 (CI: 73.94 and 75.5), which are both within the observed data range, while the location of the turning point of the HDI lies at 1.15, and is therefore outside the range of observed and even possible values. However, the data for the HDI versus male TFR model consists only of 14 years of observations, and is thus less robust than the other estimates.

Adding control variables

In Section 2.2.2, we discussed the role of gender equality and economic uncertainty in the development-fertility nexus. We introduce controls for the state-level

unemployment rate, the state-level percentage of jobs in the service sector, and the average age gap between parents, and test whether the results remain similar. Furthermore, the inclusion of time-varying controls allows us to better account for heterogeneous trends in economic conditions and gender equality. The results displayed in Table A.4 in the supplementary materials show patterns that correspond to arguments presented in the theoretical section. Controlling for unemployment or gender equality absorbs the J-shaped relationship between development and fertility. This indicates that the association between development and fertility net of economic conditions and gender equality is likely small, and that these two factors are key drivers of the overall association.

The results for the tempo-adjusted TFR are confirmed by the models with controls for the mean age at childbearing and the first and second difference time-series of the indicator, which are shown in Table A.5. The model estimates show a convex relationship and give reasonable turning points.

Different regression methods

To assess to what extent our findings are dependent on model assumptions, we used several alternative regression models. We use two-way fixed effects models to account for the fact that the FEIS models may absorb some of the variance in the outcomes that are the result of developmental processes. As hypothesized, the linear term is negative, while the quadratic term is positive, yielding a convex relationship. The results point into a similar direction, as can be seen in Table 2.3, however, the turning points occur at a higher value of the development variable and outside the observed value range. We conclude, that the selection on trends may not be captured in the two-way fixed effects model, despite giving significant results for the squared term. Using random effect models instead yields results that are in line with the J-shape hypothesis, as can be seen in Table A.6 and A.7, and that provide additional support for the existence of a J-shaped relationship.

Table 2.3: Two-way fixed effects regression on TFR of females with different development indicators.

	lag.HLI	lag.HDI	lag.e ₀
Linear	-0.075*** (0.019)	44.862*** (5.944)	-0.172*** (0.065)
Squared	0.0004*** (0.0001)	-21.614*** (3.237)	0.001** (0.0004)
State fixed effects	Yes	Yes	Yes
Year fixed effects	Yes	Yes	Yes
Years	1969 - 2018	1990 - 2018	1969 - 2018
Observations	2,550	1,428	2,550
Adjusted R ²	0.838	0.874	0.837
Within R ²	0.020	0.10	0.013
J shape	Yes	No	Yes
Turning point	88.5	1.04	89.03
Confidence interval	(87.57, 89.43)	(1.03, 1.05)	(87.79, 90.27)

Note:

*p<0.1; **p<0.05; ***p<0.01

We have modelled the relationship between development and fertility using smoothed time-series data. This approach should yield further evidence on the contribution of the impact of long-term effects of developments beyond short-term fluctuations, which are removed from the data using LOESS. The results displayed in Tables A.8 and A.9 point to the impact of long-term development on fertility. Therefore, we conclude, that it is the overall trend in development, rather than short-term fluctuations in development, that has an effect on fertility.

We have also accounted for the problem of spatial auto-correlation, which became apparent in Figure 2.2 from the within-census division similarities, by replacing state fixed effects with Census division fixed effects. The results, displayed in Table A.10, are in line with the hypothesis. The inversion of fertility decline occurs within the range of observed values. Nevertheless, the significance of the estimates and the R^2 is low, which points to considerable variation around the expected values.

Finally, we carried out a breakpoint analysis on the state-demeaned data and report the results in Table A.13. The model with two breakpoints yields the best model fit. The slope for the first interval is -0.17 (CI: -0.175, -0.152), while the slope for the second interval is 0.2 (CI: 0.027, 0.035) and the slope for the third interval is -0.08 (CI: -0.063, -0.046). The location of the breakpoints is estimated at an HLI of 68.1 (CI: 67.9 and 68.3) and 74.8 (CI: 74.56 and 75.0). These results are an indication that a) there may have been a J-shaped relationship in the past and b) the relationship likely vanished in the most recent period.

Further robustness checks

In order to investigate the periodicity of the J-shaped pattern, we calculate two-way fixed effects regression models with individual slopes for the TFR and the HLI for different time-series lengths, thus altering the start and end year of the time series, with the restriction of a minimum length of 10 years. The results, which are displayed in Figure A.6, show that the majority of models confirm the J-shape pattern. There are, however, two important exceptions. First, when the time series starts after 1975 instead of 1969, the J-shape disappears. This indicates that the decline in fertility between 1969 and 1975, which is visible in Figure 2.2, drives the negative relationship between development and fertility at lower levels. Second, when only the last period between 1995 to 2018 is considered, the relationship has an inverted U-shape, or becomes fully negative. This may indicate that the J-shaped relationship does not exist for the most recent period. Results presented in Table A.16 confirm that the relationship between the HLI and the TFR is negative for the period between 2008 and 2018. A similar analysis of state omissions indicates that the District of Columbia exerts the greatest influence, and omitting it results in a shift in the estimated turning point to a HLI value of 82.2 (CI: 75.1, 89.3), which exceeds the observed value range.

Two competing explanations may account for the diverging results across indicators: 1) the time-series length and 2) the different dimensions of development.

We re-estimate the main regression model for the same time-series, the years 1990 to 2018. This neutralizes, the impact of the first explanation. The results have changed drastically, providing evidence of the relevance of the time-series length. The J-shape for the life expectancy indicator in the main model has faded completely; while for the HLI, the estimated turning point has increased to a HLI level of 180.04. Thus, the unexpected result for the HDI is mainly attributable to only more recent data being available. However, some differences remain across the three indicators, which provides evidence that the indicators capture different dimensions of development.

2.5 Discussion

In this paper, we examined whether the J-shape hypothesis proposed by Myrskylä et al. (2009) holds for the United States at the subnational level. Leveraging state-level data covering the years 1969 to 2018, we found that the association between development and fertility followed an inverse J-shape in the period between 1969 and 2008, but not thereafter, and that this association was robust across many sensitivity checks. Thus, our findings lend support to the reversal hypothesis proposed by Myrskylä et al. (2009) for the U.S. at the subnational level when applied to historical periods. Moreover, while progress in development has led to some temporary increases in fertility, it has not necessarily resulted in fertility increases beyond the replacement level. Myrskylä et al. did not, however, expect that increases in fertility would necessarily persist for a long time; i.e., that the inverse J-shape would necessarily turn into a U-shape. While adjusting for tempo-effects indicated that these factors might have played some role in the fertility decline reversals, our main finding persisted. Moreover, we found that good economic prospects and high levels of gender equality were prerequisites for the reversal of the relationship. These results correspond to the findings of previous studies by Myrskylä et al. (2011) and Luci-Greulich and Thévenon (2014). However, for the most recent decade, we observed an overall fertility decline, despite some progress

in development. The break point analysis confirmed that the J-shaped relationship likely vanished in the most recent decade. Moreover, while the results were found to be sensitive to the choice of indicator, further analysis showed that the time-series length accounted for most of the differences across indicators.

Our subnational findings are in line with a country-level analysis by Myrskylä et al. (2009, 2011), which found evidence of fertility decline reversals at high levels of development; as well as with a study by Gaddy (2021), which found no correlation between development and fertility in the recent decade. The high shares of confirmatory HLI-TFR slopes after the estimated turning point indicate that the relationship resembles a historical J-shape in the period before the great recession, rather than an L-shape. This is also corroborated by additional analyses: since the recession, the majority of year-to-year changes in development and fertility are inconsistent with the inverse J-shape; in particular, for 58% of these year-to-year changes, the TFR is dropping despite increases in the HDI. In contrast, after the turning point estimated in our main model and before the recession, 67.7% of the year-to-year changes are consistent with the inverse J-shape hypothesis. Moreover, the temporal structure of the pattern may explain the mixed findings in existing subnational studies on the U.S., which applied cross-sectional analysis to county-level data (Porter, 2017; Ryabov, 2015). Future research may seek to examine the longitudinal relationship using county-level data.

The finding of a historical inverse J-shaped relationship has theoretical implications, as it stands in contrast to the demographic transition theory and the low-fertility trap hypothesis. The results point to the existence of factors that can relax and even reverse the negative association between development and fertility posited by demographic transition theory (Davis, 1945; Lesthaeghe, 2020; Lesthaeghe & Van de Kaa, 1986; Notestein, 1945). As was outlined in Section 2.2.1, levels of gender inequality and economic uncertainty may be reduced by increasing development, which can lead to higher fertility. Furthermore, increasing

fertility contradicts the low-fertility trap hypothesis (Lutz et al., 2006). We found no sign of entrenchment at low levels, which leads us to question whether low fertility is indeed self-reinforcing.

In the U.S., the J-shaped relationship between development and fertility, observed for the period between 1969 and 2008 underwent a notable shift around 2007/2008. We found a negative relationship between development and fertility for the period between 2008 and 2018. Moreover, continuing fertility declines beyond the year 2018 lead us to speculate that the negative relationship holds up to today. This shift, which was also noted at the country level in a study by Gaddy (2021), might be attributable to a structural break. Questions about the potential role of economic uncertainty, value change and contraceptive practices have been raised in the discourse on the recent fertility decline. First, given that the beginning of the fertility decline coincided with the economic recession, the decline might be explained by continuing economic uncertainty (Comolli, 2021; Schneider & Gemmill, 2016; Schneider & Hastings, 2015; Vignoli et al., 2020). In addition, changes in values and family norms may be responsible for the structural break. For example, a recent study argued that an attitudinal shift may be a key driver of the recent fertility decline, given that it occurred across states and social classes (Kearney et al., 2022). Thus, the recent decline may be in line with the second demographic transition theory (Lesthaeghe, 2020; Lesthaeghe & Neidert, 2006). Finally, the development and distribution of modern contraceptive technologies, especially long-acting reversible contraceptives (LARCs), may have reduced unintended births (Eeckhaut et al., 2021; Kavanaugh & Jerman, 2018). In conclusion, further research is needed to fully understand the structural factors underlying this recent decline in fertility.

An alternative explanation for the results for the period since the financial crisis is measurement error. As the indicators we use do not capture development perfectly, some degree of measurement error is unavoidable. However, if measurement error increases over time because our indicators become less predictive of development,

biased findings might result. There is, however, only modest evidence for increased measurement error. The association between different development indicators, health expenditures, GDP, wages on the one hand and life expectancy and mortality on the other has been slightly declining. For instance, Table A.15 shows that the correlation between the Human Life Indicator, our main measure of development, and the Gini coefficient has weakened. However, the association is still very strong.

Consistent with existing research, we showed that the results vary depending on the choice of the development indicator (Gaddy, 2021; Harttgen & Vollmer, 2014); in particular, no inverse J-shaped association was found when using the Human Development Index (HDI), while the inverse J-shape was observed when using life expectancy at birth and the HLI. These findings appear to support Gaddy (2021) and Harttgen and Vollmer (2014), who criticized the indicators used in Myrskylä et al. (2009). However, additional analyses showed that these results were attributable to the only recent period of data availability of the HDI time-series, which is, therefore, more greatly affected by the years after the 2007/8 financial crisis.

A key contribution of this study is that we addressed the major criticism of the J-shape hypothesis. First, we conducted several sensitivity checks that accounted for the potential impact of postponement, including the tempo-adjusted TFR, and using the mean age at childbirth as a control variable. All of these robustness checks still yielded an inverse J-shaped pattern. Thus, in contrast to findings of other studies (Bongaarts & Sobotka, 2012), we conclude that at least for the U.S., postponement does not seem to be a major driver of the association between development and fertility. Second, by changing the research design into a subnational longitudinal setup, which rules out unobserved cultural and institutional factors, we were able to address the concern raised by Lesthaeghe (2020) that national idiosyncrasies may be driving the J-shaped pattern. Finally, we took the critique regarding measurement error into account by using different indicators. We found that the general results depended more on the time-series length than on the indicator itself.

In line with previous studies, we found that economic and gender factors play a crucial role in the development-fertility nexus (Esping-Andersen & Billari, 2015; Goldscheider et al., 2015; Kolk & Barclay, 2019; Luci-Greulich & Thévenon, 2014). First, it appears that the fertility decline reversals were conditional on positive employment prospects. This evidence points to the role of economic uncertainty, as argued by Schneider and Hastings (2015) and Comolli (2017, 2021). Second, we found that the effect was moderated by household gender equality (Luci-Greulich & Thévenon, 2014). Theoretical arguments emphasize the role of the reconciliation of family and work, but also women's opportunities to achieve their personal career goals (Goldscheider et al., 2015). Therefore, the gender dimension seems to play a crucial role in fertility in highly developed states, with fertility increasing as development progresses.

2.5.1 Methodological considerations

When interpreting our results, it is important to keep in mind that they show the association between development and fertility at the macro level, and do not allow us to infer individual responses to development. Our results yield evidence only on contextual factors, which, in our analysis, might also be specific to the United States. Moreover, while the association between development and fertility we found was strong, development was only one of many determinants of fertility, as highlighted by some of our additional analyses. Some of these other determinants might be mediators or moderators of the impact of development, which calls for further research into the mechanisms linking development and fertility. Finally, it should be noted that the results refer to the average fertility behavior at the state level and do not capture the considerable heterogeneity within states (Daniels, 2018; Porter, 2017; Porter & Purser, 2008; Ryabov, 2015).

Moreover, in the interpretation our results, it is also important to bear in mind that it is difficult to predict whether the associations we found will hold in the future.

In recent years, U.S. fertility has been volatile and sensitive to external shocks. The TFR started falling between 2008 and 2010 following the Great Recession, and did not rebound thereafter (Cherlin et al., 2013; Schneider & Hastings, 2015). Thus, fertility decline reversals might be stalled, or even be undone, as indicated by our results for the period between 2008 and 2018. Moreover, it is important to keep in mind that in comparison to other countries, the United States stands out because its development increases have levelled off, and no large improvements in development have been reported in the U.S. in recent years.

This study makes a leap forward by using a wide array of robustness checks, most of which showed the existence of fertility reversals in the United States. Thus, our results confirm the existence of temporary fertility decline reversals at higher levels of development but show a different pattern for the most recent period since 2008.

God is dead.

Friedrich Nietzsche - Thus Spoke
Zarathustra

3

Secularization and low fertility

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The contemporary declines in fertility to considerably below the replacement

This chapter is co-authored with Vegard Skirbekk and Jessica Nisen. Materials from this chapter are under review in *Social Forces*. The code is accessible under https://osf.io/m6ydt/?view_only=b0d48477bdd2426abed9f9c26475766d and a previous version is available as working paper under <https://www.demogr.mpg.de/papers/working/wp-2024-040.pdf>.

level across Anglo-Saxon, Nordic, and many Western European countries represent a noteworthy yet inadequately understood demographic shift (Hellstrand et al., 2021; Kearney et al., 2022; Matysiak et al., 2021; Ohlsson-Wijk & Andersson, 2022). In Finland, the setting of the empirical investigation in this study, the total fertility rate fell by 30% between 2010 and 2023, from 1.8 children per woman to a historic low of 1.26 children per woman (Official Statistics of Finland, 2024). The fertility decline in Finland was one of the most pronounced among high-income countries in this period, and was larger than the decreases in the other Nordic countries, such as Sweden or Denmark, or in countries such as the US and the UK (United Nations Department of Economic and Social Affairs, 2024). These declines in the 2010s remain inadequately understood, given that they occurred across educational levels and geographic regions, and independent of migration background (Campisi et al., 2022; Hellstrand et al., 2024; Ohlsson-Wijk & Andersson, 2022). Evidence from Finland, Sweden, and the US suggests that this trend stems primarily from reductions in first-time childbearing among couples (Hellstrand et al., 2020, 2021; Kearney et al., 2022; Ohlsson-Wijk & Andersson, 2022). Fertility declines can impact population ageing and the fiscal sustainability and economic growth of societies (Lee & Zhou, 2017; Preston et al., 2008), as well as climate change adaption and resource use (Jones & Warner, 2016; Molotoks et al., 2021; Scovronick et al., 2017). Moreover, the implications of substantial fertility declines extend beyond the demographic realms, and may indicate that social changes are occurring that lead to increasing constraints on the realization of desired fertility (Beaujouan & Berghammer, 2019).

The Nordic countries are often considered models of societal progress due to their low levels of socioeconomic inequality, relatively equal economic opportunities, universal and generous social security systems covering both the younger and older generations, and high levels of gender equality, and thus have often been regarded as examples demonstrating that societal development can be reconciled with relatively

high fertility (Adserà, 2004; Esping-Andersen, 2009; McDonald, 1975; Myrskylä et al., 2009). However, the recent declines in fertility, notably in Finland, may cast doubt on the ability of the Nordic model to prevent fertility from declining to very low levels (Bergsvik et al., 2021). Furthermore, when fertility in the Nordic countries falls to levels below those of countries with other social models, for instance Portuguese level in 2023, the academic view of Nordic exceptionalism is called into question. It is essential to understand the reasons behind the declining birth rates and how modernization affects them. Previous research has identified many important sources of variation in fertility by studying race differences (Lichter et al., 1992; Tolnay, 1987), cohort effects and baby booms (Macunovich, 1998), regional variation (Estes, 1997; Işık & Pinarcioglu, 2007), education and labour market change (Avellaneda & Dávalos, 2017; Brinton & Oh, 2019; Jalovaara et al., 2019), and the diffusion of fertility through social networks (Guldi & Herbst, 2015; Vitali & Billari, 2017). One line of research has focused on ideational change and social change as potential drivers of declining birth rates, including trends toward more materialism, secularism, individualism, and a focus on individual happiness (Han & Qian, 2022; Lesthaeghe, 2020; Zaidi & Morgan, 2017).

Generally, secularization and religion are considered key factors in explaining long-term fertility trends and variation. Specifically, rapid changes in religious beliefs, teachings, and practices, including changes in levels of adherence to religious authorities and rapid religious disaffiliation, can affect family formation and child-bearing patterns. Classic studies in demography by Coale and Watkins (1986) and by Goldschneider (1971) emphasized through theories and empirical evidence how secularism altered Western fertility patterns. More recent studies have confirmed the findings of these classical studies (Goldstein & Cassidy, 2014; Peri-Rotem, 2016; “Religion, Religiousness and Fertility in the U.S. and in Europe”, 2008). Blanc (2024) even suggested that secularization is the main driver of the historical fertility transition in France. However, few studies have addressed the role of religion in the

marked fertility declines that have taken place in recent decades (Mogi et al., 2022; Schnabel, 2021). One potential reason for this loss of interest is the widespread assumption that religion plays a limited role in explaining variation in individual and social phenomena in modern countries where the public role of religion is relatively minor. This research gap has persisted despite the evidence that in recent years, the pace of secularization has accelerated in many countries (Inglehart, 2021a). "[S]ince 2007, things have changed with surprising speed. From about 2007 to 2019, [...] 43 out of 49 [middle- and high-income countries] became less religious" (p. 212, Inglehart, 2021a; Voas & Chaves, 2016). For instance, in the United States, the proportion of individuals stating that religion is very important was high (56% to 58%) in the 2007-2013 period, but it fell rapidly thereafter, reaching a level of 41% in 2021 (Smith, 2021). UK census data suggest that an earlier and more rapid decline took place in the UK, where the proportion of individuals aged 20-59 who identified as unaffiliated rose from 17% in 2001 to 31% in 2011 and to 45% by 2021 (Office of National Statistics, 2022).

I hypothesize that the acceleration of secularization has played a significant role in the concurrent fertility declines across a number of high-income countries, and we test this hypothesis for Finland. We argue that this dynamic is driven by a self-reinforcing — a direct and a nonlinear — fertility reducing effect of secularization. The direct effect is well-established in the literature, and points to compositional change, i.e., the decline in the share of the religious group, who generally have higher fertility than non-religious individuals. However, the nonlinear effect, which is based on two propositions that are tested empirically in this study, has not been previously discussed. First, the probability of partnering with a person who does not have any religious affiliation is expected to increase as the proportion of the population with a religious affiliation declines. Moreover, among the religiously affiliated who prefer to have a partner with the same religious beliefs, chances of partnering with a non affiliated individual or of remaining single increase as they are less likely to

find a suitable partner. This is due to the shrinking pool of religiously affiliated potential partners in a country undergoing secularization. Second, such a change in the composition of couples is expected to reduce fertility, given that the fertility of non-religiously affiliated couples and religiously mixed couples is expected to be lower than that of religiously homogeneous couples. The combination of these two propositions is expected to result in a self-reinforcing negative effect of secularization on fertility, since it is not only the composition of the population with respect to religion that changes, but also the fertility of religious people, because they are more likely to be partnered with a non-religious individual. Our couple approach makes novel theoretical predictions that are not only different from those of an individual rational-choice perspective, but are also more comprehensive (Watts, 2014).

This study assesses the relationship between secularization and fertility in Finland in the period between 1995 and 2019 using Finnish administrative register data. I measure religious affiliation using church tax payments as an indicator of church membership. In the first part of the analysis, I assess the fertility of the religiously affiliated and unaffiliated at the population level using the total fertility rate (TFR). I compare longitudinally the TFR in both groups, and assess the impact of the changing population composition on the TFR over time using a counterfactual simulation. In the second part of the analysis, I measure the changing proportions of singles, and religiously mixed and homogeneous coresidential couples in the Finnish population. A strength of the study is the inclusion of cohabiting as well as married coresiding couples. By means of iterative proportional fitting (Breen & Salazar, 2010), I assess whether the changes over time in the composition of couples with respect to religiously affiliation were the result of the overall decline in religious affiliation. If secularization, i.e., declining church membership, also affects the size of the religiously affiliated partner pool, a decline in homogeneous religiously affiliated couples is expected to occur, *ceteris paribus*. In the third part of the analysis, I use discrete-time survival models to assess how the couple

composition with respect to religious affiliation (i.e., church membership) is related to the probability of having a first birth. In particular, I assess the role of male and female religiosity separately, and examine how these characteristics interact in determining the probability of having a first birth.

This study makes the following contributions to the existing literature on fertility. First, our findings enhance our understanding of the recent declines in fertility in high-income countries. According to our results, a substantial fraction of the so far unexplained decline in the TFR in Finland from 2010 to 2019 can be explained by the declining church membership in the country, which suggests that secularization is an important factor in the recent fertility declines. This study establishes a plausible individual-level mechanism linking these two macro-level trends. Second, the chapter adopts a dyadic perspective in examining childbearing, acknowledging the importance of the joint decision-making of partners in this context (Emirbayer, 1997). Despite the repeated calls for more dyadic fertility research (Hutteman et al., 2013), this approach has, until now, remained largely unexplored with respect to religion. Third, our contribution extends the theoretical discourse on religion and fertility by introducing the concept of a self-reinforcing effect of secularization on fertility. This concept has previously been overlooked in the predominant one-sex focus of fertility research, yet it offers a novel dimension for understanding the intricate interplay of religion and fertility. Finally, our study makes innovative use of administrative register data, by measuring secularization by the cessation of state church tax payments. While acknowledging both the advantages and the limitations of this measure, I argue for its credibility given its modest measurement error compared to conventional survey-based measures (Brenner et al., 2023; Hout & Fischer, 2014; Lim et al., 2010).

3.1 Secularization, couples, and fertility change

In this study, "*secularization* at the societal level is defined as the gradual distancing of a society from religious values and institutions, while at the individual level secularism refers to people's indifference for religious doctrine or beliefs" (p. 291, Skirbekk, 2022). This definition encompasses two important dimensions of secularization: values and institutions. The first dimension describes the change in the belief system, which becomes less dominated by an incisive religious paradigm. This dimension is rooted in the idea of secularization proposed by Max Weber (1922), who described it as the consequence of the differentiation of a society into different systems, i.e., science, art, and ethics which independently follow paths of rationalization. This process leads to the collapse of transcendent belief systems, e.g., *Entzauberung*. Evidence of this dimension of secularization is provided by surveys that demonstrate a continuing erosion in the belief in God or in a shared destiny (Inglehart, 2021a, 2021b; Pollack, 2008). The second dimension of secularization pertains to the declining influence of religious institutions (*Église*), an idea that was originally introduced by Durkheim (1912). Following this line of thought, membership in religious institutions within countries is expected to decline gradually over time. This prediction is reflected in the declining numbers of religiously affiliated individuals in Western countries (Pew Reserach Center, 2017; Hackett et al., 2015; Skirbekk et al., 2010; Stonawski et al., 2015). Therefore, a central proposition of the secularization hypothesis is that alternative forms of beliefs and faith practices tend to emerge, as well as the decline in church membership (see for a review, Bruce (2002), Myers (1996), O'Brien and Noy (2015), and Wilson (2013)).

The country I focus on in this study - Finland - is widely regarded as highly secularized. For instance, according to 2011 survey results, monthly church attendance in Finland fluctuates between 4% and 14%, and only 27% of the population believes in a Christian god (Taira, 2017). However, a substantially larger

proportion of Finns belong to the Evangelical Lutheran state church. Official statistics indicate that 65% of the population was affiliated with a Christian denomination or the state church of Finland in 2022 (see Figure B.2 in the appendix). A similar cultural model has also been observed in other Nordic countries, which has even been described by the attitude of "believing in belonging" (Niemelä, 2015). At the same time, church membership is rare among those who identify themselves as non-religious. For instance, according to a survey conducted in 2015, 12% of these individuals reported belonging to the Evangelical Lutheran church and 2% reported belonging to another religious community (Taira et al., 2023). Given the relatively loose connection between church membership and religiousness *per se* in contemporary Finland, leaving the church may reflect, in addition to religious beliefs, a tendency to have less traditional and more individualistic values overall (ibid.). In addition, the apparent contradiction of low religiousness alongside robust church membership can be understood by taking into account the strong civic role and the positive perception of the state church. The church is generally regarded as an institution that actively contributes to the public good. Moreover, church membership comes with some individual advantages. For instance, for a couple to be permitted having a church wedding or to baptize a child, at least one of the partners may have to belong to the church. Finally, church membership could even be considered part of the Finnish identity (Taira et al., 2023). These factors may have contributed to the state church's retention of a substantial membership base, despite the imposition of state church taxes, the church's polarizing conservative position regarding same-sex marriage, and the overall low level of religious practice in the country.

3.1.1 Religion and fertility

Religiosity and membership in a religious institution can be related to fertility through several pathways (McQuillan, 2004; Skirbekk, 2022; Zhang, 2008). It

should be noted that the different mechanisms are not mutually exclusive, and may also interact with each other in their impact on fertility. Furthermore, I am not describing the minority or the characteristics hypothesis as they do not apply to the present study (for a review of the other mechanisms, see Zhang, 2008).

First, the *particularized theology hypothesis* states that religions influence childbearing through the propagation and teaching of religious doctrines or customs regarding childbearing (Goldschneider, 1971). For example, some religions have developed moral codes or norms regarding reproductive behavior related to the use of contraception, extramarital sexual intercourse, and abortion (Agadjanian et al., 2009; Jerman et al., 2016). These rules affect the formation of couples and their sexual behavior, which may lead to fertility differences between religious groups. Moreover, Zhang (2008) showed that after controlling for denomination, religiosity, measured as the strength of religious beliefs, significantly affects childbearing. The author concluded that religion may guide general behaviors regarding partnership, sexuality, and life goals.

Second, while the particularized theology hypothesis emphasizes the significance of the propagated religious content, the *interactive hypothesis* highlights the importance of social interactions within communities that are distinguished by their religious beliefs. According to Bongaarts and Watkins (1996), social interaction relates to fertility via three distinct pathways: "the exchange of information and ideas, the joint evaluation of their meaning in a particular context, and social influence that constrains or encourages action" (p. 657, Bongaarts & Watkins, 1996). Religious communities form social networks that affect the dissemination of ideas, assess their significance, and influence action through the imposition of constraints or the encouragement of action (Bongaarts & Watkins, 1996). Consequently, religious groups exert a profound influence on reproductive behavior. For instance, Goldstein and Cassidy (2014) demonstrated the role of the regional share of Catholics in the spatial spread of the fertility decline in Prussia.

In line with these expectations, existing studies point to a robust relationship between religious denomination and fertility in Finland (Kolk & Saarela, 2023). Using administrative register data, Kolk and Saarela (Kolk & Saarela, 2023) documented substantial fertility differences across religious denominations, which are more pronounced for women than for men. Across all groups, the unaffiliated have the lowest fertility, with an average of 1.63 children. Among women, Muslims have the highest fertility (2.7 children), followed by other Protestants (2.1 children) and state-church members (two children). Therefore, the TFR gap between the unaffiliated and the state church members is approximately 0.37. Among men, the same groups as those for women have particularly high fertility, but other Protestants have the highest number of children, at about two children on average. It is noteworthy that the disparities in childlessness across religious denominations are more pronounced than the differences in overall fertility rates. Additionally, research has demonstrated that religious beliefs are associated with higher fertility intentions in Finland (Finnas, 1991; Miettinen & Paajanen, 2003) .

Hypothesis 1 (H1) *In a modern secularized society such as Finland, fertility remains higher among the religiously affiliated population than among the religiously unaffiliated population.*

3.1.2 Religion, partnering, and couples' childbearing

In his seminal work, Peter M. Blau 1994, 1982, 1984 developed a theory of social structure that elucidates the genesis of relationships founded upon relative proportions within a population. He proposed that "structural constraints of size distributions affect marriage notwithstanding cultural values promoting ingroup marriages" (p. 45, Blau et al., 1982). The theory posits that minorities form a greater number of external ties than majorities due to their relatively smaller group size. As minority groups become smaller, the probability of interrelationships forming increases. Given that the proportion of the population that is religious

declines as a result of secularization, this theory is pertinent to our investigation. Accordingly, the decline in the relative size of this population implies an increase in the share of couples in which one partner is secular and the other is religious and a decline in the share of couples in which both partners religious. Therefore, secularization should have implications for the composition of couples within the population.

Hypothesis 2 (H2) *The diminishing share of religious individuals in the society increases the probability of a religious individual having a non-religious partner.*

I have outlined the mechanisms linking religion and childbearing from an individual perspective, although it should be taken into account that most childbearing decisions are made at the couple level (Hudde & Engelhardt, 2021; Rijken & Liefbroer, 2009; Vignoli et al., 2012). Given the persistence of gendered roles within households, which is often referred to as the stalled gender revolution, women still tend to do the major share of household chores and childcare (Cotter et al., 2011; England, 2010; Esping-Andersen, 2009; Goldscheider et al., 2015; Mattingly & Sayer, 2006). As women's lives are more directly affected by childbearing than those of men, women may have a greater say in childbearing within couples. Moreover, previous research indicates that the economic provision of the family is still more strongly associated with the domain of the male partner, whereas other categories may be more closely linked to the domain of the female partner (Stein et al., 2014). For instance, Vignoli et al. (2012) found that in Italy, the employment of the male partner is more important for fertility than the employment of the female partner. However, in the Nordic countries, the impact of economic characteristics is relatively similar across genders, which is likely attributable to the family-policies and cultures in these countries supporting a dual-earner model (Andersson & Scott, 2007; Jalovaara, 2013). The gender roles of partners in a Nordic country such as Finland tend to be more similar than those in most other countries, yet they

remain differentiated to some extent, especially around the entry into parenthood (Grönlund et al., 2017; Kleven et al., 2019). Therefore, even in Finland, the religiosity of the female partner may have a more pronounced influence on the probability of having children than the religiosity of the male partner.

Hypothesis 3 *The religious composition of a couple affects their probability of transitioning to a first birth.*

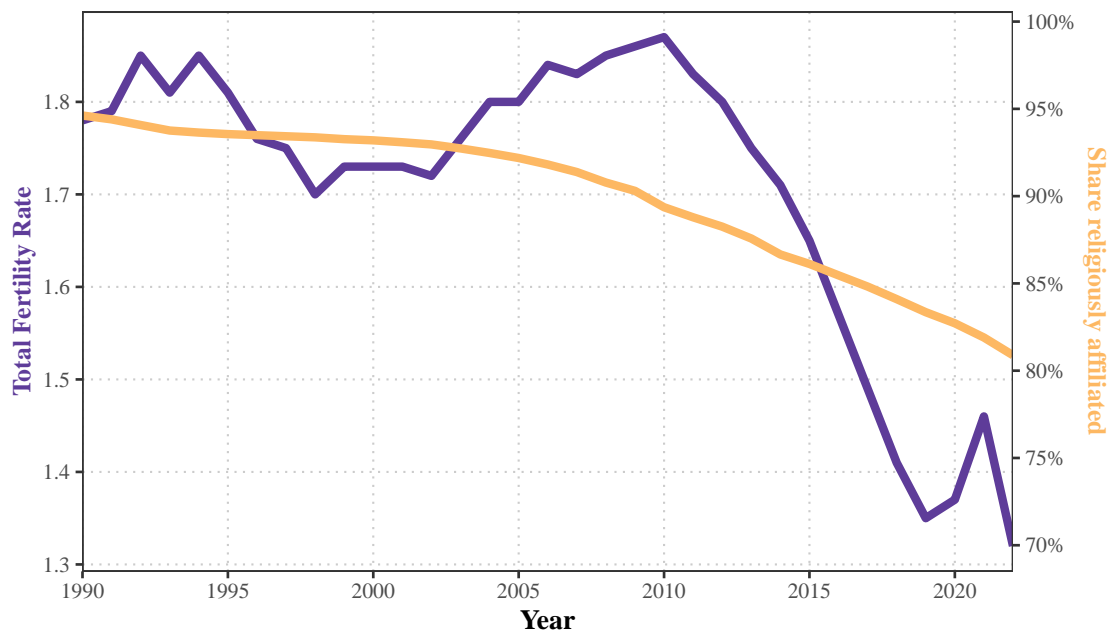
Hypothesis 3.a (H3.a) *In a largely gender-equal society such as Finland, the religious orientation of both partners is equally important.*

Hypothesis 3.b (H3.b) *The religious orientation of the female partner has a stronger positive association with the couple's probability of having a child than that of the male partner.*

The religious affiliation of the male and the female partner may interact in their effects on childbearing, in addition to having independent effects. Because they share a significant aspect of life and beliefs, homogeneous couples may be more inclined to make long-term commitments, such as having a child. Holding similar beliefs may reduce the propensity of a couple to engage in conflict about significant matters, thereby increasing the quality and the stability of their relationship (Hudde & Engelhardt, 2021). Moreover, having a shared religious orientation might also influence a couple's religious observance. Holding similar beliefs may facilitate a couple's attendance at religious services, which could, in turn, intensify their commitment and increase their fertility. Furthermore, all of the mechanisms linking religion and fertility that operate at the individual level (see Section 3.1.1) may be mutually reinforcing in a homogeneous couple. This is because the partners' beliefs and practices are less likely to be a source of conflict, and are thus able to exert their full influence. Finally, when both partners are church members in a secularized context such as Finland, they are likely to have similar life values

and orientations in a broader sense, which may facilitate their willingness to make long-term commitments.

Hypothesis 4 (H4) *In modern secularized countries, religiously homogeneous couples are more likely to have a child than religiously mixed and non-religious couples.*



Source: Data from Statistics Finland (2024).

Figure 3.1: This figure displays the total fertility rate (TFR) and the share of the religiously affiliated population in Finland in the 1990-2022 period. The purple line displays the TFR, and the purple-line's values are on the left y-axis. The orange line represents the share of the population who are members of a religious denomination, and the orange line's values are on the right y-axis. The share with religious affiliation in the population at reproductive age (15–55) is displayed in Figure 3.2. The data were obtained from Statistics Finland.

3.2 The Finnish context

Figure 1 depicts the gradual decline in the proportion of the population who are religiously affiliated in Finland. Although the connection between church membership and religiousness is not particularly strong in this context, as was previously discussed, the reduction in church membership over time is clearly

reflected in self-reported religious identification. The proportion of Finns who report identifying as non-religious increased from 25% among cohorts born in the 1960s and 1970s to 34% among the Millennials, i.e., the cohorts born in the 1980s and 1990s who reached childbearing ages in the first two decades of the 2000s (Taira et al., 2023). This decline has been interpreted as reflecting, to some extent, a change in the cultural model prevalent in Nordic secularized countries, in which affiliation with the state church is important for reasons beyond purely religious motivations. The younger generations are more inclined to challenge the traditional model and are more likely to disaffiliate from the church if they do not adhere to a belief in God (Ibid.). Furthermore, non-religious individuals tend to embrace values that are less traditional and more individualized in general (Ketola & Salomäki, 2024; Taira et al., 2023). Such values may be characterized by a stronger inclination to seek fulfillment in life through avenues other than marriage and family formation.

In Finland, the number of church leavers has been exceptionally high since the beginning of the 2000s. This trend has been driven mainly by young adults born since the early 1980s (Niemelä, 2015). For instance, in 2011, 90% of 18-year-olds were church members, but 70% of women and 62% of men aged 27-30 were church members (ibid.). At age 25, roughly half of church members, but only 8% of church leavers, stated that they believe in God, which illustrates that the stayers are more religious than the leavers. In Finland, the non-state church members constitute a distinct group who hold strong secular beliefs (Saarela & Skirbekk, 2020). Among young adult Finns of today, the majority could be regarded as neither religious nor non-religious (Ketola & Salomäki, 2024). Rather their faiths tend to be “fuzzy” and religion is not important to them (see also Voas, 2008). The level of secularization has even progressed to the point that today’s young Finns generally expect their peers today to be non-religious, which might, in turn, further accelerate cultural change (Ketola & Salomäki, 2024).

In Finland, a church tax is levied on members of the Evangelical Lutheran church, the Orthodox church of Finland, and Finnish German church at rates based on taxable income subject to municipal taxation.¹ The tax rates vary between 1% and 2.1% across parishes. Members can formally leave the church by mail or via a personal consultation at an administrative council, becoming exempt from the church tax in the following year.² The existence and the popularity of websites that translate a simple questionnaire into a termination note demonstrate the low barriers to leaving the church, which may have also contributed to the accelerated decline in church membership.³ Nevertheless, studies have indicated that the primary motivations for individuals to leave the church in Finland are largely associated with the broader process of secularization within society, with the financial aspect representing a relatively minor factor (Lyytikäinen & Santavirta, 2013). Accordingly, Niemelä (2015) identified the most significant self-reported reasons for leaving the church among young adults in Finland as a lack of identification with the religious identity, a lack of belief in the teachings of the church, and a lack of personal meaning derived from the church as an institution.

Until recently, fertility in Finland was higher than that in many other European countries. In 2010, the TFR was 1.87 compared to 1.57 in the entire European Union. However, since 2010, the TFR has gradually fallen below 1.4, which is the record low for period fertility in Finland (see the purple line in Figure 3.1). The recent decline in fertility reflects further postponement of childbearing, but it may also result in forgone childbirths and a decline in the eventual numbers of children

¹Orthodox and Finnish German church members represent a small minority in the total groups of all church tax payers (< 1.5% in 2020). From here onward, I refer to these religious communities when using the term state church membership, if not stated otherwise.

²The legislation governing church membership was reformed in 2003 (revised law of freedom of conviction, 6.6.2003/453), enabling individuals to terminate their church membership with ease via mail. Prior to this point, the only avenue for leaving the church was through a personal consultation with the administrative council.

³See for example <https://eroakirkosta.fi/dynamic/index.php/>, *engl.* optoutfromchurch.fi

born to women and men in Finland – as well as in countries with comparable strong declines (Hellstrand et al., 2020). Importantly, it was found that reductions in first births accounted for the largest part of the decline in Finland and other Nordic countries (Hellstrand et al., 2021), which may lead to increases in eventual childlessness. Levels of childlessness are relatively high in Finland compared to those in other high-income countries (Jalovaara et al., 2019; Konietzka & Kreyenfeld, 2021). A fifth of women and more than a quarter of men born in the early 1970s in Finland have remained childless (Jalovaara et al., 2022).

While childbearing was strongly connected with marriage in the past, the connection is gradually weakening (Lesthaeghe, 2020; Lesthaeghe & Van de Kaa, 1986). In Finland, the share of all births that are out of wedlock increased from 33% in 1985 to 45% in 2019, and the shares are larger in the case of first births (Hellstrand et al., 2021). Today, approximately two-thirds of first births are born to women in their first coresidential union (regardless of whether they are or are not married at the time of the birth), and more than 95% of births are to parents in any form of coresidential union (Andersson, 2023). One explanation for the trend is the institutionalization of cohabitation, which has led to a partial replacement of marriage (Rotkirch & Miettinen, 2017). Nonetheless, married couples continue to hold higher fertility intentions and more family-oriented attitudes than cohabiting couples. Hellstrand et al. (2021) studied the contribution of couple formation and couple childbearing to the recent fertility decline in Finland. Reductions in first births among cohabiting and married couples accounted for the largest share of the fertility decline. However, increases in dissolutions of coresidential unions and, to a lesser extent, decreases in union formation also had some effect. Rahnu and Jalovaara (2023) showed that entry into parenthood has declined substantially among partnered women born from the 1970s onward, while the risk of experiencing union dissolution has increased concurrently.

3.3 Data and methods

The empirical analysis uses Finnish population and other registers for the period between 1995 and 2019. The data are a complete record of the registered population residing in Finland at the end of each year. The registered population overlaps strongly with the resident population, because being registered is legally required and essential for many daily purposes and processes. Therefore, the micro-level data can be aggregated to accurately estimate population level rates and shares. I restrict our sample to individuals living permanently in Finland who either were born in Finland or were born abroad with a Finnish background (95.83% of the total population). I do so, because our indicator for religious affiliation does not capture denominations beyond the state-church. Therefore, migrants, who are often members of other churches or religious denominations, would not be appropriately captured.

I infer religiosity from state church tax payments and municipality tax payments, which are included in the population income register, and indicate state church membership. People who do not belong to the state church are not obliged to pay the church tax. Therefore, people who did not pay any church tax, but who paid municipality income tax, are not members of the state church (p. 1184, Lyytikäinen & Santavirta, 2013). The amount of the church tax paid by church members varies across municipalities, but has an average rate of 2.5% of annual individual income, which is about 650€ (704.45 US-\$ using conversion rates from 09.07.2024). There are several reasons for why this variable is a good indicator for religious affiliation. First, the state church tax involves monetary costs, which makes it a more objective assessment of religious affiliation than survey statements (Brenner et al., 2023; Hout & Fischer, 2014; Lim et al., 2010). Second, the income registers draw on high-quality, objective, and reliable information, which minimizes measurement error.

An inherent limitation of our measurement approach of religious affiliation is the challenge posed by imperfect classification, particularly with regard to a group of

individuals who cannot be definitively categorized as either affiliated or unaffiliated. This ambiguity arises when individuals have made neither church tax payments nor municipality tax payments, rendering their religious affiliation indeterminate. Approximately 6% of our dataset falls into this category. Notably, this group has certain characteristics, including lower levels of education and income, and a higher incidence of single status compared to the overall population. To address missing values, I employed a step-wise procedure leveraging the available data. Initially, when an unidentified spell occurred for an individual with consistent information before and after that spell, I utilized the available information to impute their religious affiliation. This approach enabled us to impute more than 95% of the initially missing data points, with relatively weak assumptions. Subsequently, the remaining cases with missing information were excluded from the data set.

Fertility information was derived from the birth registers and the multigenerational registers containing the parent-child links for the entire population. I estimated the timing of births and number of births by linking the demographic information of the parent and the child to the multigenerational register. The difference between the birth year of the child and the birth year of the parent is used as the age at childbirth.

3.3.1 Demographic analysis

The study examines the relationship between secularization and fertility in Finland. First, I investigate the temporal dynamics of religiosity across the population. For the 1996-2019 period, I estimate the annual share of the state church members in Finland of reproductive age. Second, we estimate the TFR for the affiliated and unaffiliated population and compare their trends over time. The TFR is a period measure of the average number of children a person would have if the fertility regime remained unchanged and the person survived through their reproductive period (Preston et al., 2008). We estimate the TFR separately for the two groups

in Finland for the 1996-2019 period. As a means of ensuring the reliability of the results, we also estimate the male TFRs for both groups, given that the fertility indicators for men differ from those for women (Dudel, 2021; Schoumaker, 2019). Moreover, state-church membership might be selective with respect to sex (Xia et al., 2023). As illustrated in Figure B.3 in the appendix, the religious groups exhibit a female-skewed sex ratio that appears to be relatively stable.

Second, we employ counterfactual simulation as a further means of quantifying the impact of declining church membership on the fertility rate in Finland (for details, see B.1.1). In the field of demography, counterfactual simulation is a methodology used to assess the contribution of a specific component, which is set to a hypothetical, counterfactual value, while the remaining components are included as they were observed. Consequently, the discrepancy between the observed and the counterfactual outcome serves to quantify the impact of the component that is being evaluated. We estimate the counterfactual TFR for the scenario in which the composition of the population with respect to state church membership and age remained constant over the entire observation period. If the model is correctly specified, any discrepancies between the observed and the counterfactual TFR can be attributed to changes in the population composition, i.e. secularization.

3.3.2 Couple formation and composition

The second part of the analysis examines the impact of secularization on couples. While most research has used an individual perspective to study the effect of secularization on fertility, the effect may also operate at the couple level, as was argued in Section 3.1. Furthermore, Section 3.2 demonstrated that the primary factor contributing to the recent decline in childbearing is the reduction in first-time childbearing among couples. This underscores the significance of considering the couple perspective, as previously highlighted by (Hellstrand et al., 2021).

First, we examine the change in the composition of couples and seek to ascertain whether a shift has occurred with regard to the religious affiliation of these couples. In order to investigate the effect of secularization on partner markets and couple formation, we quantify the composition of the population of reproductive age with respect to singlehood, and couple and partner choice with respect to religion over time. A nonparametric approach is employed to estimate population shares with respect to the interaction of union status and religion. The advantage of a nonparametric approach is that it reduces the risk of bias and captures sudden changes; however, this is at the cost of increasing variation in the estimate. The data are stratified by sex (men and women) and state church membership (members and non-members of a religious church). Using detailed register data ⁴, we categorize every person in the target population as 1) single, 2) coresiding (i.e., married or cohabiting) with a religiously unaffiliated person, or 3) coresiding with a religiously affiliated person. Given that the results might be affected by changes in the population age structure, we employ age standardization as a means of ensuring the robustness of our findings (for details, see Appendix B.1.3).

Second, we examine whether the shrinkage of the religious opposite-sex partner pool contributes to changes in the composition of couples using iterative proportional fitting (IPF, for additional details on the algorithm, see B.1.4 or Breen & Salazar, 2010; Leesch & Skopek, 2023). We use IPF, which is an algorithm that scales a contingency table to a counterfactual contingency table that has a pre-defined marginal distribution. The algorithm is employed to estimate a counterfactual couple composition with respect to religious affiliation. This entails maintaining the distribution of the contingency table observed in the original year of 1995, while

⁴The register data set contains information about opposite-sex couples living together at the turn of the year. The coresiding couples are identified based on information from various register sources. For instance, to qualify as a cohabiting couple, the opposite-sex persons need to have lived together for at least 90 days.

scaling the absolute numbers in accordance with evolving marginal distributions, such as the changing population distribution of religious affiliation among men and women. The method, however, assumes that partnering preferences with respect to religion remained constant (Breen & Salazar, 2010). The method is relevant for our example because it neutralizes the impact of changing preferences by holding them constant, and it quantifies the impact of the changing population distribution with respect to religious affiliation on couple composition, under the assumption that preferences remain unchanged. As a means of ensuring the robustness of the results, we conducted a simulation of random couple distributions, which yielded comparable outcomes while assuming no preferences, as opposed to constant preferences (for details on the matching algorithm, see Appendix B.1.5).

3.3.3 Regression approach

Beyond describing the association between the declining share of the religiously affiliated population and the change in the couple composition, we also study the impact of couple composition on childbearing. We create a set of annual panel data on childless couples for the 1996-2019 period from the cohabitation, tax, population, and birth registers. The data processing is displayed in Figure B.4. Based on these data, we estimate the impact of couple composition with respect to religious affiliation on the transition to first childbirth in a discrete-time survival model using generalized additive models with a binomial outcome distribution (“Chapter 7: Model Assessment and Selection”, 2009; Wooldridge, 2010). This model harnesses the ordering of events to identify the causal effect. The process-time is union duration in years, which is modelled with a smoothing spline that interacts with a smoothing spline for age at union formation to allow full flexibility in the hazard distribution (Ellison et al., 2022). The risk set contains all childless spells of coresidential unions (married or cohabiting) in the years between 1995 and 2019 for women aged 18 or older. Thus, some individuals may enter the risk set with

different unions, and they might enter some time after the start of the union if it was formed before 1995. The outcome variable is the transition to the first birth. Reasons for right-censoring are union dissolution, death or out-migration of one of the partners, or the couple being childless at the end of the observation period, i.e., the year 2019. We include the religious affiliation of the woman, the religious affiliation of the man, and an interactive term to evaluate the impact on childbearing of all variations of couple composition.

$$\log \left[\frac{P(Y_{i,t}=1)}{1-P(Y_{i,t}=1)} \right] = \beta_1 + \beta_2 \text{religious}_i^f + \beta_3 \text{religious}_{i,t-1}^m + \beta_4 \text{religious}_{i,t-1}^{\text{both}} + \beta_5 \mathbf{X}_{i,t-1} \quad (3.1)$$

where Y is the indicator for the occurrence of childbirth to couple i in year t , religious_i^f is a dummy variable for the woman being a state church member, religious_i^m is a dummy indicator for whether the man is a state church member, and $\text{religious}_{i,t-1}^{\text{both}}$ is the interaction of both partners being state church members. \mathbf{X} is a matrix of control variables, including the income of the woman (quantile), the income of the man (quantile), education of the female and the male partner, the activity status of both partners, and whether the couple lives in an urban, semi-urban, or rural area. The data are summarized in Table B.4. We include the income of both partners as both are associated with childbearing, given the positive gradient for both men and women in recent cohorts (Jalovaara & Miettinen, 2013; Vignoli et al., 2012). Education is found to be a key determinant of first childbirth in Finland as well, with positive gradients for both genders (Fasang & Raab, 2014; Jalovaara et al., 2019). Activity status is included to account for the negative impacts on childbearing of periods of unemployment and enrollment in education (Blossfeld, 2009; Miettinen & Jalovaara, 2020). Finally, we re-estimate the models controlling for the regional church tax rate to account for any bias arising from financial incentives to join or leave the church.

The data for the discrete-time hazard model have a couple-year structure, in which every spell refers to a year nested within a couple. All variables are time-varying and are measured at the end of the year. They are all lagged by one year to reduce any problems arising from reversed causality (Hoem & Kreyenfeld, 2006). Every couple observation consists of a variable that indicates the religious affiliation of the woman and the man. In about 73% of the couples, the religious composition is constant from the beginning of the coresidential union until the last observed spell. However, changes are rare when regarded as year-to-year transitions, with changes occurring in only 0.5% of the spells. The most frequent transition is when only the male is religiously affiliated initially, and the female later becomes religiously affiliated as well. This occurs in 7.4% of the transitions of couples in which the male is religious.

3.3.4 Robustness checks

We performed several robustness checks to ensure the stability of the results and to better understand the underlying process. First, in our robustness checks, to reduce endogeneity of religious affiliation, we hold the couple composition constant from the first observation of the couple. The reasoning behind this choice is that some couples may join the church in anticipation of childbirth or marriage in order to be able to baptize a child or to have a church wedding. The results are presented in Table B.8.

Second, we account for selection into state church membership and inheritance through parents by estimating a same-sex twin fixed effects model on whether the couple has a child within the first five years of the union (for details on the model and the data processing, see Section B.1.7). Exploiting discordant twins with respect to religiosity allows us to better identify the causal effect of religiosity while controlling for family background and inheritance of state church membership. The latter is particularly relevant because state church membership is inherited in most cases, which means that group comparisons may be subject to selection bias. Given that

twins are born to the same parents at the same time, they inherit the same religious affiliation from birth. Thus, the comparison exploits only twin constellations who experienced active change, which in this case is that either of the twins joined or left the state church. The results are presented in Tables B.12 and B.13.

Moreover, we ensure the robustness of our main findings by exploiting the regional variation in the progress and the speed of secularization in Finland. We create a region-year panel data set that consists of 69 regions (*finnish* Seutukunta) observed over the 1995-2020 period, including information on the regional TFR, the TFR of the religiously affiliated population, and the TFR of the unaffiliated population. Progress in secularization is measured by the lagged population share of the religiously affiliated in the region. We estimate several panel regression models (including first-difference and two-way fixed effects models) to account for endogeneity, time-series auto-correlation, and period effects. We test in Hypothesis 1 by measuring the effect on the TFR of the change in the population share of religiously affiliated. Moreover, we test the nonlinear effect by estimating the effect of secularization on the fertility rate of the religiously affiliated population (the combination of Hypotheses 2, 3.b, and 4).

3.4 Results

3.4.1 Demographic analysis

State church membership in the Finnish population of reproductive age gradually declined from 1995 to 2019. Figure 3.2 depicts the trend in the share of religiously affiliated people in the population of reproductive age. Whereas the share of affiliated individuals was 91% in 1996, it had decreased 15 percentage points by 2019, to 76%. We see a gradual decline of church membership in the 1990s, but the decline accelerated in the post-2010 period.

The TFR for the state church population and the TFR for non-state church population in Finland is displayed in Figure 3.3. This measure indicates the fertility

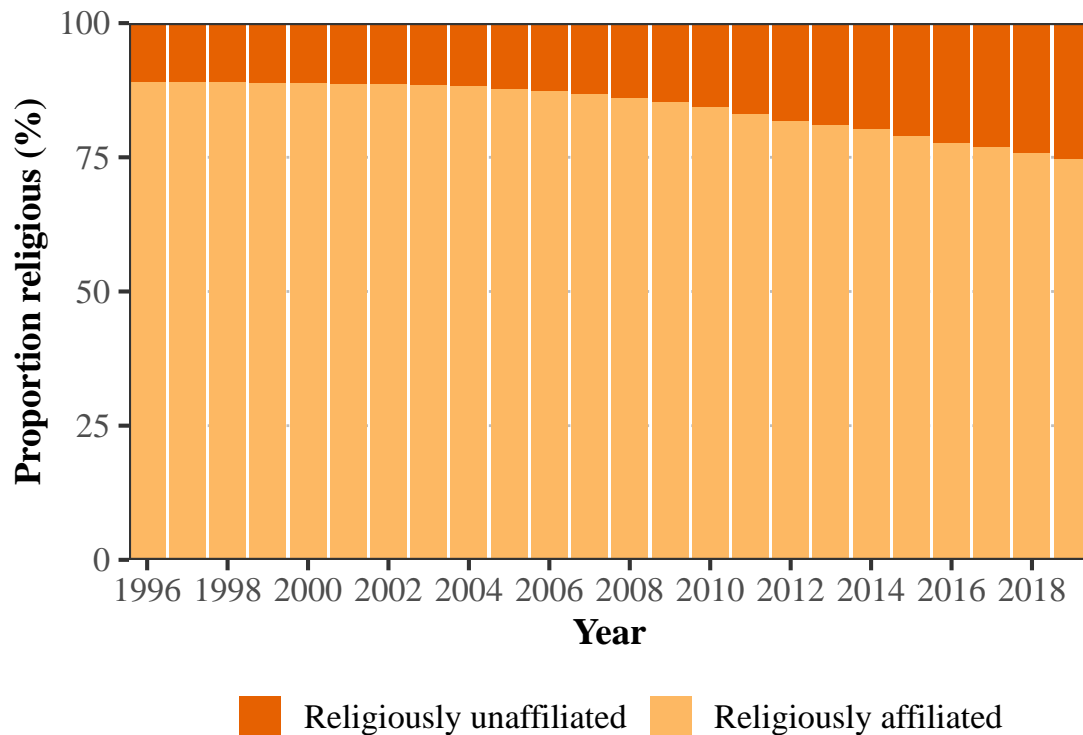


Figure 3.2: Time trend of the proportion of religious and non-religious individuals in the Finnish population at reproductive age (15–55) in Finland, 1990–2020. *Source:* own calculations based on Finnish population register data.

behavior in both groups, while ignoring the population composition with respect to state church membership. Throughout the entire period, the TFR of the religiously affiliated population was substantially higher than the TFR of the unaffiliated population. The gap between the two groups also widened over time, particularly in the first decade of the century, when TFR of the affiliated group increased modestly in line with the overall country trend. A key explanation for the widened of the gap is that the TFR of the religiously unaffiliated population had already been gradually declining since the early 2000s, and even dropped below an average of 1.1 in the year 2019. In contrast, the TFR of the religiously affiliated population remained fairly high, despite a pronounced decline in the most recent period. The decline in the 2010s was fairly similar in the two groups, indicating that other factors also contributed to the recent fertility decline or nonlinearity.

The results from the counterfactual simulation (dotted purple line in Figure 3.3) indicate that the TFR in Finland would be almost 0.1 points higher in 2019, if

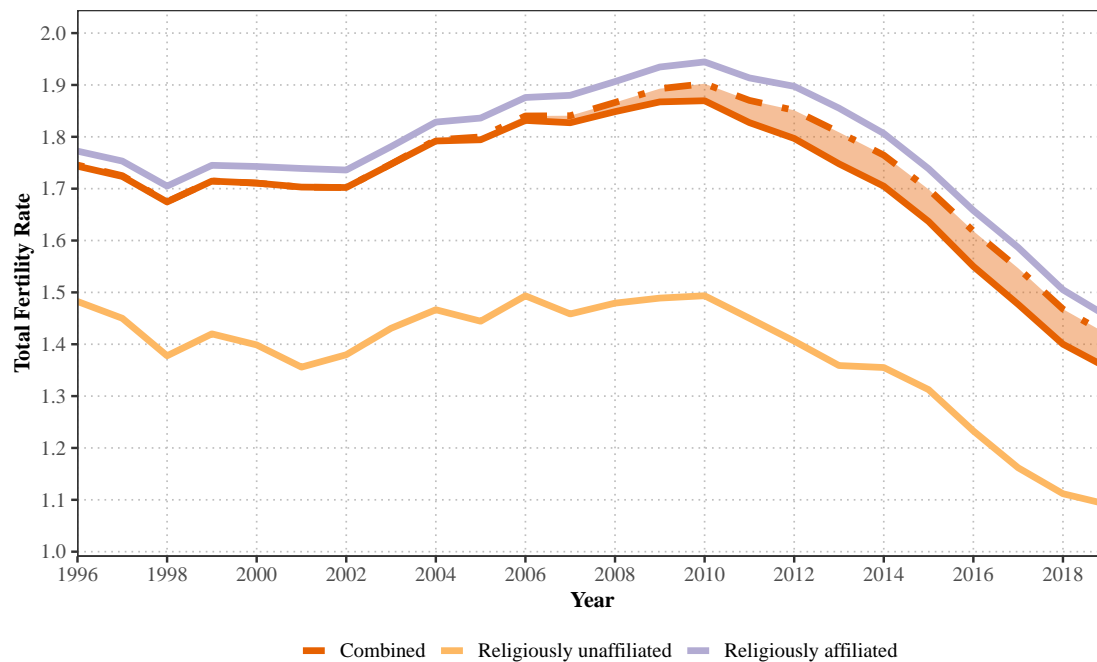


Figure 3.3: Time-trend of the TFR of the religious, the non-religious and the entire Finnish population between 1990 and 2019. The dotted line represents the counterfactual trend of the population TFR if the population remained constant with respect to the religiously affiliated share.

the population composition with respect to religion had stayed constant from 2000 onward. As depicted in Figure 3.3, the trends of the observed and the counterfactual TFR started to diverge in the late 2000s. Therefore, we can conclude that the fertility decline was partially the result of declining state church membership. The approach shows that the decline in state church membership is a key component of the fertility decline between 1995 and 2019, *ceteris paribus*. However, the fertility decline was not only the consequence of compositional change, as it remained even after holding the population composition constant. Hence, factors other than compositional change played a role as well.

3.4.2 Couple formation and composition

Figure 3.4 shows the changing couple composition in the population of reproductive age stratified by sex and religious affiliation, i.e., state church membership. Across all strata, the share of individuals with an affiliated partners declined over time,

even among people who were affiliated themselves. This pattern mirrors the overall decline of state church membership, which is also apparent in Figure 3.2. This conclusion is additionally supported by the parallel increase in the share of homogeneous unaffiliated couples. Thus, the religiously affiliated partners have been substituted to some extent by unaffiliated partners. In the contemporary period, the likelihood that both partners are not members of the state church is higher than at any point in the past. However, the substitution accounts only partially for the decline in religiously affiliated partners. The parallel increase in singlehood indicates that the substitution is incomplete. Hence, couples have not just been secularized, but singlehood has also become more common. In short, a growing share of the population at reproductive age are either in a couple with an unaffiliated partner or are single. These trends hold even after accounting for changes in the age structure through standardization (see Figure B.13) or when looking at the absolute numbers (see Figure B.14).

Given that the share of state church members is declining, the increase in couples with mixed religious and couples with no religious affiliation may result from the shrinking pool of potential partners who belong to the state church (Hypothesis 2). To evaluate this hypothesis, we use iterative proportional fitting, which assumes constant partner preferences to disentangle the impact of the changing population composition. The results depicted in Figure 3.5 illustrate the observed couple composition (solid red line) and the simulated couple composition (dashed blue line). Overall, the simulation results deviate only slightly from the observed trend, which points to the relevance of declining state church membership for the couple composition. For instance, the share of homogeneous couples increases gradually in the observed and in the simulated data. The same pattern applies to the share of mixed couples. Even the decline in homogeneously affiliated couples is captured by the simulation. Therefore, the trends in couple composition may be explained by the overall secularization of the population. However, the simulated and the

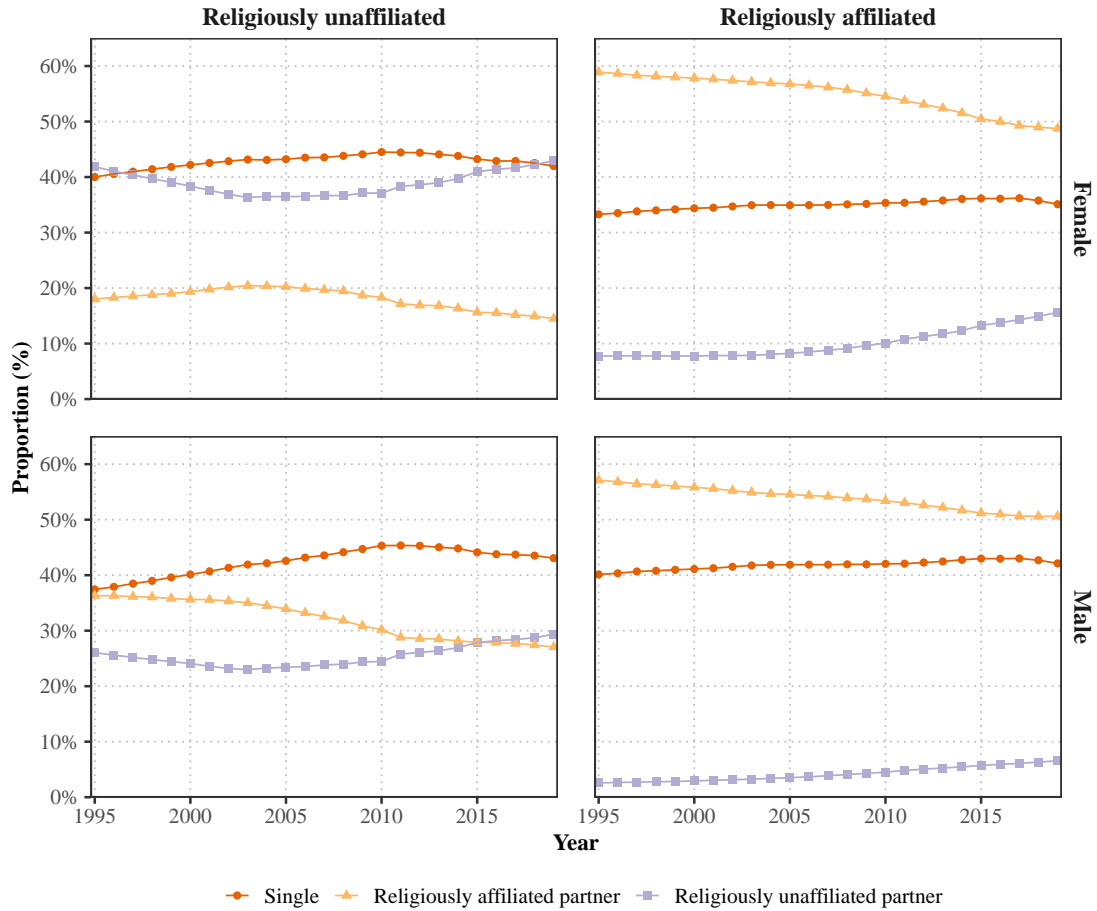


Figure 3.4: This figure shows the couple composition by sex and religiosity in the Finnish population of reproductive age over time.

observed distribution differ slightly, as the trend toward more mixed-couples is even more pronounced in the simulated data. This suggests that changing partner preferences and clustering in social groups or geographic regions has some impact. For instance, the declining salience of religion for mating observed in the United States could help to explain these trends (Kalmijn, 1991). The finding is confirmed by the random matching algorithm (see Figure B.7 in the appendix).

3.4.3 Regression approach

The results from the couple discrete-time survival model are displayed in Table 3.1. The results are presented as odds ratios, so that a value higher than one can be interpreted as a positive association with the transition to first-birth, and a value

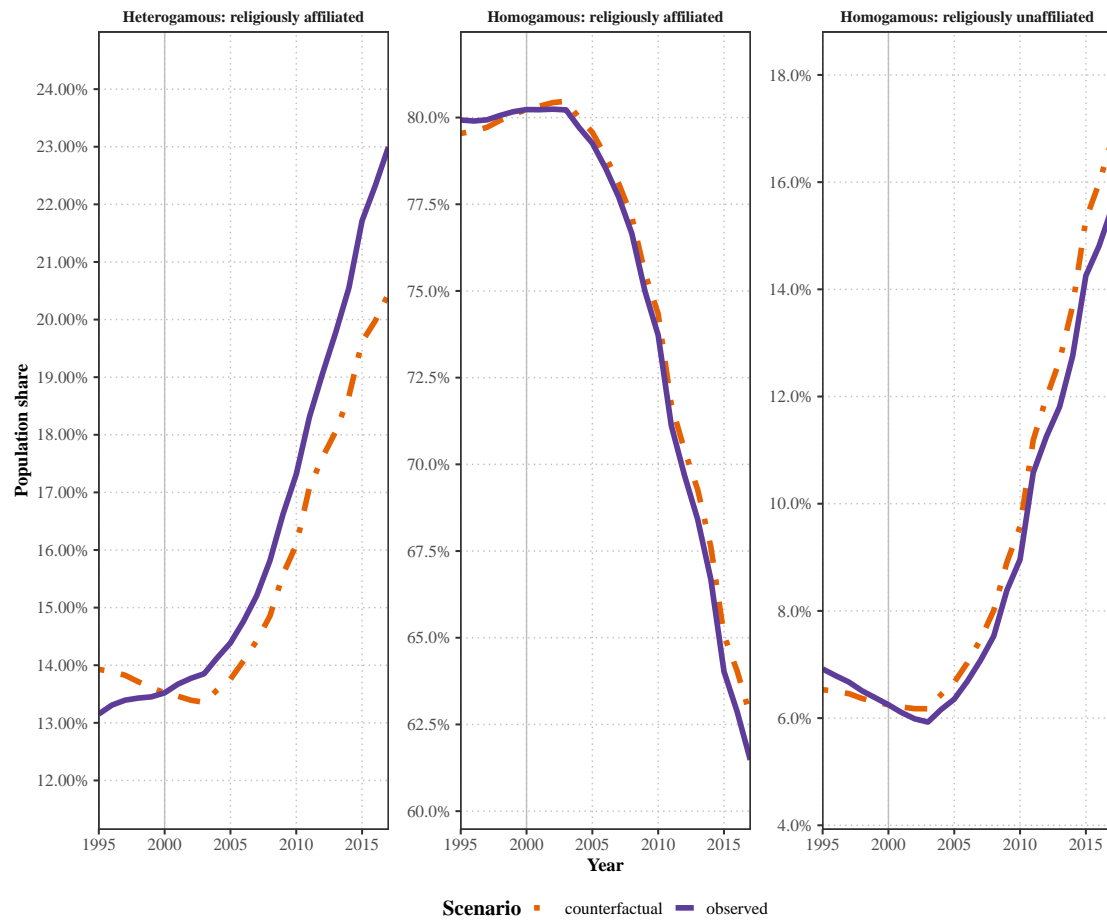


Figure 3.5: This figure shows the observed couple composition (blue line) and the counterfactual couple composition (red line) estimated by the iterative proportional fitting over time. The counterfactual figures follow the observed trend, which points to a strong impact of the changing population composition. Note that the values of the y-axis vary across panels.

below one can be interpreted as a negative association with childbirth. For average marginal effects, please see Table B.7 in the appendix. Model 1 includes only female religiosity, model 2 includes only male religiosity, model 3 includes the religious affiliation of both the woman and the man, and model 4 includes the full specification. We find that both the independent and the interactive terms of religiosity improve the model performance, as the coefficients are significant. We compared the model fit via the Akaike's Information Criterion. These results are presented in Table B.6 in the appendix B.3. We find that the model including all terms (male + female + interaction) maximizes the model fit. Therefore, both partners' religiosity and

their combined religiosity are associated with the couple's fertility.

Table 3.1: Results from discrete-time survival analysis using logit-binomial models on the probability of childbirth. Results are displayed in log-odds. The couples composition with respect to religiosity is time-varying.

	(1)	(2)	(3)	(4)
Woman religiously affiliated	1.409***		1.288***	1.167***
Man religiously affiliated		1.355***	1.272***	1.096***
Both religiously affiliated				1.210***
<i>Activity:</i> Unemployed	0.631***	0.618***	0.624***	0.625***
<i>Activity:</i> education	0.872***	0.872***	0.874***	0.874***
<i>Activity:</i> other	2.377***	2.339***	2.371***	2.377***
<i>Activity partner:</i> unemployed	0.803***	0.794***	0.803***	0.805***
<i>Activity partner:</i> education	0.720***	0.718***	0.718***	0.719***
<i>Activity partner:</i> other	0.520**	0.525**	0.528**	0.531**
<i>Education:</i> medium	1.369***	1.379***	1.377***	1.375***
<i>Education:</i> Education: high	1.914***	1.988***	1.966***	1.961***
<i>Education partner:</i> medium	1.105***	1.088***	1.091***	1.090***
<i>Education partner:</i> high	1.626***	1.609***	1.611***	1.609***
<i>Income quantile:</i> 2	1.119***	1.108***	1.105***	1.106***
<i>Income quantile:</i> 3	0.823***	0.810***	0.807***	0.804***
<i>Income quantile:</i> 4	0.572***	0.557***	0.556***	0.550***
<i>Income quantile partner:</i> 2	1.656***	1.637***	1.642***	1.640***
<i>Income quantile partner:</i> 3	1.988***	1.990***	1.976***	1.972***
<i>Income quantile partner:</i> 4	1.783***	1.810***	1.787***	1.782***
<i>Settlement:</i> semi-urban	1.486***	1.505***	1.477***	1.477***
<i>Settlement:</i> rural	1.845***	1.871***	1.823***	1.815***
<i>Period:</i> 2000-2005	1.515***	1.509***	1.506***	1.501***
<i>Period:</i> 2005-2010	1.567***	1.555***	1.567***	1.568***
<i>Period:</i> 2010-2015	1.330***	1.344***	1.370***	1.373***
<i>Period:</i> 2015-2020	1.010***	0.997***	1.038***	1.033***
Constant	0.0001	0.0001	0.0001	0.000
<i>N</i>	51,797	51,797	51,797	51,797
Adjusted R ²	0.124	0.125	0.126	0.126
Log Likelihood	-9,007.502	-9,004.736	-8,998.386	-8,994.605
UBRE	-0.652	-0.652	-0.653	-0.653

*p < .05; **p < .01; ***p < .001

Across the four models in Table B.8, we find that the religious affiliation of the women is positively and more robustly associated with subsequent childbearing than the religious affiliation of the man, which is in line with Hypothesis 3.b. In all model specifications, female religiosity has the expected positive effect on

childbearing. For men, this is the case in all models except the Model 4, where the odds of having a child are slightly lower if the man is affiliated, unless the woman is also affiliated. Therefore, we conclude that the female partner has more say in the childbearing decisions. Hence, the woman's beliefs and values have a stronger impact than those of the male partner.

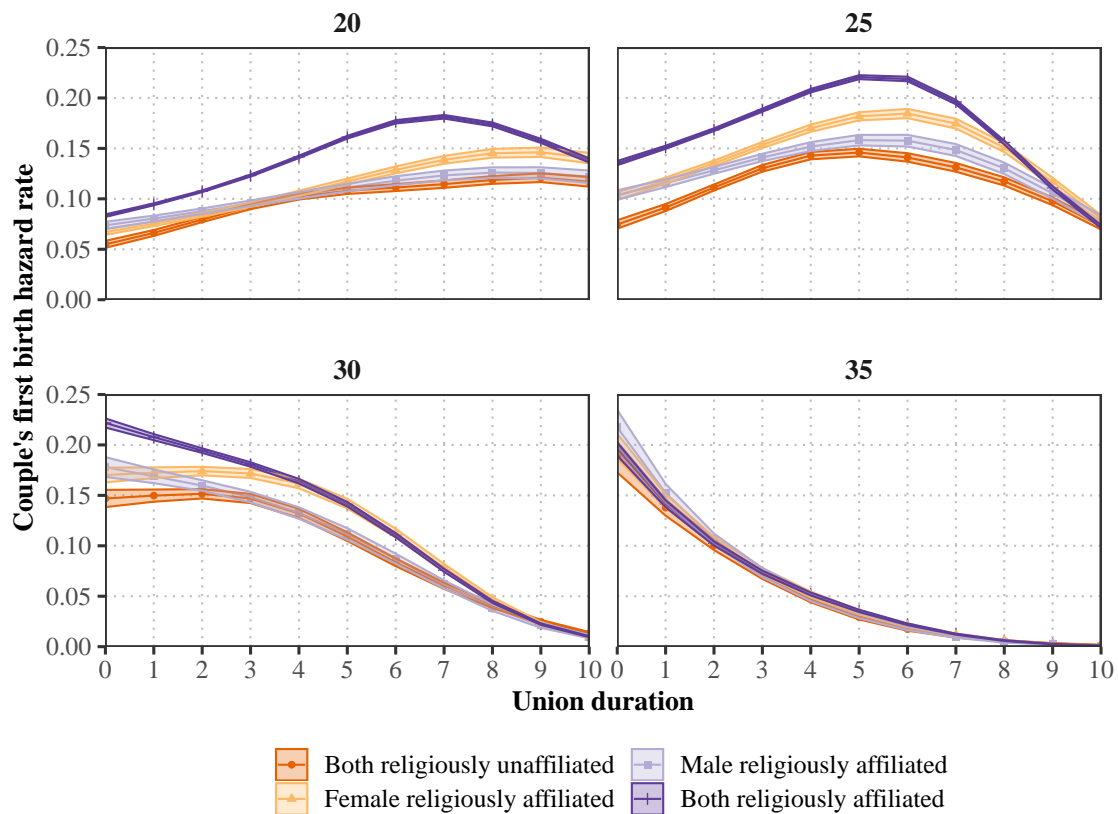


Figure 3.6: Predicted first birth rates for childless couples with different religious compositions using age-splines in a logistic-binomial regression. The different panels show the different starting ages of the union; the x-axis shows the union duration; the colors indicate the religious composition of the couple; and the y-axis shows the risk of having a first birth.

From the results in Table B.8 it becomes evident that the decision to have a child is made by the couple, which emphasizes the relevance of a couple approach. The odds of a first childbirth are 4.3% higher in couples in which both partners are religiously affiliated than in other types of couples. The interaction term is statistically highly significant, demonstrating that the combined effect is more than

the sum of the individual effects. Figure 3.6 further illustrates the high risk of having a first birth for couples in which both partners are religiously affiliated. This highlights the role of homogeneity within the couple in the probability of having a first birth.

In order to better evaluate the age-specific transition risk of the different couple compositions, we predicted the first-birth hazard rate across couple compositions in Figure 3.6. Similar to the results in Table B.8, the homogeneous religious couples have a considerably younger onset of fertility and higher fertility intensities. Moreover, we see that couples in which only the female is a church member have higher and earlier first birth rates than couples in which only the male is a church member. In terms of timing, the youngest mean age at first birth is observed in couples in which both partners are church members (29 years), followed by in couples in which neither partner is affiliated with the church (29.8 years), although their overall first birth rate is lower. The mean age at first birth is highest in couples in which only one partner is affiliated (female 30 years and male religiously affiliated 30.2 years). Thus, heterogeneity within couples seem to delay childbearing.

We further illustrate the implications of these results for the recent fertility trends in Figure 3.7. It shows the impact of the changing couple composition with respect to religiosity on the time-trend of the couple first birth rate (TFR1) using counterfactual simulation.⁵ The couple TFR1 would have declined less and remained higher after 2007 if the couple composition with respect to religious affiliation had not changed since 2000 (purple dashed line). If only the religious affiliation of the male partner had remained constant over the observation period, visualized

⁵The total couple first birth rate is estimated by summing the age-specific couple first birth rates for different couple compositions. These age-specific rates are calculated as the ratio of births to exposures, which are estimated separately by the female's age and the corresponding couple composition. In the counterfactual simulations, the age-specific rates are applied to a counterfactual distribution of couple compositions, e.g. holding the share of religiously homogamous couples constant from 2000 onward.

by the dashed orange line, the couple fertility would not deviate much from the observed pattern. This highlights the limited impact of the male religiosity on childbearing. However, the impact of female religiosity on couple childbearing is clearly evident in the dashed light purple line. Overall, the decline in the couple TFR1 in the counterfactual scenario is only about 5% of the observed decline if the couple composition had not changed from accelerated secularization.

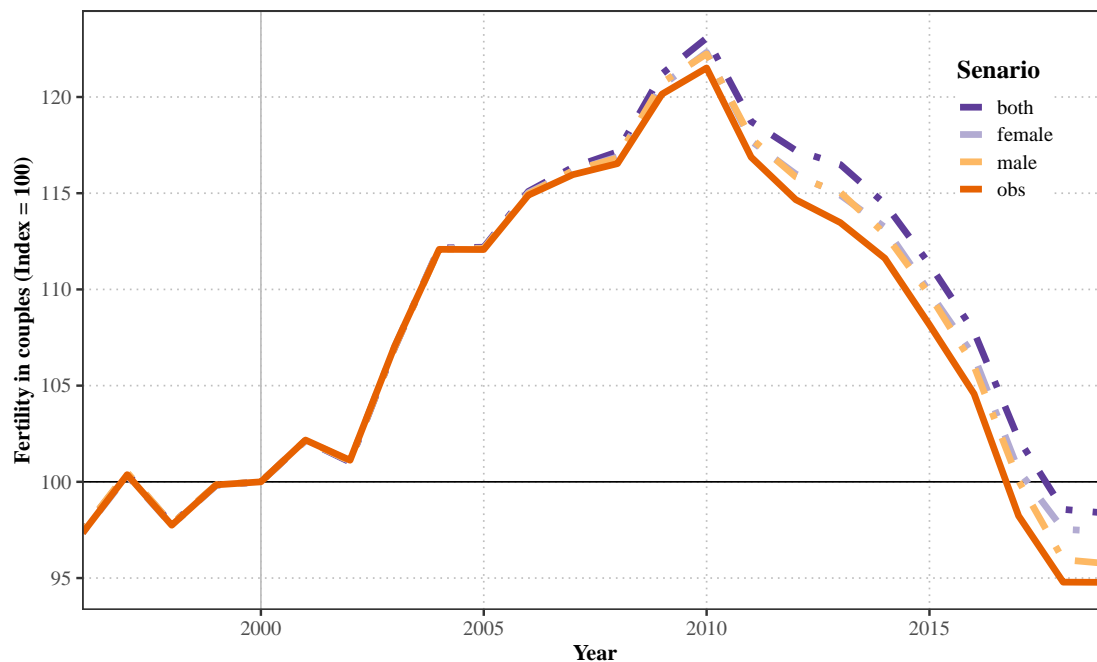


Figure 3.7: Observed and counterfactual development of couple TFR1 in 1995–2019, with the 2000 value scaled to 100. The counterfactual simulation draws on age-specific and religiously specific couple first birth rates and the counterfactual couple composition, which holds the female share, the male share, or the overall couple composition with respect to religious affiliation constant from 2000 onward. Couple first birth rates are estimated by aggregating the age-specific birth probabilities for different couple types and dividing them by the number of couple observations in the same age- and couple group.

3.4.4 Robustness checks

The findings of the discrete-time survival model persist across several robustness checks, except that measuring religious affiliation as a time-constant characteristic from the beginning of the union does not show a positive interactive effect of religious affiliation on the transition to childbirth (see below). We estimated the

main regression model with a control for the regional tax rate, which did not affect the results much (see Table B.9). The results remain largely unchanged, which indicates that monetary incentives do not bias our result. Therefore, we have confidence in the robustness of our results.

A contrasting finding is observed for the discrete-time model, in which the couple composition with respect to religious affiliation is held constant from the beginning of the union. In this model specification, the interactive term changes to being just below one (see Table B.8 in the appendix), as opposed to a positive effect observed in the main results measuring religious affiliation as a time-varying characteristic. The discrepancy in the interactive term between the time-constant and the time-varying models highlights the significance of the dynamic of the couple composition. It is plausible that some couples in which one partner is religious and the other is not may seek to harmonize their affiliation before childbearing for the purposes of getting married in a church.

Using only twin-pairs in the data from the discrete-time survival model allows us to perform a twin comparison that holds the family background and the inheritance of the state church membership constant. Results displayed in Table B.12 and B.13 support the main finding, namely that both partners in a couple being religiously affiliated has a positive effect on the transition to first birth within unions. The effect of religious affiliation for the male and the female partner ranges from a 1% to a 5% increase in the probability of having a child after five years in a union.

Moreover, we ensured the robustness of our main findings by exploiting the regional variation in the progress and the speed of secularization in Finland. We did so by creating a region-year panel data set covering 69 provinces (*Finnish Seutukunta*) observed over the 1995-2020 period that contains information on the regional TFR, the TFR of the religiously affiliated population and the unaffiliated population, and the share of religiously affiliated individuals in the regional population. We estimated several panel regression models (including region fixed effects

and two-way fixed effects models) of the regional TFR on the change in the share of the religiously affiliated in the population in the year before. Across the models displayed in Table B.10, a reduction in the share of the religiously affiliated has an effect on the TFR in the year, after ruling-out time-constant regional confounding factors. According to results from the first-difference model (Model 2), a decline of 10 percentage points in the share of the religiously affiliated is associated with a decline in the TFR of 0.28 children per women (CI: 0.15 and 0.42). In order to support our claim about the nonlinear effect, we estimated another model, changing the outcome to the TFR of the religiously affiliated population only. Thus, if there remains an effect, the reduction in the TFR is not solely related to the changing population composition, but also to changes in the fertility behavior of the religiously affiliated population, which aligns with the self-reinforcing effect. The effect of the changing population share persists even when looking only at the religiously affiliated population (see Table B.11). According to results from the first-difference model (model 2), a decline of 10 percentage points in the share of the religiously affiliated is associated with a decline in the TFR by 0.21 (CI: 0.18 and 0.24). The two-way fixed effects models yield insignificant results.

3.5 Discussion

This study examined the role of secularization, as indicated by the decline in state church membership, in recent fertility trends in Finland. State church membership gradually declined between 1995 and 2019, with the decline accelerating after 2008, although it remained at high levels (76% in 2019). We have shown that the TFR of state church members was significantly higher than the fertility of non-members, and that the gap between these groups widened from 0.3 children (1995) to 0.5 children (2019). Counterfactual simulations of the TFR for the Finnish population showed that it would have remained 5% (0.08) higher in 2019 if the composition of the population with respect to religious affiliation had remained

stable since 2000. Thus, the decline in state church membership is a relevant factor in explaining the recent decline in Finnish fertility. We also found that secularization affected the composition of couples. The decline in church membership led to an increase in the share of mixed couples in which only one partner was religiously affiliated and of couples in which neither partner was religiously affiliated, while the share of couples in which both partners were religiously affiliated decline. Our hypothesis that the declining pool of church-member partners can explain the declining probability of forming a union with a state church member is supported by our results based on iterative proportional fitting and random matching. Finally, we showed that the couple composition with respect to religious affiliation was associated with the transition to first birth. This finding is of great significance, as the decline in first births within couples represents the primary driver of recent fertility declines, as evidenced by Hellstrand et al. (2020). The lower probability of having a first birth among couples with mixed religious affiliation than among couples with homogeneous religious affiliation suggests that the decline in fertility among religiously affiliated individuals may be related to the increased likelihood of having a non-religious partner. Collectively, these findings indicate that declines in state church membership and potentially related shifts in life values, such as reduced emphasis on traditional values and an increase in individualism, were significant contributors to the fertility decline in Finland during the 2010s.

Secularization has played a significant role in the fertility decline in Finland in the 2010s. The decline in the TFR from 1.87 in 2009 to 1.35 in 2019 was 0.51 points (27.48%), and 0.044 points (8.63% of the total decline) of the TFR decline were attributable to the changing population composition, e.g., the decline in church membership. The shrinkage of homogeneous religious partnerships has additionally contributed to the decline in first births, which accounts for the largest share of the overall fertility decline, according to Hellstrand et al. (2021). The total couple first birth rate declined from 3.2 (2010) to 2.8 (2018), of which 0.05 points (12.5%) are

attributable to the decline in religiously mixed couples. State church membership remains high in Finland, although it has declined since 1995, with an acceleration from 2005 onward. Inglehart (2021a) and Hout and Fischer (2014) observed similar accelerations trends in the United States based on survey results, although data quality may have impacted their findings (Brenner et al., 2023; Hout & Fischer, 2014; Lim et al., 2010). The maps in Figures B.9 and B.10 in the appendix show the geographic pattern of secularization in Finland. We validated our estimates of the religiously affiliated population share. The size of the share is similar to the reported in official statistics from Statistics Finland.

We found that fertility was higher in the state church population than among non-state church members, and that the gap widened over time. This finding lends support to Hypothesis 1. While state church members had a TFR of 1.9 in 1996, which was just 0.3 points higher than the TFR among non-state church members, their level of fertility declined by only 0.3 points to 1.6 in 2019, whereas the TFR among non-state church members dropped by 0.5 points to a level of 1.1 children per woman over the same period.

Furthermore, we found that the composition of couples had an impact on couple fertility that extended beyond the sum of the individual characteristics of the couple members, which is consistent with the relational approach and studies on couple childbearing behavior (Doepke & Kindermann, 2019; Hudde & Engelhardt, 2021; Rijken & Liefbroer, 2009; Vignoli et al., 2012). While previous studies have largely focused on the extent to which the influence of labor market attachment on childbearing is gendered, our study is novel in that it used a dyadic perspective to examine the influence of religion. Our findings highlight the significance of the religious orientation of the female partner in influencing the childbearing decisions of couples in the Nordic context (confirming Hypothesis 3.b). Additionally, we observed that religiously homogeneous couples had the highest probability of childbearing (confirming Hypothesis 4). Yet, some caution is needed in interpreting

this finding, as the interactive term declined in the model using the couple's religious composition as a time-constant measure.

These findings have a number of sociological implications. First, they underscore that the decision to have children is influenced by both partners' preferences and characteristics, and it is based on joint decision-making. Partners who have more similar life values and orientations may feel most ready to commit to having a child and to parenting the child together, thus supporting a broader relational perspective on decision-making (Emirbayer, 1997). Second, our findings suggest that there are distinct domains that may be more influenced by either the woman's or the man's characteristics. In our case, the religious orientation of the female partner emerged as a key factor, confirming Hypothesis 3.b. This implies that partners may draw on values, attitudes, or resources from specific domains associated with their gender to influence the decision-making process regarding childbearing. This prompts us to advocate for further research into other domains that may be dominated by a specific gender in order to shed light on additional factors that might shape couples' fertility decisions in contemporary societies.

This chapter argued for a novel self-reinforcing effect of secularization on fertility. Secularization changes the couple composition with respect to religion. The couple composition, in turn, affects the transition to first birth. Despite the separation of church and state in modern societies, our study revealed that religious affiliation continues to exert a significant influence on fertility levels and trends. Specifically, we found that the diminishing proportion of church members had both linear and nonlinear effects on the overall level of fertility. Given the interaction with partner market dynamics and the role of the religious composition of the couples, the decline in state-church membership may have had a self-reinforcing effect on declining fertility. Couples in which the partners had different religious orientations may have also differed with respect to their life values and preferences for having children, which may have led them to have. While existing research has predominantly focused

on the individual effects of church membership (Goldscheider & Uhlenberg, 1969; McQuillan, 2004; “Religion, Religiousness and Fertility in the U.S. and in Europe”, 2008; Skirbekk, 2022; Westoff & Frejka, 2007; Zhang, 2008), our unique dyadic perspective provides novel insights. This approach helps us to better understand the recent decline in fertility in Finland, and potentially sheds light on similar trends in the United States and other high-income countries.

The findings presented in this chapter seamlessly align with established research, particularly with the socio-structural theory posited by Blau (1994). According to this theory, there is a proportional relationship between the reduction in group size and an increased likelihood of inter-group relationships. This mathematical consequence, rooted in socio-structural dynamics, has been empirically demonstrated in studies investigating partner market imbalances and their repercussions for marriage patterns (Crowder & Tolnay, 2000; Lichter et al., 1995; Qian & Lichter, 2018). It is noteworthy, however, that the observed trend is not solely characterized by the replacement of religiously homogeneous religious couples with secular or religiously mixed couples; there is also a discernible decline in couple prevalence overall. This is evidenced by the increasing prevalence of singlehood, a phenomenon that has been previously documented in the context of Finland (Andersson, 2023; Hellstrand et al., 2021; Jalovaara & Andersson, 2023). Thus, our study extends beyond the realm of intergroup dynamics to shed light on how secularization drives broader trends in couple formation, childbearing, and singlehood.

While our findings highlight the significant impact of secularization on the declining fertility rates in Finland, it is crucial to acknowledge that other factors have likely contributed to this phenomenon as well. Beyond secularization, various alternative explanations for the recent fertility declines merit consideration, including the influences of economic uncertainty (Hellstrand et al., 2024; Vignoli et al., 2020) and broader global uncertainty (Comolli et al., 2021), weakened preferences for having children (Golovina et al., 2023), as well as changes in attitudes (Jalovaara

& Andersson, 2023; Kearney et al., 2022; Lesthaeghe, 2020; Rahnu & Jalovaara, 2023). Further research is needed to quantify the impact of these factors and to explore alternative explanations that may contribute to our understanding of the dynamics influencing fertility trends in Finland and beyond.

3.5.1 Strengths and limitations

We inferred religious affiliation from state church membership as measured by the payment of state-church taxes. This approach has both strengths and limitations. The financial component of state church taxes links the membership to costs, which incentivises individuals to leave the church when they have lost their faith. Compared to surveys on religiosity, our measure is less affected by social desirability, by misreporting (e.g., recall bias), or by non-response and attrition. Moreover, the data exist longitudinally, which allowed us to perform longitudinal compositional and survival analysis. A unique strength of the study is that it was able to identify and follow couples who were living together, and to measure both partners' religious affiliation.

However, the measure of religious affiliation may be subject to three limitations.

First, using state church tax payments may introduce some measurement error. Measurement error may result from the fact that individuals who made state church tax payments may not have done so based on their religious beliefs and values alone, but also for other reasons, such as their level of thriftiness, civil engagement, and even their family situation. For instance, state church membership may also indicate support for the church because it is an actor in civil society or because it fulfils humanitarian and civic roles. Similarly, Kolk and Saarela (2023) have argued that in Finland, those who do not pay state church tax constitute a distinct group who may hold particularly strong secular beliefs. An indication for such an error is the high proportion of church membership despite the overall high degree of secularization in the society.

Second, using state church tax payments as an indicator of religious affiliation somewhat restricts the generalizability of the results. Given that only members of the Lutheran, German, and orthodox Christian churches are eligible for paying state-church taxes, we had to restrict our sample to the population with a Finnish background. Therefore, migrants were excluded from the sample to minimize measurement error. However, migrants constituted only a small fraction of the full population of reproductive age (4.2%). Moreover, our results may not be directly generalizable to countries that do not have a system of state church taxes. Such a system is not typical for modern societies due to the widespread principle of separation of church and state. Nonetheless, state church taxes are also collected in Austria, Germany, Sweden, Denmark and Iceland.

Third, our indirect measure of religiosity is conceptually simplistic. State church tax payments indicate religious affiliation, which is likely to capture factors other than the strength of religious faith, such as whether a person has more conservative life values or supports the civic and humanitarian roles and positions of the church. Religiosity is a complex construct that encompasses various dimensions, of which religious affiliation represents only one. In addition to affiliation, strength of spiritual beliefs, religious practices, and membership in a like-minded community are important dimensions of religiosity. However, these dimensions are subjective, and are therefore not observable in the administrative register data utilized in this study.

In the course of evolution, nature has gone to endless trouble to see that every individual is unlike every other individual. We reproduce our kind by bringing the father's genes into contact with the mother's.

Aldous Huxley

4

Biological and social predictors of couple's fecundity

Contents

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The complex interplay between behavioral, biological, and chance factors

This chapter is co-authored with Mikko Myrskylä, Siri Edvic-Håberg, Cecilia Ramlau-Hansen and Yunsung Lee.

underlies human fertility (Bongaarts, 1993). Unravelling the relative contributions of these elements is crucial for enhancing our understanding of reproductive health. While theories regarding the social and cultural determinants of fertility behavior have been the subject of extensive exploration in the demographic literature (for an overview, see Chapter 1), the biological and chance components of fertility have received comparatively less attention. Recent research, however, suggests that biological factors, such as declining sperm and ovarian quality, may be playing an increasingly important role in shaping fertility outcomes around the world (Levine et al., 2017, 2023; Swan & Colino, 2021). This phenomenon carries profound implications for the field of demographic research, as it may be a contributing factor to shifts in fertility patterns. In light of these findings, this chapter aims to enhance our comprehension of the interplay among behavior, biology, and chance by predicting time-to-pregnancy (TTP) in couples. Time-to-pregnancy (TTP), which is the duration of regular unprotected sexual intercourse undertaken until successful conception, is an indicator of fecundity. This chapter contributes to the aforementioned objective in two distinct ways. First, we utilize a rich data source and advanced machine-learning techniques to maximize predictive performance. This process sheds light on the extent to which fecundity can be predicted by structural, biological, health, and social variables. It also distinguishes this from the error, the unpredictable component, which may be related to chance or unmeasured factors. Secondly, another objective is to identify the most significant predictors of fecundity, thereby providing novel insights into the factors that influence fertility outcomes.

A large array of studies has attempted predicting time-to-pregnancy (TTP) in couples (Lam et al., 2020; Liu et al., 2019; Nakamura et al., 2018; Potter & Parker, 1964; Sozou & Hartshorne, 2012; Van Der Steeg et al., 2007; Yland et al., 2022; Zhan et al., 2022), which produced mixed predictive performances. Coppus et al. (2009) reviewed existing prediction models and concluded that the classification performances are weak. The authors argue that while classification models assume

two distinct subpopulations, e.g. fecund and subfecund, fecundity poses rather a “complex multifactorial phenomenon, corresponding to a gradual continuum of impaired reproductive capacity” (pp. 1775, Coppus et al., 2009). However, more recent prediction models reached better prediction performances despite these inherent problems (Yland et al., 2022; Zhan et al., 2022). For instance, Zhan et al. (2022) reached an area under the curve (AUC) of 0.955 using 37 lifestyle, biological, and clinical variables in a Lasso regression model with a binomial-link function. However, this study was limited due to the small selective Chinese sample, and may therefore not be able to elicit conclusions about the entire population.

This chapter examines fecundity by integrating two data sets, MoBa and Norwegian register data ($N = 66,435$ couples), using machine learning methodologies. The primary outcome is whether time-to-pregnancy (TTP) is shorter than 12 months (subfecundity = 0) or longer (subfecundity = 1). The target population consists of all couple pregnancies in Norway between 1998 and 2008, with TTP information obtained retrospectively in week 17 of pregnancy. This definition is used because TTP is strongly associated with completed family size; for instance, couples with shorter intervals between initiating and conceiving are more likely to achieve their desired family sizes (Joffe et al., 2009). Additionally, 12 months is the clinical cut-off for defining infertility (Patel et al., 2018). In this study, TTP is predicted using social, behavioral, biological, and genetic factors measured from both partners at the beginning of trying to conceive. We apply several classification models, including logistic regression, generalized additive models, elastic-net regression, lightGBM, and neural networks, with the main model selected based on out-of-sample prediction performance. The social predictors consist of education, employment, and residential biographies leading to conception, as well as socio-economic background. Biological information includes BMI and age, while health measures comprise hypertension and various reproductive diseases for both partners. Behavioral factors include coitus frequency, smoking, and alcohol consumption. For a subsample, genetic information

is available, including polygenic risk scores for endometriosis and subfecundity (Rahmioglu et al., 2023; Venkatesh et al., 2024).

This study seeks to address two significant questions concerning the fecundity of couples. First, whether subfecundity in couples can be predicted using a comprehensive data source and state-of-the-art machine learning methods? Our data is arguably the most extensive resource available for predicting subfecundity in couples, integrating Norwegian medical, residence, education, and income registers with survey questions and biomarkers from the MoBa data (see section 4.2). The machine learning models employed in this study, gradient boosted decision trees and neural networks (see section 4.2.4), represent a significant advancement over the current state of reproductive predictive modelling, which has yielded only limited predictive performance (Coppus et al., 2009). Second, which are the most significant predictors of TTP? Traditionally, research in this field has focused on biological factors such as sperm characteristics or diseases, overlooking the crucial role of the social dimension. Consequently, social factors represent a significant blind spot in the research. We address this by supplementing biological and health information with variables on education and residence.

4.1 Background

Fecundity is defined as the biological propensity to conceive a child, while infertility is operationalized by the World Health Organization as failure to conceive after 12 months of regular unprotected intercourse (Patel et al., 2018). However, existing studies refer to subfecundity if couples eventually conceive after a duration of 12 months (for an example, see Ramlau-Hansen et al., 2007). We follow Ramlau-Hansen et al. (2007) and use subfecundity in the remainder of this chapter, given that our sample selection consists of couples that eventually conceived.

4.1.1 Previous research

Subfecundity affects about 5-30% of couples that try to conceive dependent on the country and year (Gnoth, 2003; Gnoth et al., 2005; Keiding, 2002; Thoma et al., 2013). One explanation for such a large 25 percentage-point range could be compositional or contextual differences between populations. The former may be attributable to different education, economic systems, whereas the latter may pertain to different cultural practices, including the frequency of sexual intercourse, or environmental effects (Konishi et al., 2020). Infertility cannot be attributed to an ultimate cause in about 30% of the affected couple, which is termed unexplained infertility (Ray et al., 2012; The Guideline Group on Unexplained Infertility et al., 2023).

Predictors of subfecundity

Among the strongest predictors for TTP are age of the woman, age of the man, BMI of the woman, education of the woman, smoking and reproductive health (Chua et al., 2020; Rafael et al., 2023; Yland et al., 2022). There are various other factors associated with or affecting TTP, which can be grouped into social, behavioural and biological. It should be noted, however, that the classification is analytic and the lines are blurry. Moreover, caution regarding the causal interpretation should be warranted because of recall bias, selection bias and measurement error (Hong et al., 2022).

Biological factors are central for subfecundity. Proximate biological determinants relate to sperm and ovarian characteristics. Sperm concentration, volume, count, and motility are associated with the probability to conceive within one menstrual cycle in subfertile men, with concentration appearing to have the strongest impact (Bonde et al., 1998; Buck Louis et al., 2014; Keihani, 2021; Lamb & Marinaro, 2023). Nevertheless, the association remains weak in the general population and shows considerable variation (Andersen, 2002; Guzick et al., 2001). In women, the

characteristics of the menstrual cycle, hormone levels and the number of oocytes are predictive of TTP in some studies (Cordova-Gomez et al., 2023; Nelson et al., 2024; Steiner, 2013), but not in others (Harris et al., 2023).

Diseases relate to subfecundity. Foremost, diseases of the reproductive system, especially endometriosis (Cook & Adamson, 2013) and myoma (American Society for Reproductive Medicine, 2008), in men and women have detrimental effects for fecundity. Sexually transmitted diseases and some chronic illnesses are important risk factors for subfecundity as well (Liu et al., 2022; Tsevat et al., 2017). In addition, diabetes and obesity are associated with prolonged conception and lower fertility (Garfield et al., 2016; Hernaez, 2021; Jensen et al., 2004; Lee, 2022). Moreover, genes are critical determinants of subfecundity through a variety of pathways (Ignatieva, 2021).

Genes have been linked to the characteristics of sperm and ovaries, as well as to major diseases. In addition, research points to the importance of epigenetics in subfecundity and childbearing (Lee, 2022; Sharma et al., 2015). Genetic variation is likely to be increasingly important for fecundity, as childbearing takes place at higher ages (Benonisdottir et al., 2024). Age is an important determinant of subfecundity in humans, which relates to both biological and social processes and relates to the TTP via hormonal and epigenetic channels as well as oocytes and sperm characteristics (Dunson, 2001; Kidd et al., 2001; Lee, 2022). In men, alterations to the hypothalamic-pituitary-testicular axis have implications for testosterone production and spermatogenesis (Martins Da Silva & Anderson, 2022).

The social factors affecting the TTP are plentiful and are often mediated by biological pathways. Environmental factors such as air pollution and environmental toxins are also related to subfecundity and show a strong social pattern as consequence of spatial segregation (Kumar & Singh, 2022; Swan & Colino, 2021). Social contacts and relationships seem to affect subfecundity as well, but the evidence base is weak (Banks, 2021; Dinh et al., 2021). Furthermore, socioeconomic characteristics

influence the TTP, net of biological and lifestyle factors (Liu et al., 2019). However, there remain large gaps in the understanding of the impact of the life course on TTP. For instance, a recent study demonstrated the importance of life course ordering and structure for mortality and attitudes (Savcisen et al., 2023).

Lifestyle factors play a role in subfecundity (Salih Joelsson et al., 2019). Low coitus frequency, the diet, smoking habits, physical inactivity and alcohol consumption can prolong TTP (Wootton et al., 2022). Smoking was robustly related to prolonged TTP (Hernaes, 2022). Moreover, the majority of evidence points towards a negative association between alcohol and fecundity (Fan et al., 2017), but a few studies do not find an effect (Wootton et al., 2022).

4.1.2 Measuring subfecundity

Measuring fecundity is a challenging task. Only in a small fraction of couples suffering infertility a single causal factor can be identified. Thus, a direct explanation of subfecundity is usually not available. In the majority of couples, however, not a single cause can be identified, rendering the couples unexplained subfertile. In these situations, prediction models may guide clinical practice (Coppus et al., 2009; Leushuis et al., 2009). In this section, we present the possible research designs to assess fecundity in humans, and discuss their respective strengths and limitations.

Biomarkers of fecundity

The life sciences assess fecundity using biomarkers in humans that are mechanistically related to subfecundity. These markers are objective characteristics of the reproductive capacity. For instance, men's subfecundity is measured using sperm count, sperm quality indicators, and hormonal characteristics, which are associated with TTP (for a review, see Olsen & Ramlau-Hansen, 2014). In women, markers of ovarian reserve are used frequently, like the Antimüllerian hormone levels (Harris et al., 2023; Nelson et al., 2024; Salih Joelsson et al., 2019; Tarín et al., 2020).

However, this approach comes with several issues. First, these biomarkers are only weakly associated with TTP, which shows that these markers may serve only as proxies of subfecundity (Bonde et al., 1998; Lamb & Marinaro, 2023). Moreover, given that the main definition of subfecundity is dyadic, the measurement of biomarkers of each of the partners raises follow-up questions. Is the impact of the two individuals additive, or is there an interactive effect on TTP? Is the combined effect mediated by the relationship between the two individuals? Second, the measurement of the biomarkers is difficult and expensive, which has repercussions on the data quality. For instance, sperm samples need to be analyzed within 2 hours after ejaculation (World Health Organization, 2021), which places a time pressure on the analysis and may require the study participants to travel to the laboratory, rendering the participation burdensome. Burdensome participation will lead to unit non-response and sample selection. In addition, the accompanied costs of the analysis may reduce the sample size to small numbers. Third, the procedures underlying sperm analysis have changed over time and are often still performed manually to some extent, which increases the human component. The World Health Organization publishes guidelines for the analysis of sperm and egg cell samples, standardizing the procedure. However, given that the current edition is number six, there have been changes over time to the procedures. Thus, changes to the analysis may affect time-trends in the results. In a similar vein, technological progress led to automatization of parts of the analysis, which may improved the quality of the results and led to changes over time. Because of the aforementioned limitations, bio markers in humans may not be suitable to address population level questions (Jørgensen et al., 2021). The results will be based on small selective samples, which do not serve as sufficient for drawing inference for the entire population and especially not over time.

Time to pregnancy

Alternatively, subfecundity has been measured using TTP. TTP information can be collected either prospectively, e.g. recruiting a sample that is about to start regular unprotected intercourse, or retrospectively, e.g. asking a sample about the duration of trying to conceive. Both approaches have advantageous and limitations.

Prospective data comes either from medical trials that followed couples in their attempt to reach pregnancy (Lam et al., 2020; Zhan et al., 2022) or from mobile phone apps that track cyclic activity and other information during the attempt to conceive (Liu et al., 2019; Nakamura et al., 2018). However, recruiting prospective cohorts is challenging, which rises the issue of selectivity. People likely participate if they had past reproductive problems, anticipate reproductive issues, or have a scientific interest.

The retrospective cohort designs ask about past attempts of conceiving, including those who succeed, i.e. parents. The sample size is usually larger. The sampling scheme often ensures that the results may be generalized to the entire population. However, this approach is not without limitations. A major concern of retrospective studies is recall and social acceptability bias (Hong et al., 2022). The former refers to the erroneous recollection of the time the couple is trying to conceive a child, which likely increases as the duration gets longer. The latter may relate to potential stigma of fecundity problems, so that people adjust the response to the normative appropriate answer. However, evidence of bias in retrospective TTP information is mixed (Jukic et al., 2016).

4.2 Materials and methods

In this chapter, we build several machine-learning models using rich population-scale data to evaluate the predictability of subfecundity. Overall, the evaluation of predictive performance enables us to draw conclusions about the ability to

predict subfecundity. Incomplete data, measurement error, or randomness in the reproductive process may account for the remaining error. Estimating the predictive power of the different variables is a secondary objective.

We apply a retrospective cohort design to data from the MoBa questionnaires Q1, Q2, QF and the biological samples and the Norwegian health, residence and education registers. The different Norwegian administrative registries are linked to the MoBa-data through the CL2 – Centralised at a pseudonymous register. The target population consists of all parents who gave a childbirth between 1998 and 2008 ($n = 66,435$). The respondents were sampled during the medical visit in the 17th week of gestation. It is noteworthy that the sample consists of couples who managed to conceive after all, indicating that there were no sterile couples included. This sample selection comes with advantages and limitations discussed below. A complete description of the data is provided by Magnus et al. (2006).

The sample consists of couples that conceived eventually at some point. Hence, couples that are completely sterile or infertile are not included. Therefore, we cannot infer infertility for the entire couple population in Norway, as the target population of the study are couples that eventually conceived. While this sample selection is the consequence of the data collection process, it may have also some advantages. For instance, couples that conceived a child have less social pressure about the response to the question about TTP. This may reduce measurement error compared to information from couples that have not conceived, which may downplay the period of regular unprotected intercourse.

4.2.1 Building a predictive model of fecundity

The main outcome is a binary indicator for whether TTP was 12 months or longer (subfecundity = 1), rendering the empirical design a supervised classification problem. The final data consists of 66,435 couples. We split the data into a training ($n = 37,478$; 60%), validation ($n=12,554$; 20%) and a test set ($n=12,393$; 20%). We

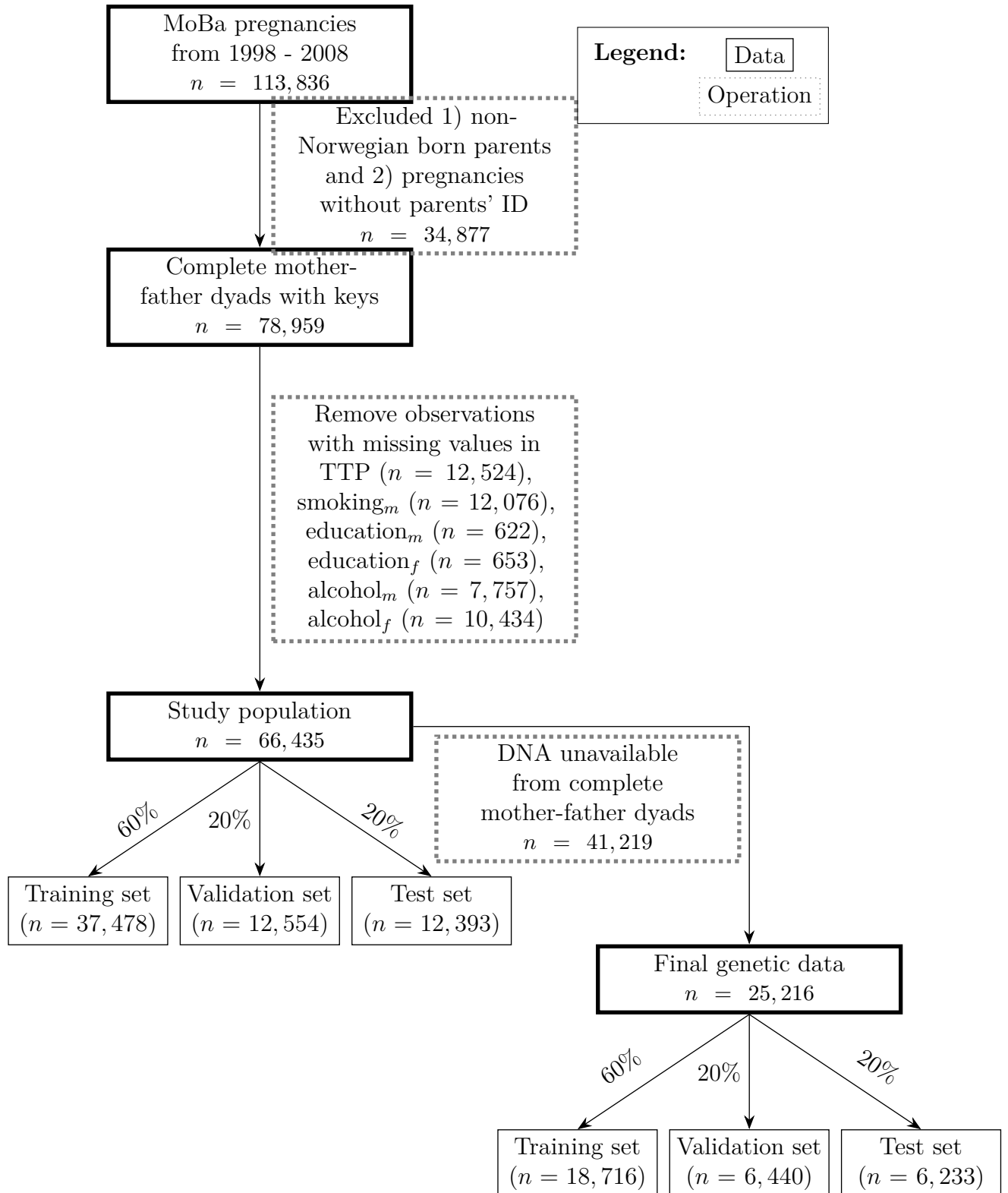


Figure 4.1: Inclusion criteria. MoBa, Norwegian Mother, Father and Child Cohort Study; MBRN, Medical Birth Registry of Norway; ART, assisted reproductive technologies.

evaluate the model performance using the AUC on the test set, e.g. performing out-of-sample validation. The AUC provides a comprehensive measure of the model's ability to accurately classify observations into their respective outcome categories, across a range of probability thresholds. Specifically, the AUC value can be interpreted as the probability that a truly subfecund couple is assigned a higher predicted probability of subfecundity than a truly non-subfecund couple (Spiegelhalter, 2019).

4.2.2 Outcome: Time-to-pregnancy

The main outcome of the study is a binary transformation of time-to-pregnancy (TTP). The outcome of interest is whether a conception happened after 12 months or longer of regular unprotected intercourse or not ($1 = \text{TTP} \geq 12$, $0 = \text{TTP} < 12$). Time to pregnancy was missing in 12,524 cases (15.86%), which we removed from the data. Beyond the binary outcome, we estimate models on TTP using a continuous outcome, which exploits more variability in the data, at the cost of clinical interpretability.

4.2.3 Predictors: biological, social and behavioural

The predictors are obtained from MoBa and the administrative registers pertaining to the social, biological and behavioural characteristics of both partners' lives. The partners' were linked via keys of the father and the mother, allowing to perform a couple-level examination. All continuous variables were centered around the mean and rescaled by their standard deviation.

The MoBa data provides information on key characteristics of the childbearing couples prior to conception (retrospective). We use the age of the mother ($\mu = 29.36$, $\text{sd} = 4.451$), age of the father ($\mu = 31.256$, $\text{sd} = 5.141$), the BMI of the mother ($\mu = 24.194$, $\text{sd} = 4.356$) and the BMI of the father ($\mu = 25.921$, $\text{sd} = 3.225$). Furthermore, we include socio-economic characteristics of the parents, e.g. the education of the mother (Basic school level (GS) = 10.53%; Upper secondary education (VGS)

= 38.01%, Tertiary vocational education (FS) = 5.15%, Higher Education, short (UHK) = 31.06%, ; higher education, long (UHL) = 15.25%) and the education of the father (Basic school level (GS) = 8.29%; Upper secondary education (VGS) = 27.03%; Tertiary vocational education (FS) = 1.64%, Higher education, short (UHK) = 49.68%; Higher education, long (UHL) = 13.35%). Moreover, we include some variables on health behaviours, such as frequency of smoking and alcohol consumption. Secondly, we use genetic information from MoBa on a subsample of pregnancies (n=19,149), which are transformed into Polygenetic Risk Scores (PGS) for endometriosis (Rahmioglu et al., 2023) and subfecundity (Venkatesh et al., 2024) in the pre-processing, and later included in the prediction model.

4.2.4 Statistical methods

We use six different classification models to predict the outcome. As a theory-driven baseline model, we estimate a logistic regression, which are standard in epidemiological research for modelling binary outcomes and provide interpretative results, but which imposes pre-specified parametric relationships between the predictors and the outcome, implemented in the R package `glm`, with both parents' age (exponentiated), BMI (exponentiated), and educational level as predictors. Previous research has indicated that age, BMI and education are the most important and readily available predictors of prolonged time-to-pregnancy (Committee on Clinical Consensus—Obstetrics, 2022; Hernaez, 2021; Jørgensen et al., 2023). The terms for age (Sheps & Menken, 1973) and BMI (Hernaez, 2021) were exponentiated to capture their non-linear impact. Second, for interpretation purposes, we use a logistic regression model including all predictor variables. Third, we use an elastic net regression, implemented in the R-package `glmnet`, which include a lasso and a ridge penalty term in the regression function, mitigating the risk of overfitting. “The elastic net simultaneously does automatic variable selection and continuous shrinkage, and it can select groups of correlated variables” (p. 302, Zou & Hastie,

2005). We find the best parameter value for λ using 10-fold cross-validation. Fourth, we use generalized additive regression models (GAM), implemented in the R-package `gam`, which flexibly models the parametric relationship between continuous variables and the outcome (Hastie & Tibshirani, 1986). Fifth, we use gradient boosted decision trees, i.e. implemented in the `lightgbm` Python-package, which draws on boosted classification trees that model interactions and non-linear relationships flexibly, but underperforms in fitting smooth gradients for continuous variables (Ke et al., 2017). We optimize the hyperparameters using 5-fold cross-validation, which was implemented in the `optuna`-package. Finally, we use a neural network from the Python-package `pytorch` which performs well in pattern detection in high dimensional large-scale data (“Chapter 7: Model Assessment and Selection”, 2009).

We use importance scores — split importance, gain importance, coverage importance — to quantify the impact of features in the lightGBM model. Split importance counts the number of times a feature is used to split the data across all trees in the model. Gain importance measures the total gain (improvement in the loss function) brought by a feature when it is used for splitting. Coverage importance measures the number of data points affected by splits involving the feature.

4.2.5 Model performance evaluation

We use the AUC to quantify model performance and compare the different machine-learning models against a theoretically-driven baseline model. The AUC ranges between 0.5 and 1, whereas higher values indicate a better model fit. Model evaluation is done in two ways. First, the AUC is compared across models and against the baseline model for couples in the test set. Minimizing the prediction error rate is a key objective of the study. Second, the models are used to estimate fecundity scores for couples, and we study how well the models can distinguish between couples with instant conception, medium TTP, and long TTP. The fecundity score is estimated using rescaled predicted probabilities, so that values higher than

0 indicate a high risk of prolonged TTP, and values below 0 indicate a low risk of prolonged TTP. Rescaling is done to allow comparisons across contexts with different baseline levels of fecundity and to ease interpretation.

4.3 Results

4.3.1 Descriptive results

Subfecundity is a rare phenomenon among the MoBa parents, as the majority of couples conceived within the first 12 months after deciding to get a child (58762, 88.45%). Only 11.5% of couples conceived after 12 months. The mean TTP is four and a half months (0.38 years) and the median duration is less than a month. The distribution is skewed with a long right tail and ranges between 0 months and 8.25 years.

The bivariate relationships of the theoretically most important variables (age, BMI, education, and PGS for endometriosis as well as subfecundity) with TTP are in the expected direction, except for age, which is not associated with TTP. Mother's age surprisingly is not correlated with prolonged TTP, as the mean age in the group with shorter TTP is 29.67 compared to 29.15 among couples with prolonged TTP. The same holds for father's age, as the mean age differs only by 0.33 years between the groups (short TTP = 31.49, prolonged TTP = 31.16). The mother's BMI is positively associated with TTP, showing an average BMI of 25.01 in the group with prolonged TTP and an average BMI of 24.03 in the group with shorter TTP. The positive association between BMI and TTP is weaker for fathers, as the group with prolonged TTP has an average BMI of 26.26 and the group with shorter TTP has an average BMI of 25.85. Mother's education is statistically significantly related to TTP ($\chi^2 = 321.21, df = 4, p < 0.0001$) and shows a clear negative gradient. The highest share of prolonged TTP is observed among mothers with basic school education (short TTP = 79.74%, prolonged TTP = 20.26%) and the lowest share among higher tertiary educated mothers on a long track (short TTP

= 89.58%, prolonged TTP = 10.42%). Similarly, father's education is statistically significantly related to TTP ($\chi^2 = 242.83, df = 4, p < 0.0001$) and shows a clear negative gradient. Fathers with basic school education have the highest share of prolonged TTP (short TTP = 80.64%, prolonged TTP = 19.36%) and higher tertiary educated fathers on a long track have the lowest share of prolonged TTP (short TTP = 89.44%, prolonged TTP = 10.56%). The genetic information is correlated with TTP, as the PGS for endometriosis is 0.1 standard deviations higher among couples with a prolonged TTP (PGS endometriosis = 0.079) than in couples with shorter TTP (PGS endometriosis = -0.02) and the PGS for subfecundity is 0.13 standard deviations higher among couples with a prolonged TTP (PGS subfecundity = 0.106) than in couples with shorter TTP (PGS subfecundity = -0.021).

4.3.2 Model accuracy

Figure 4.2 summarises the predictive performances for the test-sample and shows that the lightGBM model outperformed all the other models by a large margin. The figure illustrates the out-of-sample prediction performance of the five models using the receiver operating characteristic curve (ROC-curve). The area between the colorful lines and the diagonal line indicates the quality of the prediction; larger areas indicate a better classification than smaller areas. While the lines for the logistic regression, the generalized additive model (GAM), the elastic net regression and the neural network are relatively close, indicating a similar predictive performance, the lightGBM is clearly separate from the others. The strength of the lightGBM model is also captured in the AUC metric, which quantifies the size of the area under the ROC-curve. The lightGBM has an AUC of 0.772, while the other models have substantially lower performances ($AUC_{Logistic} = 0.683$; $AUC_{GAM} = 0.686$; $AUC_{ElasticNet} = 0.682$; $AUC_{Neuralnetwork} = 0.665$). The theory-driven model ($AUC_{baseline} = 0.574$) is outperformed by all data-driven machine-learning models, which indicates that the theories of fecundity have shortcomings and that

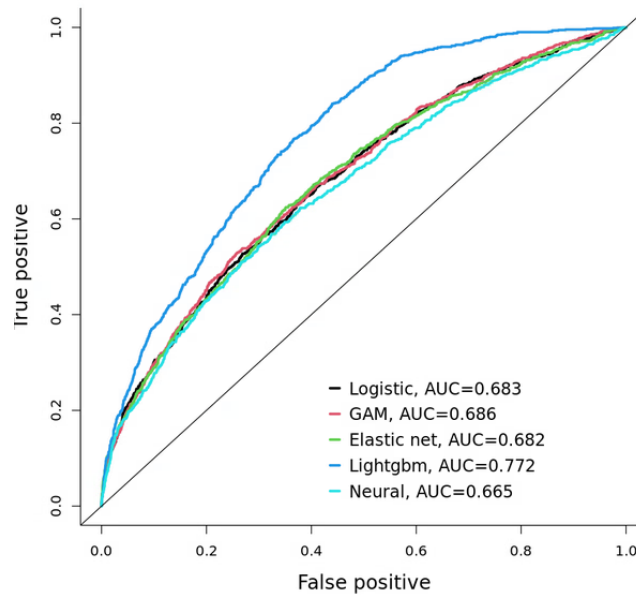


Figure 4.2: This figure presents the model out-of-sample performance using the receiver operating characteristic curve (ROC-curve). The x-axis displays the false-positive rate (1-specificity) and the y-axis represents the true-positive rate (sensitivity). The lines represent the classification of the model using different cut-offs for the classification.

fecundity is likely a complex trait. The theory-driven model ($AUC_{baseline} = 0.574$) demonstrates a moderate level of performance. However, it is outperformed by all data-driven machine-learning models. This suggests that perhaps the statistical model may take a too simplistic functional form or that the current theoretical frameworks of fecundity may be constrained by their simplistic functional forms, narrow factor considerations, and operationalization of measures. Furthermore, this outcome may also indicate that fecundity is influenced by a complex interplay of factors, with more direct health-linked predictors potentially playing a more proximate role in shaping reproductive outcomes.

4.3.3 Fecundity scores

Based on the different prediction models, we present fecundity scores that indicate the risk of prolonged TTP in Figure 4.3. The best-performing model, the lightGBM, accurately distinguishes the group with short time-to-pregnancies (below 3 months) from the rest, as indicated by a large fraction of values below 0 in this group. This

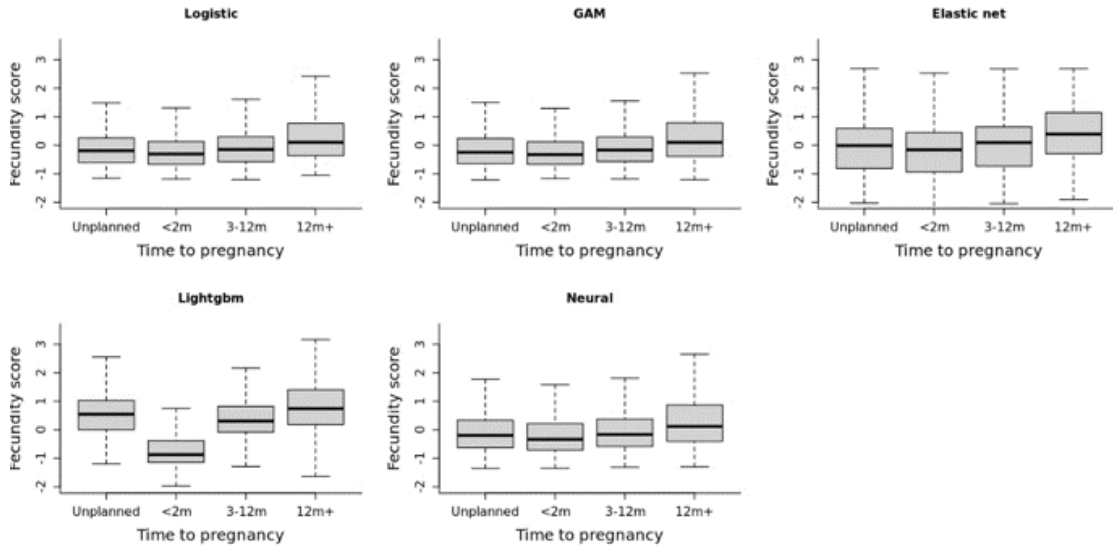


Figure 4.3: This figure displays the fecundity scores in the test set for the different models

group, which is also the largest in the sample ($N_{TTP < 3} = 31107$, 46.82%), seems to be structurally different from the others and has a low risk of prolonged TTP. The fecundity scores in the unplanned, 3-12 months, and more than 12 months groups are positive, indicating a higher risk of prolonged TTP. These groups have similar fecundity scores, indicating that fecundity seems to be a continuum for them and that the factors in the model are not able to distinguish these groups.

4.3.4 Predictors

To investigate what predictors contributed to predicting TTP, we analyzed the results from the logistic regression. It suggests a particularly strong associations of mother's reproductive health with TTP (Figure 4.4). Among them, endometriosis showed the strongest association with TTP, as the risk of prolonged TTP is fivefold in women with endometriosis (odds ratio = 5.779 ; 95% CI = 4.735-7.045). Myoma (odds ratio = 2.34; 95% CI = 1.753-3.094), ovary cysts (odds ratio = 1.868; 95% CI = 1.646-2.115) and previous miscarriages up to the 23rd week of pregnancy are also associated with subfecundity. While these predictors have particularly strong associations with subfecundity, it should be noted, that their prevalence in the data

is small, for instance endometriosis affects only 1.5% of couples, limiting the overall predictive value. Multiparous mothers are likely to have shorter TTP compared to nulliparous mothers. The strongest negative association with subfecundity have previous births of parity one (0.551, 95% CI = 0.504-0.601), parity two (odds ratio = 0.343; 95% CI = 0.298-0.395), parity four (odds ratio = 0.298; 95% CI = 0.167-0.475) and parity three (odds-ratio = 0.288; 95% CI = 0.213-0.382).

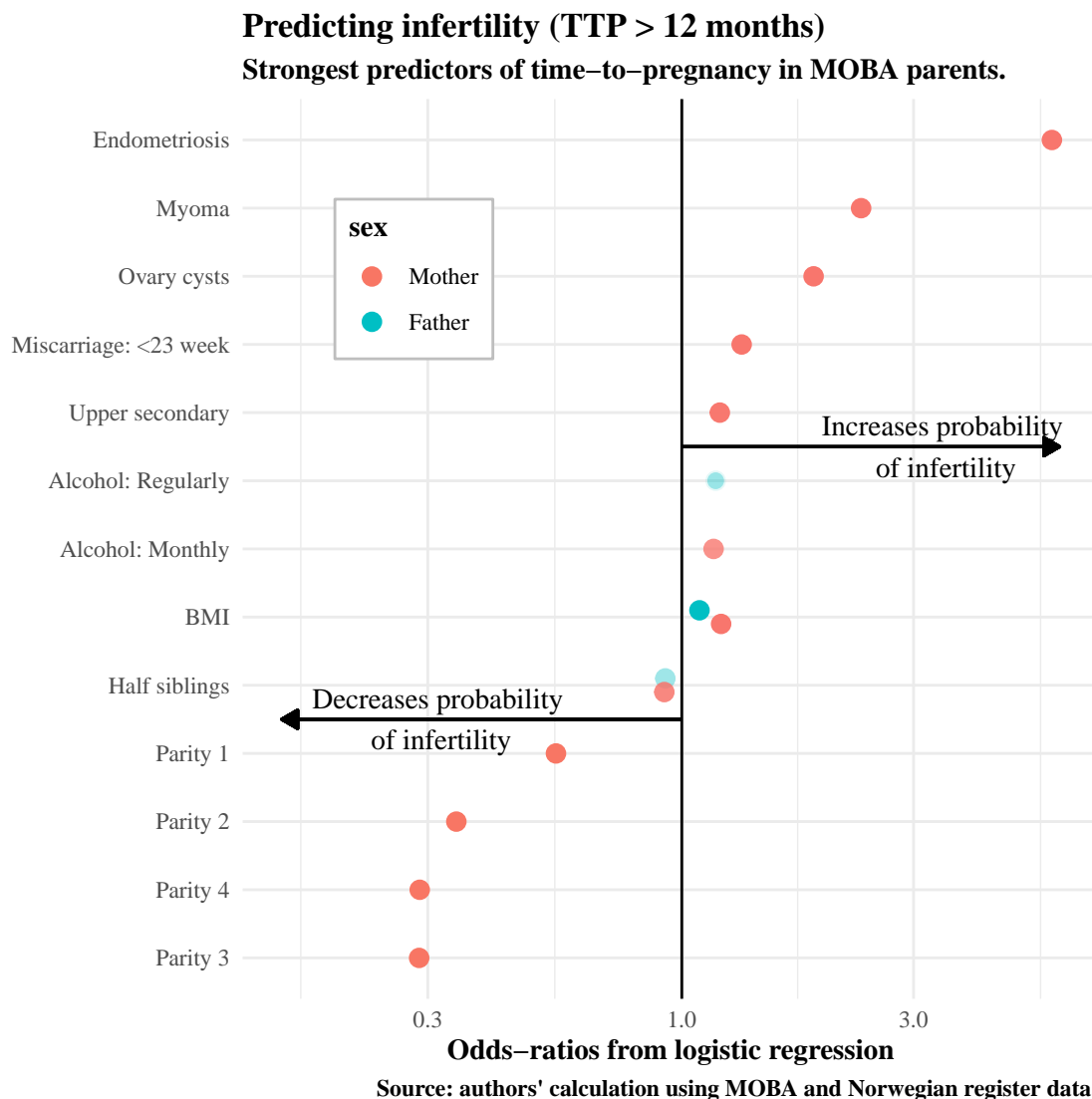


Figure 4.4: Odds-ratios from log-binomial regression model of subfecundity (TTP > 12 months) on the most significant biological and social predictors (top 20 Z-Scores). Values above 1 indicate a positive association with subfecundity, e.g. increased risk, and lower values indicate a negative association with subfecundity, e.g., a reduced risk.

Furthermore, we estimate several logistic regression models stratified by maternal

age (15–24, 25–29, 30–34, 35–50) to investigate the changing impact of predictors by age on fecundity (see Figure 4.5). The most relevant predictors are largely the same across maternal age groups, but the variables related to maternal reproductive health have a weakening impact on fecundity with age. This can be attributed to two possible reasons: (1) a substantive reason, suggesting that the reproductive health of the mother has a weaker impact on fecundity at older ages, or (2) a data artifact, whereby the increasing baseline risk of prolonged time-to-pregnancy (TTP) with age attenuates the odds ratio.

We present the results from the GAM model to assess potential non-linear relationships between continuous predictors and TTP (Figure 3). A modest non-linear effect of maternal BMI on TTP was observed (Figure 4.6). The AUC of the GAM was comparable to that of the logistic regression (Figure 4.4), which indicates that accounting for non-linear relationships did not improve predictive performance. Additionally, we explored non-linear interactions of two continuous predictors but found no improvement in prediction power.

The importance scores from the lightGBM model describe the impact of features for the model, see Figure 4.7. Father’s characteristics obtain high importance scores, in particular, father’s age has the highest importance score (Gain = 0.544, Cover = 0.383). It is followed by father’s (Gain = 0.094, Cover = 0.060) and mother’s BMI (Gain = 0.092, Cover = 0.05) respectively. Then comes mother’s age (Gain = 0.046, Cover = 0.041), mother’s history of endometriosis (Gain = 0.044, Cover = 0.008) and mother’s parity (Gain = 0.27, Cover = 0.19).

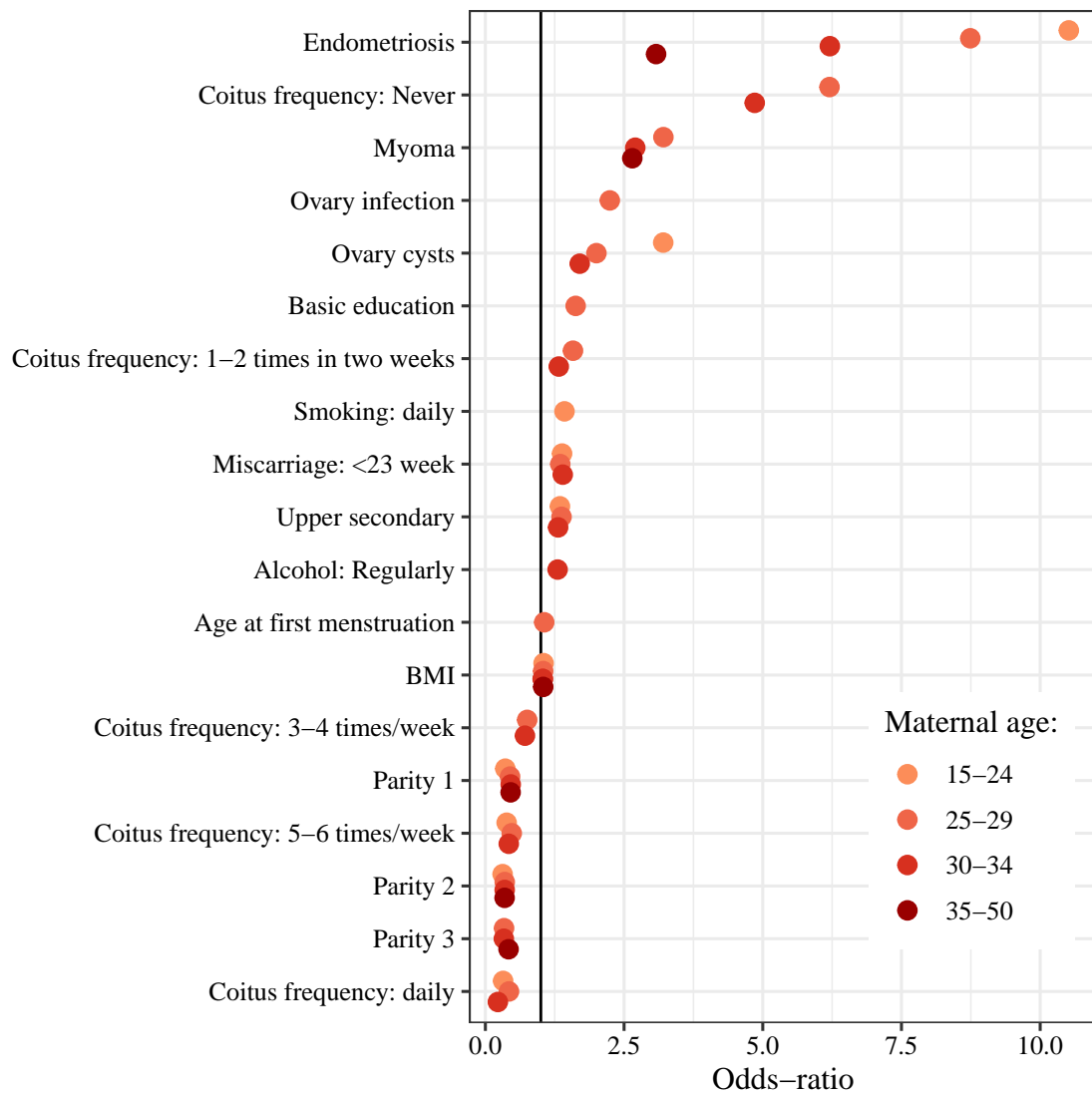


Figure 4.5: This figure illustrates the impact of the most important predictors on subfecundity (TTP < 12 months) stratified by maternal age groups (15–24, 25–29, 30–34, 35–50) in several logistic regressions. Only predictors with a z-score above 2.5 were selected as relevant.

Parental age and BMI and subfecundity

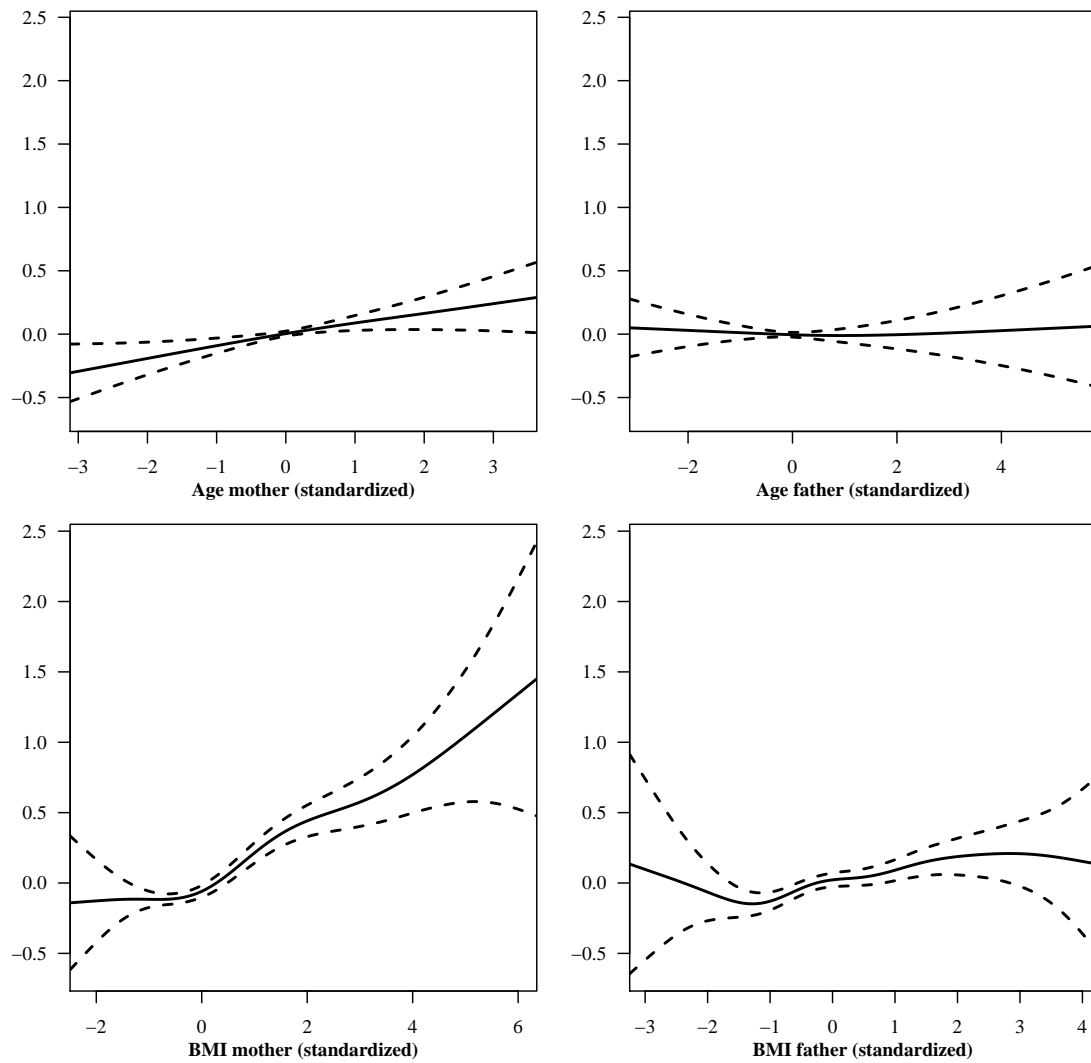


Figure 4.6: Predicted values for splines in generalized additive model on subfecundity (TTP>12months) of standardized paternal and maternal body mass index (BMI) and age. Higher values indicate higher risk of subfecundity.

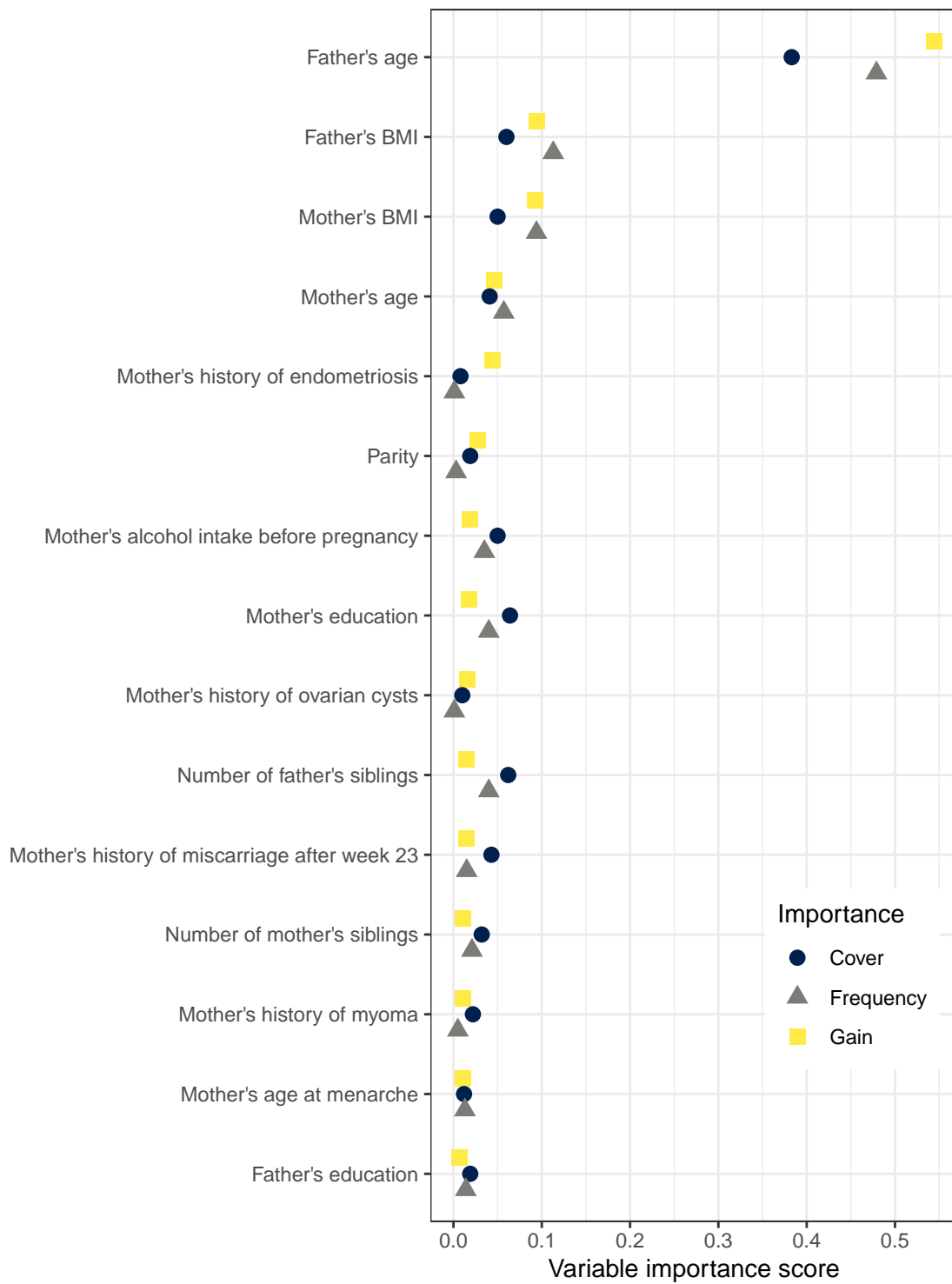


Figure 4.7: Variable importance scores from lightGBM model ordered by feature gain. Higher values indicate that more couples are affected by the particular feature (Cover), that trees are split more often on that feature (Frequency) and that the feature's average contribution to the loss-function was greater (Gain).

4.4 Discussion

In this chapter, we assessed the predictability of TTP using a wide array of biological and social variables in a sample of 66,435 pregnancies in Norway in the period between 1998 and 2008. The study's aims were twofold: i) quantify the predictability of fecundity problems in couples, and ii) to quantify the importance of different biological and social factors for fecundity. The best performing model, lightGBM, reached a good level of predictive performance (AUC= 0.772). This highlights the relevance of non-linear and interactive associations. This model distinguishes well between couples with instant conception (less than three months) from couples with longer conception times. Finally, age and BMI of the male and female partner are the most important factors for predicting fecundity. We conclude that biological and social factors have decent predictive power, but the overall predictive performance is not sufficient for clinical applications.

The different machine-learning models achieved varying levels of predictive performance. Notably, the lightGBM model stood out from the others in terms of its predictive performance. The lightGBM are well suited for predictions using rectangular data, as it captures non-linear and interactive covariate effects between continuous and categorical predictors ("Chapter 7: Model Assessment and Selection", 2009; Ke et al., 2017). Thus, we may suspect that there exist strong non-linearities and interactions between the different predictors. Neural networks, which are developed for image and pattern recognition, performed worse and achieved a similar predictive performance to the regression-based models. The regression-based models perform very similar, their AUC ranged between 0.682 and 0.686. The GAM performed best among the regression models, although by a small margin, which might relate to its strength in detecting non-linear relationships (Hastie & Tibshirani, 1986). Zhan et al. (2022) developed a model that predicted subfecundity with an AUC of 0.989, and, therefore, better than our best-performing model. There

are two differences between their and our model. First, their model contained more features. For instance, their model incorporated markers for sperm quality and ovarian reserve, as well as information on the social-mental health of the respondents. This information likely increased the predictive performance, however, at the cost of being harder to measure and to find in common data sets. Second, their data was more homogeneous. They sampled respondents from a single clinic in a short time window, which increase homogeneity of the sample respondents, while our data contained the full Norwegian pregnancy population from 1998 to 2008.

The best model distinguished couples that had very short conception times, the largest fraction in the sample (31,107 couples, 46.82%), from couples with longer conception times. This indicates that highly fecund couples can be i) predicted with a handful of social and biological characteristics, ii) that they differ systematically from couples that have longer TTPs, and iii) that they seem to form a somewhat homogenous group. The prediction model distinguishes worse between couples with medium (3 – 12 months) and long conception times (≥ 12 months). Several factors may explain this weakness. Either, as argued by Coppus et al. (2009), subfecundity is a continuum rather than a qualitative distinction. Or, our data did not contain the variables that are important to distinguish between medium and long TTPs. Future research should aim to develop models and explanations that distinguish couples between intermediate and long TTPs.

The most important predictors for subfecundity were diseases histories of the reproductive system, previous births as well as age and BMI of both partners. Yet, the ordering of the predictive strength of these factors varies across models, which might be related to model strengths and weaknesses. In the best performing model, e.g. lightGBM, father's age and BMI had the highest importance scores, followed by mother's BMI, age, and mother's history of endometriosis. While in the GAM model, the maternal BMI and age had stronger associations with subfecundity. This discrepancy could be due to several reasons. First, the GAM, as

a regression model, suffers from multicollinearity, which may absorb some impact of the father. Evidence for this explanation comes from the weak impact of father's age, which differs from existing research findings (Dunson et al., 2004). Second, the lightGBM model detects interactive relationships better, but performs worse in gradual associations. Father's age may have a cascade linear relationship with TTP rather than a gradual increase, which was not captured properly by the GAM. Or, father's age becomes important in certain groups of the respondents, e.g. further down in the trees, which is better captured by the lightGBM. The latter explanation may be more sensible, given that the lightGBM outperforms all other models.

Our models had a fairly good predictive performance, which contrasts predictions of other life outcomes (Salganik et al., 2020). This might be related to the biological grounding of fecundity, which may serve as an easier predictive outcome than social variables that have a higher share of unexplained variance (Lundberg et al., 2024). However, the predictive performance may not yet satisfy standards for widespread clinical applications. A diagnosis based on our prediction model could mislead couples, based on misclassifications, to use or not to use artificial reproductive technologies (ART). Furthermore, a diagnosis of subfecundity has the potential to induce stress in affected individuals, which can lead to a multitude of health implications, including those that extend to fecundity itself. We therefore recommend setting a high threshold for the introduction of machine-learning models in clinical applications, with the Area Under the Curve (AUC) of the out-of-sample prediction exceeding 0.9. This is due to the sensitivity of the topic and the potential harmful consequences of misclassifications for partnership stability and the mental health of both partners.

This study has some limitations. First, the target population were couples that eventually conceived, so that we are only predicting variation in the timing of the conception, but not the qualitative information of whether a conception took place. Therefore, our results do not lend any conclusion about sterile or infertile couples.

Second, the information on TTP may be subject to recall bias as it was asked retrospectively in gestation week 17 (Hong et al., 2022). In addition, and even more severe for the substantial interpretation of our results, the extent of recall bias may even relate to TTP itself, as very long duration may increase the bias. Although retrospective information might be biased due to the sensitivity of the topic and recall bias (Hong et al., 2022), a study by Jukic et al. (2016) indicated that retrospective information for TTP corresponds to information obtained prospectively.

Part II

The role of men in fertility

Order and simplification are the first steps towards mastery of a subject

Thomas Mann

5

Subnational birth squeezes

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In high-income countries, the quantum of fertility at the national level is often very similar for women and men. This insight comes from a recent strand of research

This chapter is co-authored with Christian Dudel.

built on methodological innovations and new data sources (e.g., Dudel & Klüsener, 2019a, 2021; Schoumaker, 2017). Previously, fertility research was predominantly focused on women due to the lack or limitation of data on male fertility. This new research shows that differences in indicators of the quantum of fertility between men and women, such as differences in the total fertility rate (TFR), are often modest with a few exceptions (Bratsberg et al., 2021; Dudel & Klüsener, 2016, 2019a, 2021; Schoumaker, 2019; Zhang, 2011). These gender differences in the level of fertility can be explained by differences in the population sizes of men and women, gender differences in the timing of fertility, and the interaction of fertility timing and differences in the cohort sizes of men and women (Dudel & Klüsener, 2021; Schoumaker, 2019). Theoretically, gender differences in fertility quantum could be much more pronounced given specific conditions; however, at the national level, it seems that the factors impacting fertility differentials cancel each other out to some extent (Canudas-Romo et al., 2023).

Less is known about gender differences in the quantum of fertility at the subnational level. It can be speculated, however, that differentials could be larger at the subnational level. This is because of gender-selective subnational migration (Gulczynski, 2023), subnational variation in gender differences in mortality (Sauerberg et al., 2023), and subnational variation in the causes of gender differences in fertility behavior (Campisi et al., 2020; Fox & Myrskylä, 2015). A recent study showed considerable heterogeneity in subnational adult sex ratios worldwide, which tend to be more skewed than those at the national level (Gulczynski, 2023). The few studies looking at fertility differentials at the subnational level have confirmed this expectation. For instance, Dudel and Klüsener (2016, 2019a) found that the difference in the TFR between men and women is bigger in Eastern Germany than in Western Germany, likely due to gender-differential internal migration.

This paper examines subnational differences in the quantum of fertility, as reflected in the TFR, with a particular emphasis on potential birth squeezes

(Schoen, 1985). A birth squeeze is a situation in which the fertility of one gender is considerably lower than of the other gender. We discuss which indicators and thresholds to use for assessing whether there is a birth squeeze. We harmonize and analyze high-quality register data from Australia, Colombia, Finland, France, Germany, Mexico, Spain and the United States, covering a wide range of regions and institutional settings. We find birth squeezes at the subnational level in several of these countries. For Finland, we are able to conduct additional analyses by parity and for childlessness, which shed some light on demographic explanations for the observed patterns.

The term “*birth squeeze*” was introduced by Schoen (1985) in analogy to the concept of a “marriage squeeze” (e.g., Akers, 1967; Muhsam, 1974), although the basic idea was recognized earlier (Brouard, 1977). Essentially, a marriage squeeze occurs if there is an imbalance in the numbers of women and men leading to differences in marriage rates between women and men (Schoen, 1983). Thus, a birth squeeze is a difference in fertility rates between women and men caused by an imbalance in adult sex ratios (Schoen, 1985). In contrast to the marriage squeeze, the birth squeeze concept has received very little attention in the literature, likely due to the above-mentioned fact that differentials in the quantum of fertility between women and men are mostly small at the national level. Moreover, there is little guidance on what level of difference can be really considered a birth squeeze.

Birth squeezes, as well as skewed adult sex ratios, have been hypothesized to have a significant impact on various domains, including social, family, and economic outcomes (for a review, see Dyson, 2012). The primary concern is the effect on fertility and childlessness, as cohorts exposed to birth squeezes face a structural constraint to childbearing, potentially leading to increased childlessness among men and women (Klein, 2003; Kravdal, 2021; Schubert et al., 2024). Birth squeezes may also indicate imbalanced mating markets in which the more abundant gender faces structural constraints on partnership formation, and may affect union compositions

in terms of age gaps between partners and bargaining power (Abramitzky, 2009; Akers, 1967; Albrecht, 2001; Filser & Willführ, 2022; Muhsam, 1974). Furthermore, birth squeezes may have downstream implications for social and health outcomes, including increased violence, the spread of sexually transmitted diseases, and economic vulnerability, particularly among unpartnered and childless individuals, who may suffer from loneliness and have fewer kin to care for them at older ages (Angrist, 2002; Angrist, 2000; Edlund, 2005; Gupta, 2010; Hesketh, 2009; Hesketh & Xing, 2006; Tucker et al., 2005).

The selection of countries in this study represents a variety of contexts and exhibits substantial subnational heterogeneity. For instance, Colombia and Mexico are middle-income countries, while Germany and the United States are among the wealthiest nations. Furthermore, the countries reflect different world regions, as evidenced by the inclusion of the continents of Australia, South America, North America, and Europe. The countries are at very different stages of the demographic transition, which is reflected in the broad range of fertility levels. Spain has consistently reported lowest low fertility for several decades, while Mexico just recently experienced fertility levels below the replacement level. Finally, the selected countries exhibit considerable subnational heterogeneity with regard to historical, economic, and developmental characteristics. In the United States, for instance, Alaska is noteworthy as a highly industrial and population-sparse state, in sharp contrast to the state of New York. In Mexico and Colombia, internal armed conflicts have impacted certain regions. Germany has historically been divided into Western and Eastern Germany. Additionally, the countries under investigation provide high-quality micro-level birth registration data.

Overall, this paper makes several contributions to the literature. At the conceptual and methodological level, we provide a detailed discussion of the birth squeeze concept and how it can be measured. In particular, we provide several thresholds that allow us to assess what level of gender difference in the TFR can

be considered high. In our empirical analysis, we provide comparative evidence of the relevance of the birth squeeze, and of fertility differentials more broadly, at the subnational level, covering not only high-income countries, but also middle-income countries. While this paper focuses on the subnational level, the indicators and thresholds we discuss are generally applicable at the national level. Finally, we present a new high-quality data source for the study of fertility differentials at the subnational level that draws on vital statistics and register data from eight countries, some of which have received little attention in the previous literature.

The remainder of this paper is structured as follows. In the next section, we discuss male-female differentials in the quantum of fertility at the national and the subnational level and their causes. In the third section, we provide a detailed discussion of the birth squeeze, indicators to measure male-female differentials, and thresholds to decide whether a value of an indicator shows a birth squeeze. The data we use for our analysis is described in Section 5.3. Results are presented in Section 5.4 and discussed in Section 5.5.

5.1 Gender differences in the quantum of fertility

5.1.1 Differences at the national level: reasons and results

The average number of children born to women can be quite different from the average number of children born to men (Dudel & Klüsener, 2021; Schoumaker, 2019), which has been known for some time (Karmel, 1947). These differences can be explained by four main demographic factors: first, differences in the size of the male and female populations; second, gender differences in the timing of fertility; third, the interaction of differences in the timing of fertility and cohort sizes (Dudel & Klüsener, 2021; Schoumaker, 2019); and fourth, gender differences in data quality, which may underlie and exacerbate gender differences in fertility. We explain these factors below and illustrate them using Alaska and Oaxaca as examples in Figure 5.1.

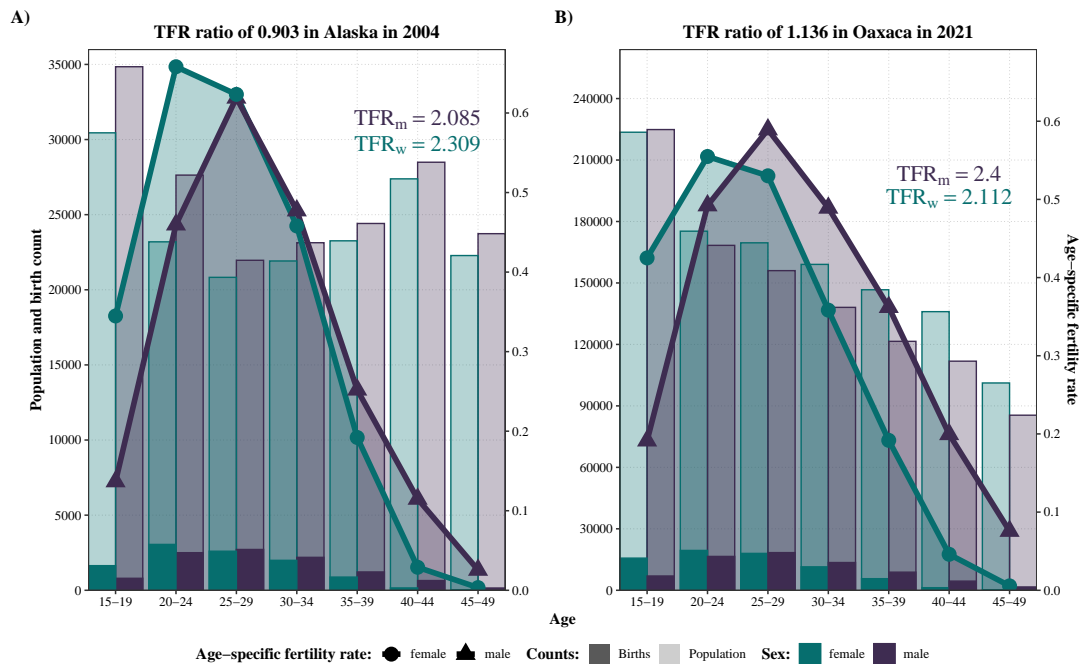


Figure 5.1: This figure illustrates the concept of birth squeezes in Alaska (United States of America) and Oaxaca (Mexico) in 2004. The count data refers to the left y-axis, population exposures are illustrated in the shaded bars and the birth counts are illustrated in the solid bars. The age-specific fertility rates shown in lines refer to the right y-axis. The TFR ratio is the ratio of the area under the purple line to the area size under the green line. Panel B) illustrates a male birth squeeze in Alaska, where the TFR ratio was at 0.9 as the male TFR was lower relative to the female TFR. Panel B) shows a female birth squeeze for Oaxaca where the TFR ratio was at 1.14, indicating a higher male TFR relative to female TFR.

First, differences in the number of women and men impact fertility differentials via exposures. In a very simple scenario, in a population of 100 women and 80 men, with 10 births, the average number of children per woman will be 0.10, while the average number of children per man will be 0.125. For example, Panel A) in Figure 5.1 shows that there are more men than women in every age group in Alaska. Differences in the population size can be caused by three factors: the sex ratio at birth (SRB), mortality differentials, and differences in migration. The SRB is influenced by biological and behavioral aspects, and averages around 105 male births per 100 female births (Chao et al., 2019; Hesketh, 2009). Mortality differentials exhibit a consistent pattern of advantage for women, with men usually displaying higher mortality rates across all age groups (Luy & Gast, 2014; Oksuzyan et al.,

2008; Remund et al., 2018; Sauerberg et al., 2023). Thus, the impact of mortality differentials on fertility differentials will usually counterbalance the impact of the SRB, at least to some extent. Finally, differentials in migration have a less clear impact. Historically, men have marginally dominated in numbers in international migration (Castles, 2003; Donato & Gabaccia, 2016), likely due to gender norms and economic roles, but international migration among women has been catching up, and has surpassed the migration among men in some places (Donato & Gabaccia, 2016). Moreover, immigration to one country generally implies emigration from another country; thus, for instance, the inflow of men to one country will mean a reduction in the number of men in one or several other countries.

Second, gender differences in fertility timing also influence male-female fertility differences. On average, men have their children later than women (Dudel et al., 2021; Schoumaker, 2019). In many high-income countries, the father tends to be around 3 to 4 years older than the mother at childbirth (Dudel et al., 2023). Globally, there is considerable variation, and much larger age differences can be found (Schoumaker, 2019). For example, the male fertility schedule is shifted to older ages compared to the female schedule in Panel B) in Figure 5.1. Age differences can have an impact even if the total population size and the age structure are the same for men and women. To illustrate, consider a population comprising three age groups. In the first age group, there are 10 men and 10 women; in the second age group, there are 20 men and 20 women; and in the third age group, there are 5 men and 5 women. Let us further assume that there are 5 births in this population, all to mothers from the first age group. However, these women have their children exclusively with men from the second age group. The total fertility rate (TFR) will be 0.5 for women and 0.25 for men, using the population counts as exposures.

Third, the interaction between fertility timing and cohort size provides an additional explanation for gender differences in the quantum of fertility. This interaction has been well established in the literature on marriage squeezes (Akers,

1967; Muhsam, 1974; Schoen, 1985). As an alternative to cohort size, this point can also be viewed as an interaction of fertility timing and age structure. As stated above, men tend to have children with younger women. If, for instance, cohort size declines, there will be fewer women relative to men. In a simplified example, assume that in each cohort there is the same number of men and women, but cohort size declines. If men from any cohort c exclusively have children with women from the cohort $c - 3$ and vice versa, and the relative decline in cohort size between cohorts c and $c - 3$ is a factor d , then the ratio of the TFR of men relative to the TFR of women will be d (for simplicity using cohort size as exposure).

Fourth, data quality is also potentially relevant for gender differentials in fertility. Generally, information on the fertility of men is often of inferior quality and has more issues compared to information on the fertility of women. For instance, even in high-quality birth register data, it is quite common that the age of the father is not known for a large proportion of births (Dudel & Klüsener, 2019b). Such issues can be expected to lead to an underestimation of the quantum of male fertility. It has been demonstrated, for instance, that data quality may contribute to gender differences in childlessness in register data (Kravdal, 2021). Moreover, there is strong evidence that surveys may underestimate male fertility because men are more likely than women to underreport the number of their children when participating in such studies (Joyner et al., 2012).

Empirical evidence shows that the level of male fertility usually follows the level of female fertility very closely (Dudel & Klüsener, 2021). For instance, in the United States in 2015 the male TFR was 1.824 and the TFR of women was 1.845. However, differences may occur. Gender differences in fertility quantum, expressed in the ratio of the male TFR to the female TFR (TFR ratio), range from 0.54 for Bahrain in 2011 to 2.5 for Gambia in 2011 (Schoumaker, 2019). In general, higher values of the TFR ratio are reported for countries in sub-Saharan Africa, while lower values are reported for high-income countries. This pattern is produced by the stage of the

demographic transition, which affects the factors mentioned above (Schoen, 1985; Schoumaker, 2019): the gender gap in mortality is narrowing as a result of improved access to health care and declines in lifestyle-related deaths; the gender gap in fertility timing is narrowing as a result of progress in gender equality and significant postponement of childbearing among women; and the population growth rates approaching equilibrium. Some African countries diverge from this pattern, as in these countries age differences are stagnating due to the high prevalence of polygamy and the unique fertility transition associated with this practice (Bongaarts, 2017; Garenne & Van De Walle, 1989; Schoumaker, 2019). However, once the demographic transition is completed in a country and it has reached below replacement fertility, the trends are less clear and can fluctuate (Dudel & Klüsener, 2021).

5.1.2 Differences at the subnational level

Both the level of fertility and the differentials in the quantum of fertility between men and women can be heterogeneous at the subnational level. Geographic heterogeneity in the level of fertility at the subnational level is mainly due to the characteristics of the subnational units (e.g., Campisi et al., 2020; Nisén et al., 2021). For instance, Fox and Myrskylä (2015) demonstrated that subnational variations in income play an important role in fertility. Moreover, rural-urban disparities have been well documented, with fertility rates generally being lower in urban areas and higher in rural areas (Campisi et al., 2020; Kulu & González-Ferrer, 2014). The characteristics of subnational areas not only increase or reduce the individual risk of having children and impact the timing of births through various channels, but they also lead to differences in population size and age structure between men and women due to internal migration. These difference, in turn, affect local partner markets, which have been demonstrated to be highly relevant for fertility outcomes (Chudnovskaya & Ueda, 2021; Kravdal, 2021; Schubert et al., 2024). Finally, general socioeconomic developments such as changes in gender relations might arrive at

different times in different subnational units, and might spread spatially over time (e.g., Blanc, 2024; Goldstein & Cassidy, 2014).

There may be subnational variations in the aforementioned factors that lead to gender differences in fertility. First, Gulczynski (2023) found that the sizes of the female and male populations of reproductive ages differ considerably at the subnational level in many countries. Gender-selective subnational migration was found to be the main driver of this gap, but differences in cohort size also play a role. Second, beyond migration, gender differences in mortality also vary considerably at the subnational level, although the gender gap in mortality has narrowed recently in some places (Sauerberg et al., 2023). Third, the age pattern of the fertility differences between men and women is heavily influenced by gender inequalities and economic development (Dudel et al., 2023; Presser, 1975; Schoumaker, 2019). Given the sometimes considerable variation in economic development within countries (Scherbov & Gietel-Basten, 2020), the timing of fertility may also differ between men and women.

5.2 The birth squeeze

5.2.1 Concept and previous evidence

The term “*birth squeeze*” was introduced by Schoen (1985) to describe discrepancies in fertility rates between men and women in analogy to the “*marriage squeeze*”. A “*marriage squeeze*” occurs if there are differences in the marriage rates of men and of women; i.e., the marriage rates of one gender are lower than those of the other gender. This is usually assumed to be caused by imbalances in the population size, the age structure, and the age preferences of men and of women (e.g., Akers, 1967; Muhsam, 1974). These imbalances can arise from the same factors as those driving the differentials in the quantum of fertility described in the previous section. The assumption is often implicit that the “*marriage squeeze*” leaves some people who actually want to marry unmarried (Muhsam, 1974); that is, if the imbalances

leading to the squeeze were reduced, the differences in rates would also be reduced, and the involuntarily unmarried would marry, at least to some extent.

A birth squeeze is defined as a substantial difference in the fertility of men and women. For instance, a birth squeeze occurs if the TFR of women is substantially higher than the TFR of men, or *vice versa*. This difference is implicitly assumed to have implications for childlessness and birth counts. The present study will test this assumption for birth squeezes and examine the relationship between birth squeezes and childlessness in Finland (see Section 5.4.4).

There is little empirical research on the occurrence of birth squeezes, likely because birth squeezes at the national level seem to be rare, at least for high-income countries (Dudel & Klüsener, 2021). There are, however, some notable exceptions. Although the term birth squeeze was not used, Brouard (1977) reported substantial differences between male and female fertility in France after World War I, likely due to pronounced differences in war-related mortality. Schoen (1985) was the first to use the term when he found that abruptly changing cohort sizes led to a birth squeeze in England and Wales as well as the United States in the 1970s. Kravdal (2021) attributed the growing sex differences in childlessness in the last 15 years in Norway to fluctuating cohort sizes between the mid-1950s and the mid-1970s, although no reference was made to birth squeezes. Finally, sex-selective migration after reunification caused a birth squeeze in East Germany (Dudel & Klüsener, 2016; Klein, 2003).

Another potential reason why there is little empirical research on birth squeezes is that most of the literature only vaguely defines what level of difference in the quantum of fertility can be considered a birth squeeze, if at all. Generally, it is likely that differences in quantum will always occur, as the mechanisms causing them discussed in the previous section will be present in most cases, and they will not necessarily cancel each other out. This means that some threshold is required to determine whether there is a birth squeeze or just a minor difference in quantum.

In what follows, we will approach and operationalize the birth squeeze in two steps. First, we will discuss indicators that can be used to measure differences in the quantum of fertility between women and men. Second, we will provide a set of thresholds that allow us to determine if a quantum differential can be considered as indicating a birth squeeze. This set of thresholds will be developed from several ideas, including stable population theory and its relevance for downstream outcomes such as childlessness. While the focus of this paper is on subnational birth squeezes, the indicators and thresholds we discuss are generally applicable at the national level as well.

5.2.2 Indicators: measuring quantum differentials

We assess fertility quantum through the total fertility rate (TFR). The TFR is a widely used demographic measure that describes the average number of children a person would conceive under the fertility regime of a given year (period), if the person survives the entire reproductive period (Preston et al., 2008). It is calculated as the sum of age-specific fertility rates. Usually, it is preferred over crude birth rates, because it accounts for the age distribution. However, in our discussion below it could easily be replaced with any indicator that provides a measure of the average number of children, be it a period indicator or a cohort indicator.

We quantify gender differences in fertility quantum with the ratio of the TFR of men (TFR_m) relative to the TFR of women (TFR_w) (Dudel & Klüsener, 2019a): $R = \frac{TFR_m}{TFR_w}$. Values higher than 1 indicate that the TFR is higher for men than for women, while values below 1 indicate a higher TFR for women. The measure is comparable to other sex ratios in demography, such as the population sex ratio or the sex ratio at birth, and it can take values from 0 to ∞ . The TFR ratio is easy to calculate, to understand, and to interpret, and it is closely related to more elaborate measures; as discussed below. For instance, it can be applied as a scaling factor to the female TFR, enabling the calculation of the male TFR and providing

a clear and interpretable measure of the gap between the two. Furthermore, its data demands are relatively modest.

An alternative measure is the birth squeeze index U , as suggested by Schoen (1985). U is defined as $\frac{TFR_m - TFR_w}{0.5 \cdot TFR_m + 0.5 \cdot TFR_w}$; i.e., the difference in TFRs relative to the average TFR of men and women. It differs from the TFR ratio R by a multiplicative factor M and the constant 1. M is given by $M = 0.5 \cdot (R + 1)$. Then $U = \frac{R-1}{M}$ and $R = U \cdot M + 1$. This means that U and R will differ more if M is further away from 1. Given the approximation, the thresholds we provide below to determine a birth squeeze can be easily translated to apply to U , and we provide corresponding tables in the supplementary materials.

Several other approaches have been used in the literature to assess gender differences in fertility, for instance for childlessness. Kravdal (2021) estimated and decomposed the differences in the level of childlessness between 45-year-old women and men who are two years older. This approach requires data on the parity of the resident population, which are not available for other countries. Klein (2003) took a cohort perspective and found a higher probability of remaining childless among men than among women using German panel data. Therefore, we analyze gender differences in parity-specific fertility in Finland (see Section 5.4.4), which is, unfortunately, not possible for the other countries as parity-specific exposures are missing.

5.2.3 Thresholds: When is it a birth squeeze?

Before we describe different approaches to derive thresholds for high or low values of the TFR ratio, we first briefly discuss what value of the TFR ratio can be considered to be “balanced”. While a TFR ratio of 1 indicates that the TFRs of women and men are the same, and are in this sense balanced, some deviation from this value is to be expected. For example, assume that both the male and the female population have a rectangular age structure, but their population sizes differ because of the sex

ratio at birth. If the sex ratio at birth is 105 boys to 100 girls, then the TFR ratio in this population will be $1/1.05$, or around 0.95. Allowing the age structures to differ due to mortality, mortality differentials by gender will push the TFR ratio somewhat toward 1, as men usually experience higher mortality than women (Rogers et al., 2010; Sauerberg et al., 2023). More complexity could be introduced, but these examples show that typical demographic patterns will lead to TFR ratios deviating at least slightly from 1. We will nevertheless use a TFR ratio of 1 as a reference point, as it is straightforward to interpret; however, not all deviations from this reference are of substantive relevance, highlighting the need for thresholds.

Thresholds that specify what level of quantum differential can be considered a birth squeeze can be derived in several ways. We explore four different approaches: first, an expert-based approach, in which the threshold is derived from experts' assessments in the literature; second, a data-based approach, which determines empirical thresholds using outliers in observed TFR ratios; third, a stable population approach, which uses mathematical relationships and certain combinations of input parameters to determine the threshold; and, fourth, an outcome-based approach, which first empirically assesses to what extent TFR ratios are predictive of childlessness using regression modelling, and then uses regression parameters to find thresholds. A summary of the results for the different thresholds is provided in Table 5.1 at the end of this subsection.

Expert-based approach: First, the expert-based approach obtains thresholds from the existing literature. This assumes that the authors of previous studies had good reasons to choose the thresholds they used, regardless of whether they made the reason explicit. Dudel and Klüsener (2021) took the lowest TFR ratio reported by Schoen (1985) as a lower threshold: i.e., 0.89, which occurred in 1973 in England and Wales. Schoen (1985), in addition, described the TFR ratio of 1.12 in the United States in 1970 as relatively high, at least among high-income countries. Taken together, these observations would suggest that thresholds of 0.89

and 1.12 may be used. Coleman (2000) reported sex ratios between 0.91 (Denmark in 1988) and 1.1 (German birth cohorts from 1902 to 1928). Gulczynski (2023) did not study TFR ratios, but instead examined adult sex ratios, and suggested that deviations from 1 greater than ± 0.085 are rare and indicate gender-skewed populations. This leads to slightly narrower thresholds of 0.915 and 1.085. In what follows, we will use 0.9 and 1.1 as the expert-based thresholds, because these values fall in between the three variants, differing only slightly from each. Moreover, they are equivalent to rounding the TFR ratio thresholds from the literature.

Data-based approach: Second, the data-based approach builds on the observation made by Schoumaker (2019) that TFR ratios tend to be high if the TFR of women is high, and they tend to decline if the TFR of women declines. We utilize this pattern and integrate existing country-level data with a regression approach to identify thresholds for outliers. We estimate a Bayesian linear regression model of the TFR ratio on female TFR using country-level data from the register-based Human Fertility Collection (Dudel & Klüsener, 2021) and the survey-based as well as the UN-based estimates by Schoumaker (2019), which cover a wide range of low-, middle-, and high-income countries. The thresholds for birth squeezes are obtained from the 90% posterior prediction intervals; that is, TFR ratios that lie outside the range of likely values are considered to indicate a birth squeeze, conditional on the level of fertility of women. Using this approach, we find a lower threshold of $\exp(-0.161 + 0.304 \cdot \log(TFR_w)) - 0.12$ and an upper threshold of $\exp(-0.161 + 0.304 \cdot \log(TFR_w)) + 0.12$. Technical details are provided in the supplementary materials. This method relies on the assumption that the relationship at the national level holds at the subnational level, or at least is a good benchmark. Plugging in a value of the TFR of 1.5, which is typical for high-income countries, gives bounds of 0.843 to 1.082.

Stable population approach: Third, the stable population approach builds on the stable population approximation of the TFR ratio developed by Schoumaker (2019)

and Tucker and Van Hook (2013). In this approximation, the TFR ratio depends on the sex ratio at birth, the survival differential between men and women until the mean age at childbearing, the mean generation length for men and women, and the growth rate of the population. For each of these parameters, we use a set of input values that represent common demographic scenarios. For instance, we use values between 1.04 and 1.06 for the sex ratio at birth (Chao et al., 2019). We calculate the result of the equation for all possible combinations of input values. Then, we take the minimum and the maximum value resulting from this exercise as the lower and the upper threshold, which gives thresholds of 0.78 and 1.15, respectively. Technical details, including information on the input parameters and their derivation, are provided in the supplementary materials. This approach essentially derives what can be considered common TFR ratios based on common demographic scenarios, and it replaces the direct choice of thresholds for the TFR ratio with the choice of input parameters for well-known demographic characteristics.

Outcome-based approach: Fourth, the outcome-based approach identifies thresholds for TFR ratios based on their impact on individual-level outcomes. Here, we use childlessness as an outcome in the comprehensive Finnish register data. Specifically, we assess the impact of the TFR ratio at age 30 on the probability of men being childless at age 40 using a logistic regression model. Based on the coefficient estimates, we can calculate the difference from a TFR ratio of 1 needed to increase or decrease childlessness by 1 percentage point. Applying this difference to get both lower and upper thresholds yields values of 0.86 and 1.13, respectively. More details are again provided in the supplementary materials. Unfortunately, we can do the analysis of the impact on individual-level childlessness only for Finland and not for the other countries, and we have to assume that the results for Finland can be carried over to the other countries.

An overview of all thresholds is provided in Table 5.1. Overall, the upper and lower thresholds are close to each other across approaches, with some minor

Table 5.1: This table summarizes the different approaches to identify a birth squeeze and their respective lower and upper cut-offs for birth squeezes.

Approach	Reasoning	Lower	Upper
Expert-based (E)	TFR ratios in previous literature.	0.9	1.1
Data-based (D)	TFR ratios conditional on fertility level.	$\exp(-0.161 + 0.304 \cdot \log(TFR_w))$	
Stable population (S)	Sources of abnormal TFR Ratios.	0.78	1.15
Outcome-based (O)	Impact of TFR ratios on childlessness.	0.86	1.13

variation. This indicates that there is a small gray area in which the result will depend on the choice of threshold. Similar thresholds for the birth squeeze index of Schoen (1985) are provided in the supplementary materials.

5.3 Data

We calculate TFR ratios using birth counts and population exposure by age and by gender at the subnational level. In our final data, we have 5,278 region-year observations. For birth counts, we use vital registration data from Australia, Colombia, Finland, France, Germany, Mexico, and the United States. The coverage of years differs across countries, as do the size and the population density of the spatial units that make up the subnational level. For Finland, we can estimate fertility indicators for small spatial units (*fin.* Maakunta), while Australia and the United States provide only data at the state level with relatively large units in terms of area and/or population. The information for maternal age was complete for all births in all countries, while the information for paternal age was missing for 1-10% of the births. Missing information was imputed following Dudel and Klüsener (2019a). The population exposures are based on the two-year average of population counts for each age, gender, and regional unit (Wachter, 2014). Table 5.2 summarizes the data sources used in the study.

Generally, the data we use can be considered to provide high-quality information. First, the information is based on birth certificates, which are both mandatory and official documents. Legal enforcement minimizes case and item non-response.

Table 5.2: The table summarises the data used in the study, providing information on the country, the observation period, the spatial unit, the number of spatial units, and a link to the source.

Country	Period	Level	Units	Source
Australia	1990-2020	States, Territories	8	explore.data.abs.gov.au
Colombia	1998-2020	Departments	32	https://microdatos.dane.gov.co
Finland	1990-2020	Regions	19	https://www.stat.fi/
France	1989-2013	Departments	81	insee.fr/fr/statistiques
Germany	1990-2018	States	16	https://www.destatis.de
Mexico ^a	1990-2021	Regions	32	inegi.org.mx/programas/natalidad
USA	1969-2004	States	51	https://data.nber.org/nataliy/
Spain	1998-2020	Provinces	32	https://www.ine.es/

^a The time-series is not complete for all states. There is no information for Aguascalientes, Baja California, Baja California Sur, Campeche, Chiapas, Chihuahua, Ciudad de México, Coahuila de Zaragoza and Colima after 2015.

Second, birth certificates are issued shortly after birth, which reduces the risk of measurement error from recall bias. It also minimizes the risk of missing information on the father, as it is unlikely that the father has left the country, and the father is less likely to be neglected due to couple separation. The data quality may differ across countries due to different administrative procedures and reporting behaviors. Regardless, the male-female comparisons should be unaffected, because we include the exact same number of births in the male TFR as in the female TFR due to imputation of missing ages for men.

5.4 Results

5.4.1 Descriptive results

Figure 5.2 shows the male TFR and the female TFR for each region-year observation in our data; points above the diagonal line indicate that the TFR of men is higher than the TFR of women, and points below the line indicate a higher TFR of women. For instance, the point in the top-right of the figure is the region Chiapas in Mexico in the year 1990, in which men had a TFR of 9.01 and women had a TFR of 7.91. The TFR of men exceeds the TFR of women in about half of the region-year

observations, as the majority of points lie below the diagonal line (50%, 2,633 observations). The geometric mean of the TFR ratios across N regions is 1.005, indicating a higher TFR for men than for women. A second pattern emerges, as the gender differences are larger at higher levels of TFR and diminish as fertility declines. Larger gaps between the point and the diagonal line appear more toward the right part of the figure, while the points get closer to the line or even cross it at lower fertility levels. For instance, the average TFR ratio (geometric mean) for regions with a high fertility regime, i.e., a female TFR higher than 3, is at 1.164. In a substantial share of regions the TFR among women is higher than the TFR among men, as some points land below the diagonal line, especially those with low fertility. The average TFR ratio in regions with low fertility, i.e., the female TFR is below 2, is 0.975. Figure C.3 in the supplementary materials compares our subnational results with the existing country-level data. We find that the spread of male-female TFR ratios is larger at lower levels of fertility, while data from Schoumaker (2019) show a larger spread at higher fertility levels. While the data from Schoen (1985) and Dudel et al. (2021) and our own data land on a line, the data from Schoumaker (2019) deviate substantially from the line, which may be related to the practice of polygamy in some African countries or data quality issues with male fertility information in surveys (Joyner et al., 2012).

Moreover, male-to-female TFR ratios also depend on the characteristics of the subnational unit. Metropolitan and capital regions exhibit comparatively high male-female TFR ratios for the overall level of fertility. A simple regression analysis indicates that capital regions have a TFR ratio that is 0.04 higher than the TFR ratio in non-capital regions, holding the level of female TFR constant. For instance, the TFR ratio was 1.01 (2009) in the Australian capital Region, 1.06 in Washington D.C (in 2004), 0.95 in Berlin (in 2018), 1.05 in Île-de-France/Paris (in 2013), and 1.01 in Mexico City in 2020. In metropolitan regions, the TFR ratios are also higher relative to the fertility level, such as in Massachusetts, where it was 1 in 2004 or in

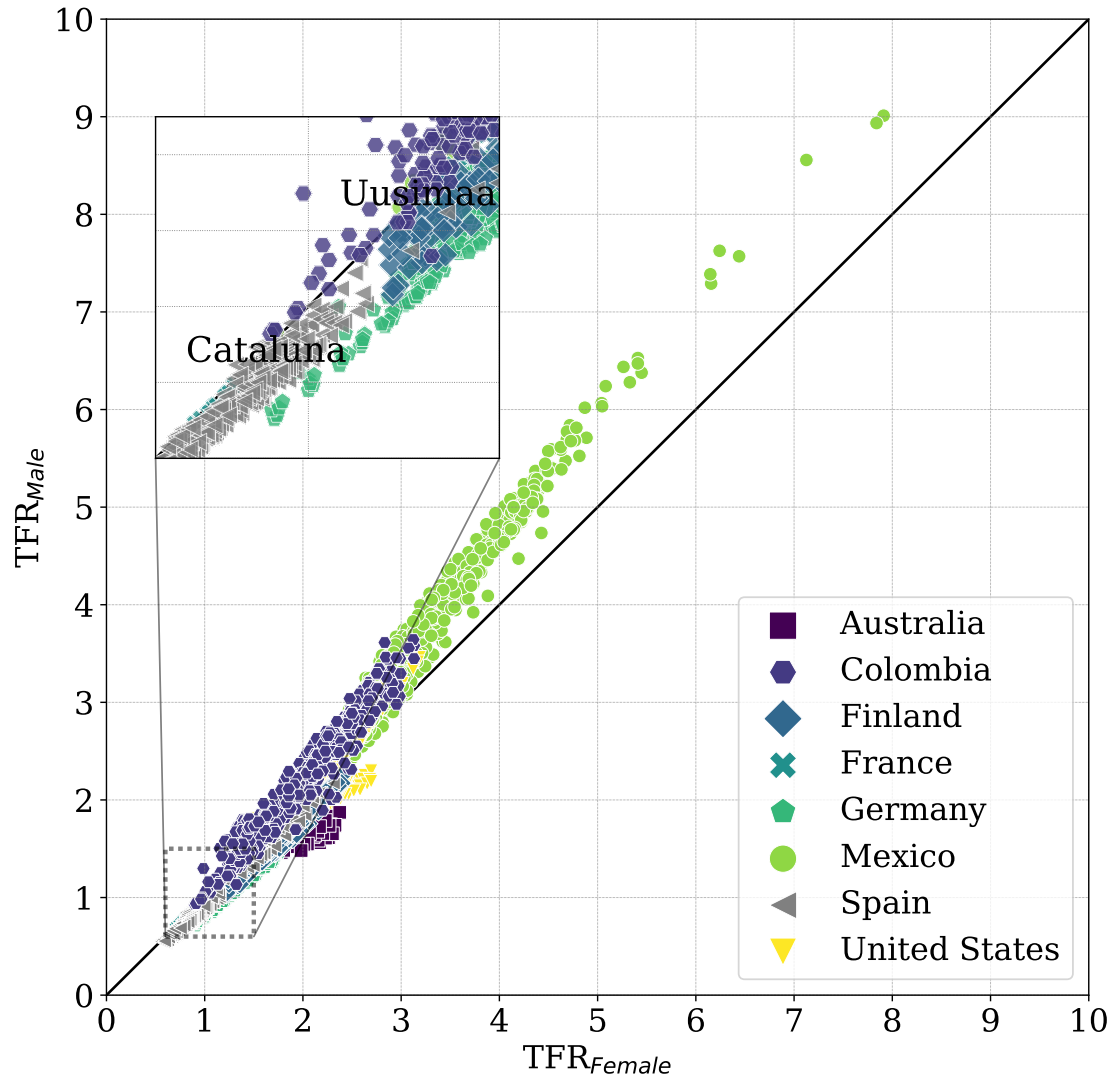


Figure 5.2: Gender differences in fertility quantum at the regional level. The figure shows the relationship between the TFR of women (TFR_w) displayed on the x-axis and the corresponding value for the TFR of men (TFR_m) in the same region in the same year on the y-axis. The lower the overall TFR of women the smaller the gender difference.

Hamburg, where it was at 0.99 in 2018. This pattern may be related to particularly delayed childbearing of women and female skewed population structures. The presence of universities and strong service sectors may lead to fertility postponement among women (Blossfeld, 2009), and may also specifically attract women, because women are more likely than men to enroll in tertiary education (Gulczynski, 2023).

Furthermore, some regions in Germany, Australia, and Spain exhibit idiosyncrasies. Eastern German states show particularly low TFR ratios (TFR ratio

< 0.85), which may be related to the highly female skewed outmigration after reunification (see Figure 5.3). As a consequence, the population structures are male skewed in East German states, which increases the size of the exposures for men relative to women, and therefore depresses the TFR of men. In more recent years, the gender difference in fertility may be sustained by the decline of cohort sizes resulting from the small cohorts born in the 1990s after reunification, e.g., the interaction of cohort changes and age patterns discussed in Section 5.1.1. The second case is the Northern Territory in Australia, which exhibits a similar pattern in terms of TFR ratios. Overall, the TFR ratio is very low, which may point to similarly skewed population structures. For instance, in this region, there are 11% more men than women in the 20-24 age group, which reduces the male TFR.

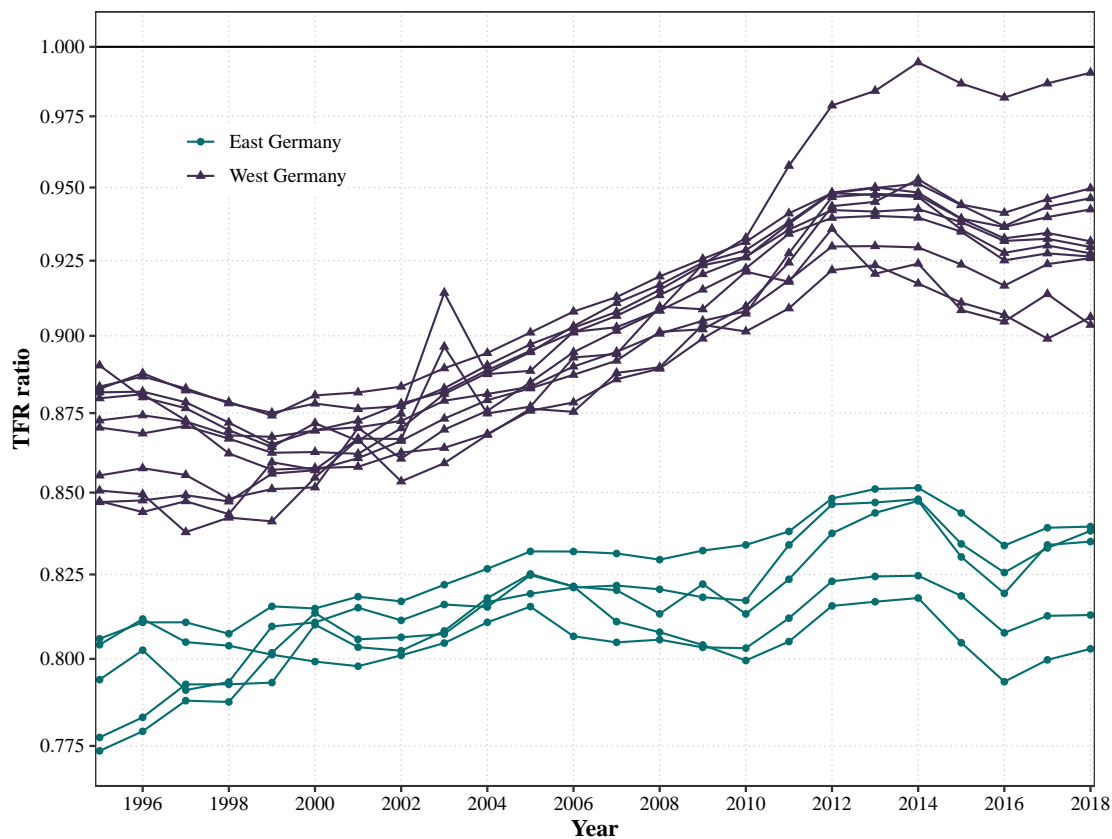


Figure 5.3: Male TFR / Female TFR ratio over time and across states (*German Bundesländer*) in Germany.

5.4.2 Temporal trends in the TFR ratios

Figure 5.4 shows TFR ratios over time for different subnational units across countries. Note that higher values indicate higher TFRs among men, while values below 1 indicate higher TFRs among women. The male-female TFR ratios follow different trends over time across countries. Australia, France, and Finland have stable levels of TFR ratios over time with some minor fluctuations up and down, although the levels differ markedly. The United States, Colombia, Germany, Mexico, and Spain exhibit noticeable temporal trends over the observation period. For instance, the male-female TFR ratios for West Germany have risen in recent years, particularly in city-states like Hamburg and Berlin, which suggests that the male TFR increased relative to the female TFR. Over the same period, the TFR ratios of the East German states stagnated at low levels. Therefore, instead of an East-West convergence, the polarization between East and West-Germany has been reinforced three decades after reunification. By contrast, in the United States, Colombia, Mexico and Spain, the TFR ratios have declined sharply over time. The TFR ratio decreased first in the United States in the 1980s, when the TFR ratios declined from above 1.1 to below 1. In Mexico, the TFR ratio declined from 1.18 in the 1990s to 1.06 in 2021. In Colombia, the regional TFR ratios converged to a level of 1.04 between 1998 and 2020.

However, some regions in Mexico and in Colombia have deviated from the larger country-level trend. Figure C.4 in the supplementary materials shows that the TFR ratios in some Mexican states actually rebounded between 2000 and 2010. These increases occurred in states with amplified cross-border migration to the United States and Canada, and mortality related to the war on drugs. Previous research has highlighted the demographic impact of the war on drugs on mortality (Aburto et al., 2016), but fertility seems to be affected as well. The impact of violence on TFR ratios is clearly observed through the impact on population exposures: first, by increasing mortality predominantly among men; and, second,

by increasing migration. This underscores the impact of external factors, such as exposure to conflict and its consequences, on the TFR and gender differences in the measure (Castro Torres & Urdinola, 2019; Keilman et al., 2014). In Colombia, some departments show TFR ratios while others have declining TFR ratios over time. As in the case for Mexico, this may be related to the internal armed conflict and migration. These findings persisted in our sensitivity analysis when we accounted for potential under-coverage of men in areas affected by armed conflict (see section C.4 in the supplementary materials).

5.4.3 Birth squeezes

Figure 5.5 shows the existence of birth squeezes; the region-year observations are represented as dots and the thresholds are represented as lines. The x-axis shows the TFR of women on a logarithmic scale and the y-axis shows the logarithm of the male-female TFR ratio. The various approaches to defining thresholds are distinguished by the colors of the lines, which yield disparate insights into the data. Furthermore, Figure 5.6 shows the country share of birth squeezes among region-year observations across measurement approaches. We discuss below which countries may be classified as experiencing a birth squeeze, and why.

The derivation of cut-offs for birth squeezes from previous research underpins the expert-based approach (orange line in Figure 5.5), which yields 1,724 observations (32.53 %) pertaining to the birth squeeze phenomenon, with a high concentration of birth squeezes in Mexico ($n = 586$, 57.28%), Germany ($n = 254$, 67.15%), and Colombia ($n = 358$, 48.44%). In Germany, for instance, the East German states of Brandenburg, Mecklenburg-Vorpommern, Saxony, Saxony-Anhalt, and Thuringia are consistently identified as experiencing birth squeezes, whereas a combination of birth squeeze and non-birth squeeze observations are found for the West German states. The occurrence of birth squeezes in Germany is likely attributable to two key factors: the migration of women from the East to the West German states

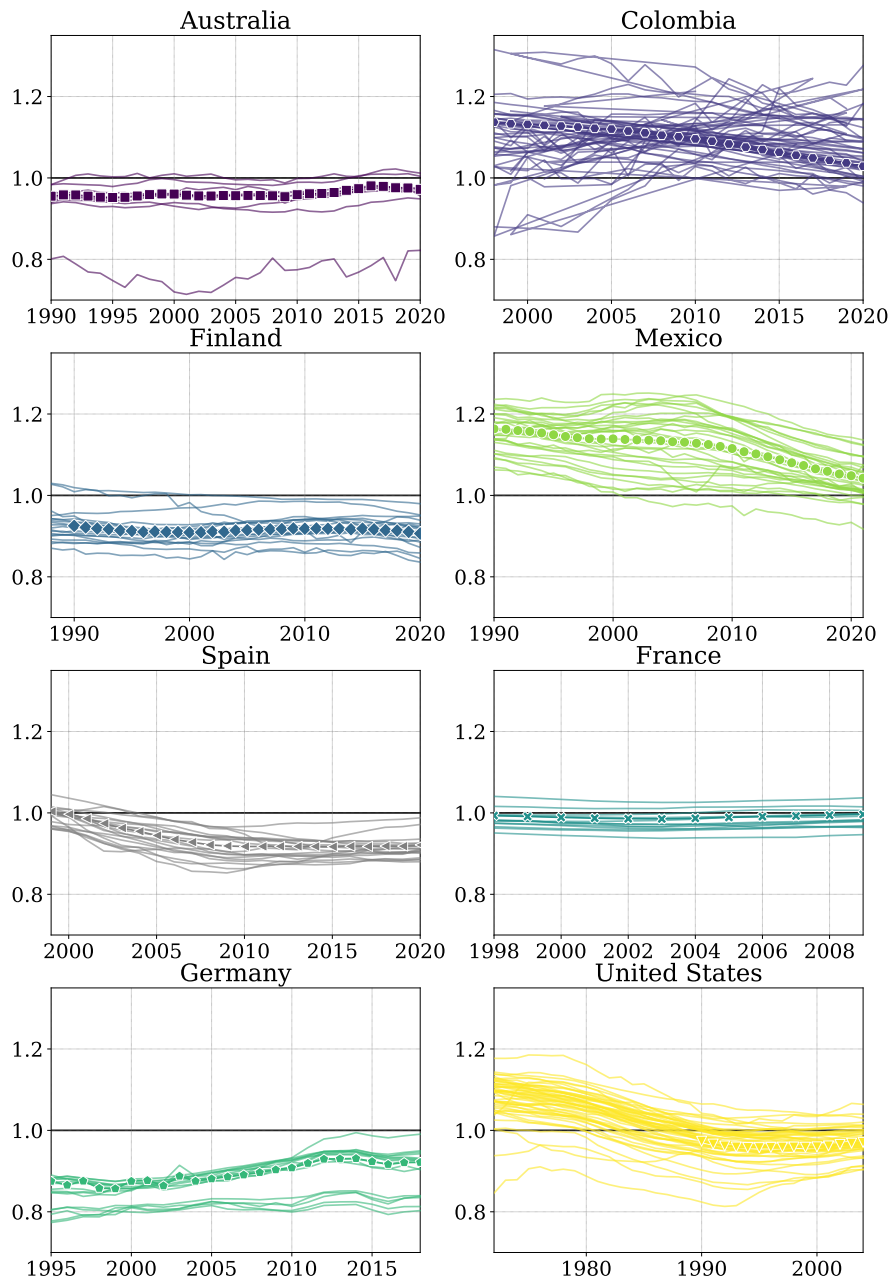


Figure 5.4: This figure displays the temporal trend of the male female TFR ratio over time across countries. The panels display the values for different countries. Note the different scales on the x-axis.

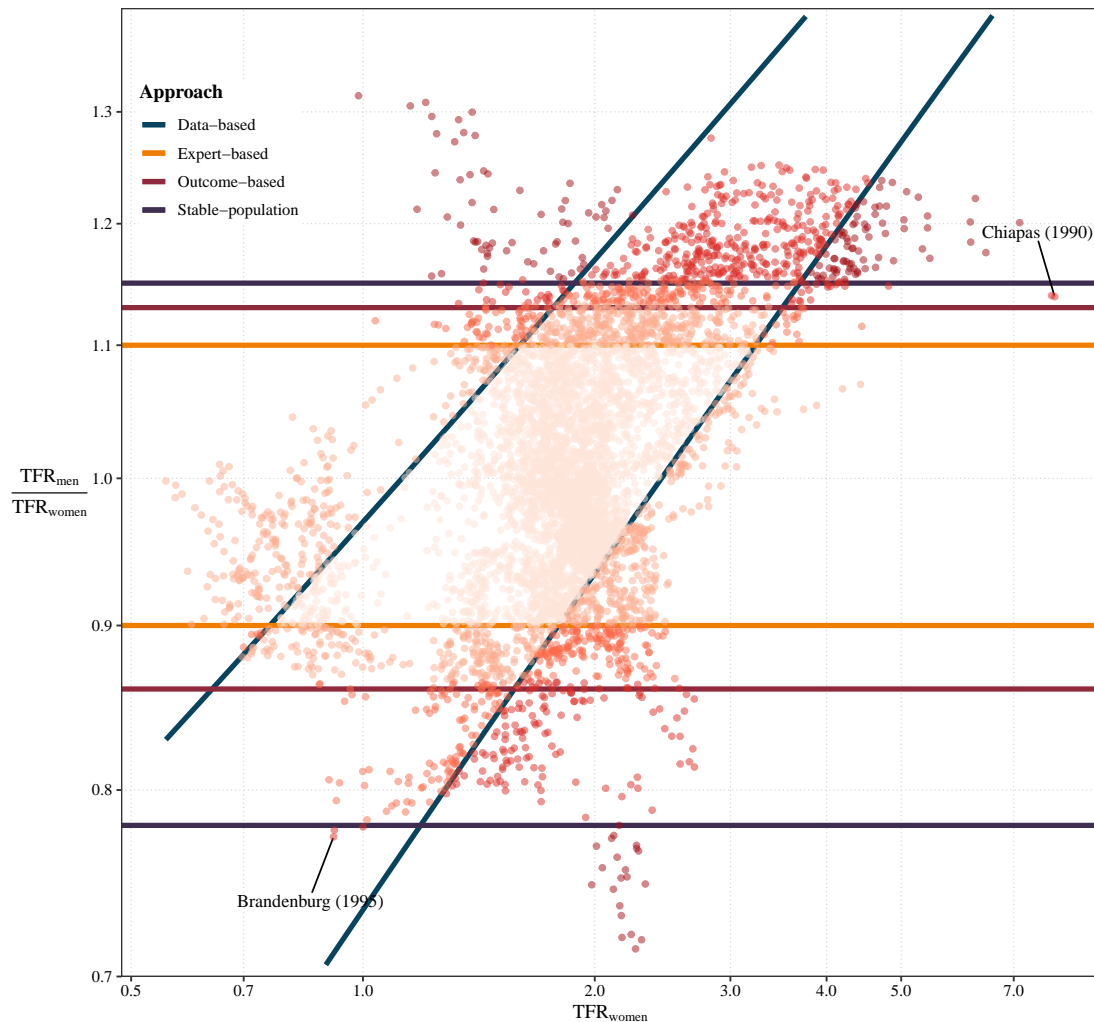


Figure 5.5: This figure displays the thresholds for detecting birth squeezes in a cartesian coordinate system showing TFR ratios (y-axis, logarithm) in relation to the TFR of women (x-axis, logarithm). The lines indicate the thresholds for the different threshold approaches of birth squeezes. The points are the subnational region-year observations and the colour coding of the points indicate how many thresholds classify the points as a birth squeeze, if zero it is not classified by any approach as a birth squeeze, and if it is four, all threshold approaches classify the observation as birth squeeze. For example, the point in the bottom left corner represents Brandenburg in the year 1995, where the TFR of women was 0.916 and the male-female TFR ratio was 0.774. In the top right corner lies the point for Chiapas in 1990, where the TFR of women was 7.91 and the male-female TFR ratio was 1.14. For a different representation of the data, see Figure C.5 in the supplementary materials.

and the sudden decline of birth cohorts in the 1990s. In Mexico and Colombia, the regions with high emigration and those that are affected by internal conflict are likely to be categorized as experiencing birth squeezes.

The data-based approach (gray line in Figure 5.5) accounts for the robust relationship between the fertility level and the male-female fertility differences, which classifies about the same number of region-year observations as birth squeezes as the expert-based approach ($n = 1587$, 29.94%). However, the pattern of birth squeezes is different from that observed in the expert-based approach, because it is relatively equally spread across countries (see Figure 5.6). Moreover, in a few cases the birth squeezes are shifted to other regions. For instance, Finland has a high prevalence of birth squeezes ($n = 283$, 45.14%). Finland exhibits a discernible central-periphery pattern, with the Helsinki region diverging from the other regions by not having any birth squeeze during this period. The eastern and northern parts of Finland exhibit a notable prevalence of birth squeezes, a finding that aligns with the conclusions presented in Schubert et al. (2024). Female-skewed birth squeezes appear to be concentrated at higher fertility levels, defined as a TFR for females exceeding 5. This is because most of the previous research analyzed country-level data, and found a steeper decline in TFR ratios with fertility levels than it is the case in our subnational data (see Figure C.3). However, some caution is needed here as the country-level data may be biased, particularly the data on male fertility based on survey estimates (Joyner et al., 2012).

The stable population approach (purple line in Figure 5.5) is more conservative regarding the identification of birth squeezes, which translates into few birth squeeze observations. The overwhelming majority of region-year observations are classified as exhibiting normal deviations ($n = 4802$, 90.6%), while only a negligible proportion demonstrate TFR ratios indicative of a birth squeeze ($n = 498$, 9.4%). The stable population approach is most effective in detecting birth squeezes in regions with rapid population change, such as those observed in Mexico and Colombia, where up

to 35% and 14% of region-year observations, respectively, are classified as such. In contrast, the occurrence of birth squeezes is infrequent in Australia (except for the Northern Territory), the United States (District of Columbia), Spain (Teruel), and Germany (Brandenburg, Saxony-Anhalt, Mecklenburg-Vorpommern). Therefore, it can be concluded that the approach detects significant outliers with regard to age-sex structure. All observations in the United States, Spain, Finland, and France fall within the normal range.

The outcome-based approach (red line in Figure 5.5) identifies a significant proportion of birth squeezes ($n = 910$, 17.17%), although the majority of region-year observations fall within the normal range ($n = 4383$, 82.83%). According to this approach, the most birth squeezes are found in Mexico (445, 43.50%), Germany (158, 41.15%), and Colombia (183, 24.76%). In Mexico, as much as 44% of the region-year observations are classified as birth squeezes, and the proportions are similarly elevated in Colombia (25%) and Germany (41%). In contrast, only a few birth squeezes are observed in the United States and none are observed in France.

France is notable for the small number of subnational birth squeezes across time, across regions, and across measurement approaches. These findings are consistent with research on the population structure in France, which has been very balanced between the sexes in recent decades (Breton et al., 2024). The balance of men to women may be attributed to the demographic history of France, which has influenced the population structure. Due to stable fertility rates, cohort sizes have changed only marginally and gradually. The TFR exhibited only small fluctuations between 1.8 and 2 over the past four decades. Moreover, the very low female mortality in combination with a noticeable mortality hump among males compensates for the sex ratio at birth (Breton et al., 2024). Finally, the population is more female than the EU average due to migration patterns (Breton et al., 2024). Migration from former colonies attracts both genders.

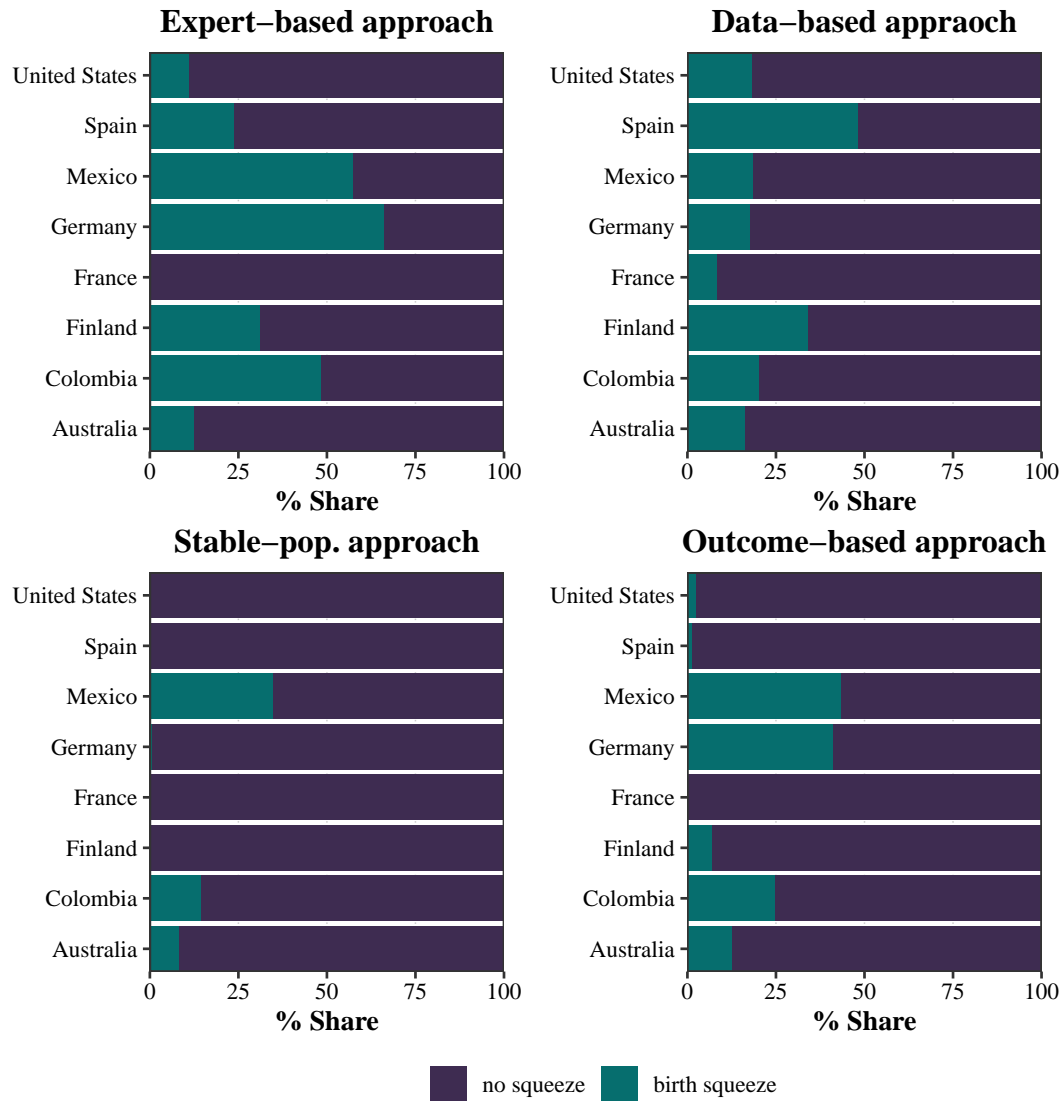


Figure 5.6: This figure displays the share of birth squeezes across countries. The yellow bar indicates the share of birth squeezes, whereas the purple bar illustrates the share of normal fluctuations.

5.4.4 Parity analysis for Finland

We exploit the richness of the Finnish register data by studying the gender differences in childlessness and parity-specific fertility. Our estimates, e.g., the parity-specific hazard-ratio between men and women across time ($hazardratio(t) = \frac{\gamma_m(t)}{\gamma_f(t)}$), region and age, show that the main gender differences pertain to the transition to first birth (more details in C.3). We thus proceed to discuss the results pertaining to gender differences in childlessness in greater detail, which are presented in Figure 5.7.

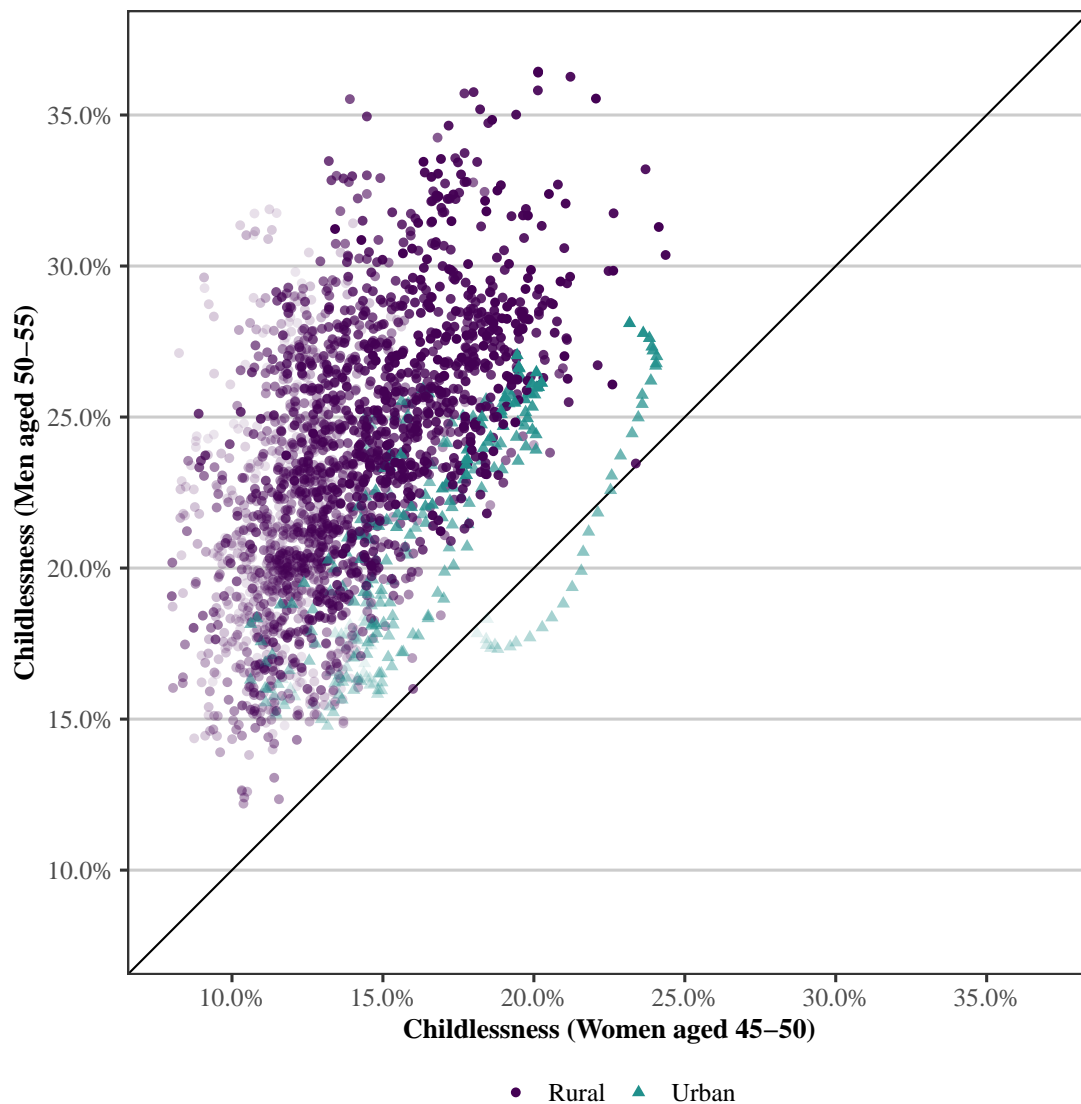


Figure 5.7: This figure illustrates the relationship of male and female childlessness across regions in the period between 1987 and 2020. The purple points represent rural regions and the turquoise urban regions. The transparency of the points indicates the time of the observation, showing more recent observations in stronger colours.

Childlessness among men is consistently and substantially higher than childlessness among women, as presented in Figure 5.7. The large majority of region-year observations are above the diagonal line, which indicates that childlessness is more frequent among men than women. Note that this observation even accounts for the wider fertility time window among men, as we compare the level of childlessness among men at ages 50–55 to their female counterparts at ages 45–50. The central-periphery pattern emerges again, which is highlighted by color, showing that the

gender differences are larger in rural areas and smaller in urban regions. Helsinki is the only region that had higher levels of female childlessness in some years, and thus falls below the diagonal line. The transparency highlights the temporal dimensions, showing more recent observations in darker colors. The temporal trend indicates that region-year observations have become less spread out and converged to a difference of about 8 percentage points.

5.5 Discussion

5.5.1 Main findings

In this paper, we examined gender differences in fertility at the subnational level over time and across countries. We systematically assessed whether these differences can be considered a birth squeeze; that is, a gender differential in the quantum of fertility that can be considered high. To measure differentials and birth squeezes, we employed the TFR ratio, i.e., the ratio of the TFR of men relative to the TFR of women. We revealed substantial differences between male and female fertility, and found that birth squeezes occurred in several countries. Intriguingly, the differences at the subnational level often exceed the national-level results. Capital and metropolitan regions often have relatively high TFR ratios, which may be related to female-skewed populations. The results for Australia, Colombia, Mexico and East Germany show that historical events, which skew population age-sex structures, can have strong impacts on gender differences in fertility. France stands out with balanced TFRs for men and women.

We argue for the use of the TFR ratio as an indicator of quantum differentials by gender, and developed a series of thresholds for the identification of birth squeezes. The TFR ratio is the ratio of the TFR of men relative to the TFR of women. Moreover, we have suggested several approaches to identify strong deviations in TFR ratios from unity, e.g., birth squeezes. These thresholds are derived from the literature (*expert-based approach*), from empirical patterns in country-level data

(*data-based approach*), from the demographic mechanisms driving TFR ratios (*stable population approach*), and from the potential impact on childlessness (*outcome-based approach*). While there is some variation in the thresholds, and thus in what levels of the TFR ratio can be considered to indicate a birth squeeze, the thresholds are mostly close to 0.9 as a lower bound and 1.1 as an upper bound, respectively. This is largely consistent with the thresholds used previously in the literature. Moreover, our findings on the occurrence of birth squeezes also match those from the previous literature; e.g., our findings for Eastern Germany match those of Dudel and Klüsener (2016) and our results for the United States are in line with those of Dudel and Klüsener (2021) and Schoen (1985).

More broadly, we find that fertility differentials at the subnational level, whether birth squeezes or not, are larger than those observed at the national level. This observation is in line with Dudel and Klüsener (2016), who found significantly larger differentials in Eastern Germany than in total Germany. Moreover, our subnational results on male-female fertility differentials are consistent with those from cross-country comparisons by Schoen (1985), Schoumaker (2019), and Dudel and Klüsener (2021). In line with Schoen (1985) and Schoumaker (2019), we find declining fertility differentials in all countries except for Australia and France. At low fertility levels, TFR ratio fluctuations support the country-level findings of Dudel and Klüsener (2021).

The results of our study indicate that population structures exert a considerable influence on gender differences in fertility rates. The most significant factor influencing gender differences in fertility appears to be the population growth rate, which impacts the change in subsequent cohort sizes due to the decline in TFR ratios associated with the female TFR. Another noteworthy observation is the tendency for capital regions to exhibit relatively high TFR ratios compared to the level of female TFR, which may be attributed to the presence of a large tertiary sector and a well-developed education system. Additionally, regions with distinct

cultural or economic characteristics often have higher TFR ratios, as evidenced by examples such as Massachusetts and the Northern territory in Australia.

Beyond these common patterns, the demographic history of countries and regions is reflected in their TFR ratios. For instance, regions in Mexico and Colombia, which were affected by conflict related-mortality and substantial cross-border emigration, show high TFR ratios and even reversals of the narrowing of the gender difference in fertility. Moreover, Eastern German states exhibit considerably lower fertility rates for men than for women, which may be related to the gender-selective migration in conjunction with declining cohort sizes. This has meaningful implications, as the record low TFR of 0.703 was observed for men in Brandenburg in 1995, which is substantially lower than the value for women in Brandenburg in that year (0.772) and the record low TFR at the country level in South Korea of 0.72 (2023).

Furthermore, parity-specific analysis for Finland revealed that the most-robust gender differences exist for the transition to first birth, with women having a higher risk relative to men (Chudnovskaya & Ueda, 2021; Kravdal, 2021). This also translates into a robust gender difference in ultimate childlessness, as childlessness is more widespread among men across almost all region-year observations. However, at higher ages and higher parities, men also show higher relative birth risks, which may be related to the more gradual age-related decline in fecundity among men (Hassan & Killick, 2003).

5.5.2 Strengths and limitations

The data we use in this paper come with challenges. First, the subnational units vary strongly in terms of population size and surface area, making cross-country comparisons difficult. Nonetheless, the variation in spatial units also allows us to examine how the level of analysis may impact the results. Second, data quality may vary across countries and over time. This problem is particularly relevant for regions affected by internal conflicts, such as regions in Mexico and Colombia. Finally,

variations in subnational age-sex population structures might reflect a delay in household registration or job-related migration. Moving from one region to another within the same country may not result in immediate registration of a new residence, which could distort demographic data. Consequently, some age-sex population structures might be data artifacts rather than accurate demographic representations.

Our key indicator is the TFR ratio. It is straightforward to calculate and easy to interpret. However, a potential drawback is that changes in the numerator (male TFR) and the denominator (female TFR) affect it differently. That is, an increase in the TFR of men by a certain amount δ will not have the same effect as the same increase in the TFR of women. Relatedly, inverting the TFR ratio and using the TFR of men as the reference can lead to inconsistent results when thresholds symmetric around 1 are used. If, for instance, the thresholds are 0.9 and 1.1, then a TFR ratio of 1.11 will be considered a birth squeeze; while its inverted value, $1/1.11$, is slightly above 0.9 and thus is not a birth squeeze. Finally, TFR ratios are period measures, using the concept of a synthetic cohort. This means that the findings do not readily translate to any lived experience by real cohorts. If the fertility of one sex is substantially lower than the fertility of the other in one year, this gap could be compensated for over the span of their reproductive life course. Nevertheless, Klein (2003), Kravdal (2021), and Schubert and Dudel (2025) have demonstrated that regional population imbalances affected the number of children born in the more abundant sex, and in this paper we also linked the TFR ratio to childlessness.

We combine the TFR ratio with a series of thresholds to determine birth squeezes. These thresholds are not without issues. The expert-based thresholds partly pick up at least seemingly arbitrary choices from the previous literature. The data-based approach might be problematic if many observations from the input data are actually affected by birth squeezes, as this approach would classify these as not affected by a birth squeeze. The assumptions of the stable population approach are very simplifying, and in particular ignore migration, which seems to be a key

driver of fertility differentials. Finally, the outcome-based approach only builds on Finnish data, and requires the assumption that findings for Finland also apply in other, sometimes very different contexts. Despite these limitations, however, these heterogeneous approaches lead to relatively consistent thresholds.

5.5.3 Outlook

Our findings underscore that there is not just one number summarizing the state of fertility, but one for men and one for women, which can diverge substantially at times. Therefore, we encourage publishing the TFR of men along with the TFR of women, and argue that empirical analysis should use both the TFR of men and the TFR of women, as showcased in Schubert et al. (2024). An avenue for future research is the development and application of two-sex fertility measures, in line with work by Keilman et al. (2014).

We detected the existence of subnational birth squeezes across eight middle and high-income countries, but there is reason to expect that similar imbalances would be observed in other countries around the world. For instance, gender differences in fertility might be even more widespread and even larger in countries simultaneously experiencing sudden fertility declines and high SRBs, such as China (SRB in 2017 = 1.1143) and India (SRB in 2017=1.098) (Dyson, 2012). Subnational migration related to education, marriage prospects, and employment may reinforce these gender imbalances (Edlund, 2005; Gupta, 2010). Moreover, while we have linked birth squeezes to increased levels of childlessness, further studies on the demographic and socio-economic consequences of a birth squeeze would be valuable.

It is a truth universally acknowledged, that a single man in possession of a good fortune, must be in want of a wife

Jane Austen - Pride and prejudice

6

Regional partner markets and male childlessness

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This chapter is co-authored with Christian Dudel and an earlier version is published under <https://www.demogr.mpg.de/papers/working/wp-2024-010.pdf>.

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Levels of childlessness have been rising steeply in the Nordic countries (Jalovaara et al., 2019; Zeman et al., 2018), particularly among men. For instance, in Finland, childlessness among men aged 40 to 44 has increased continuously from 19% in 1990 to 29% in 2022, and it exceeds the corresponding levels for women by about 10 percentage points. The increase in childlessness has been a key driver of declines in Nordic fertility since 2008 (Hellstrand et al., 2020, 2021; Jalovaara et al., 2019). High fertility rates in the Nordic region before 2008 have been attributed to these countries' generous welfare states in general and family policies in particular as well as to their progress in terms of gender equality (Duvander et al., 2010). This leaves the development after 2008 largely unexplained, including trends and levels in childlessness.

Most research on childlessness focuses on women, even though the levels for men exceed the levels for women (Tanturri et al., 2015). Among the strongest predictors for childlessness among men are the absence of a romantic relationship and relationship instability (Andersson, 2023; Jalovaara & Fasang, 2017; Rahnu & Jalovaara, 2023; Saarela & Skirbekk, 2020). The importance of partnerships is also reflected in the individual perceptions of childless male Finns, with the majority of them giving not having found a suitable partner as the primary reason for being childless (Miettinen, 2010). The role of relationship histories for childlessness raises questions about the structural determinants of partner availability (Miettinen, 2010). Regional partner markets are crucial determinants of the likelihood of having a partner (Eckhard & Stauder, 2019; Häring et al.,

2014; Ní Bhrolcháin & Sigle-Rushton, 2005; Stauder, 2011; Stauder & Eckhard, 2016; Stauder & Röhlke, 2022; Ugglá & Mace, 2017). Thus, imbalanced partner markets - that is, partner markets in which it might be difficult for men to find a partner due to structural constraints - could be an important driver of childlessness. Such structural constraints might also influence the socioeconomic gradient in childlessness, as childlessness is disproportionately concentrated among males of low socioeconomic status and the link between socioeconomic status and childlessness has grown stronger over time (Bratsberg et al., 2021; Jalovaara et al., 2019).

This paper examines whether regional partner markets are associated with male childlessness at the individual level in Finland. These regional partner markets are structurally determined by the regional population structure. In particular, we investigate whether regional imbalances in the age-sex-education structure drive Finland's male childlessness levels using Finnish population register data for the years 1987 to 2020. We estimate several partner market measures at the subnational level to assess the partner market opportunities over time and across regions. These metrics encompass factors such as the demographic distribution of the opposite sex, the level of competition for potential partners, and individual preferences for partner characteristics regarding age and education. In a second step, we use these measures to model the relationship between the partner market situation throughout the life course and being childless at the end of the reproductive period. The main specification regresses being childless at age 45 on the average lifetime partner market measure. Moreover, we estimate several additional models, including sibling fixed effects models, to account for potential issues such as unobserved heterogeneity and model misspecification, as well as discrete time survival models.

In line with recent findings from Gulczynski (2023) and Menashe-Oren and Sánchez-Páez (2023), we hypothesize that regional partner markets may have become unfavorable for Finnish men as a result of several interrelated processes. We therefore argue that the regional context is a crucial factor in the debate on contemporary

fertility and childlessness. Changes in the economy and society may contribute to sex-selective migration, given that jobs and educational institutions are not evenly geographically distributed. Together with increasing educational attainment and employment levels among women, these developments can cause migration pattern of men and women to diverge. Urban areas are becoming the main destinations for women, because they are more likely to be enrolled in tertiary education or to be working in service sector jobs, which are usually concentrated in cities. By contrast, men are more likely to be employed in the agriculture and manufacturing industries, which are more often located in rural areas. Thus, the geographic dispersion of jobs and educational institutions might be the underlying driver of sex differences in mobility, which may, in turn, increase the subnational heterogeneity of partner availability. Moreover, improved education and public health campaigns have reduced the mortality hump among males, which has narrowed the sex gap in mortality. Thus, the male surplus resulting from the skewed sex ratio at birth (SRB) is now sustained throughout the life course.

There are multiple potential mechanisms connecting partner markets to childlessness. Research has shown that partner markets with sex imbalances reduce mating chances (Eckhard & Stauder, 2019; Häring et al., 2014; Ní Bhrolcháin & Sigle-Rushton, 2005; Stauder, 2011; Stauder & Eckhard, 2016; Stauder & Röhlke, 2022; Ugglá & Mace, 2017) as well as the quality of the matches between partners (Lyngstad, 2011). Partner markets also affect relationship quality (Stauder & Röhlke, 2022), have implications for the division of roles within partnerships (Stauder & Röhlke, 2022), and are theorized to relate to the risk of separation (Becker, 1977). Lower union formation rates and lower union quality may lead to higher childlessness in the population (Rijken & Liefbroer, 2009). Moreover, we hypothesize that a lack of partners could increase childlessness among men with low socioeconomic status in particular, as they have less resources to cope with the heightened competition on the partner market (Stauder & Kossow, 2021).

This paper adds to the existing literature on partner markets and childlessness by providing the first micro-level analysis of regional partner markets and male childlessness. Previous work in this area has often focused on the macro level and on women. As results based on macro-level data might be driven by compositional change, they may not translate directly to the individual level, and might not be able to capture the effects of partner markets that unfold over the life course. Moreover, results for women do not represent the experiences of men, as male and female fertility have long been known to differ, in some cases quite substantially (e.g., Dudel et al., 2021; Schoumaker, 2019). Moreover, we address two methodological issues. First, we use several indicators to quantify the partner market situation in a specific region at a specific time. Filser and Preetz (2021) and Eckhard and Stauder (2019) demonstrated that the measurement of partner markets has implications for results on partnership formation and individual perception of partner markets. Hence, using a variety of indicators allows us to assess the stability of the results. Second, we address the modifiable areal unit problem (Openshaw, 1983). Administrative boundaries rely on arbitrarily drawn spatial units, which produce measurement error and might affect the results. Aggregating fine-scaled data at the municipality level based on spatial proximity allows us to reduce this arbitrariness, and to improve the ability of the measure to capture the spatial proximity of partner markets.

6.1 Background

6.1.1 Partner search and markets

Oppenheimer (2000; 1988, 2003; 1997) conceptualized the complexities of the partner search by drawing inspiration from job search theory. Individuals, guided by rational decision-making to maximize utility from potential partners, navigate uncertainties using a reservation value as a heuristic. This value sets a minimum standard for accepting a match, guiding the search until a qualified match is found.

The individual partner searches are embedded in wider partner markets. The partner market serves as a sociological concept that helps to explain the dynamics of partnership formation (Haandrikman, 2019; Haandrikman et al., 2008; Uggla & Andersson, 2018). At its core is a twosided search process, in which both parties must mutually agree to form a partnership (Van Bavel, 2021, p. 220). This market perspective connects individual-level partner search behaviors with larger demographic trends. Imbalances in partner markets, influenced by boundedness, preferences, availability, and competition, significantly shape and constrain individual partnering decisions.

Mate selection unfolds within a spatially bounded area (Haandrikman, 2019; Haandrikman et al., 2008); though online dating has the capacity to modify these spatial constraints. Preferences, especially in terms of age (Kolk, 2015; Skopek et al., 2009), income (Chudnovskaya & Kashyap, 2020), and education (Mare, 1991; Skopek et al., 2011), exert a profound influence on individual partner searches. Assortative mating, reflecting age and education cues, results in non-random partnering patterns across time and countries (Ausubel et al., 2022; Schwartz, 2013). Partner markets due to factors such as sex ratios at birth, cohort sizes, and mortality differences (Eckhard & Stauder, 2019) have socioeconomic implications for individual mating decisions and union formation.

6.1.2 Effects of unbalanced partner markets on fertility

The influence of partner markets on fertility operates through various channels, including partner availability and other mechanisms. Initially, partner markets contribute to the rates of union formation. In regions where one gender is more prevalent, heightened competition and a limited pool of available options can impede mating opportunities. As a result, less favorable partner market conditions may reduce individuals' chances of attracting and forming relationships. Previous research has consistently shown that a scarcity of available partners impedes

partnership formation. Research conducted in the United States has highlighted how imbalances in partner markets affect marriage rates (Akers, 1967; Albrecht, 2001; Albrecht et al., 1997; Lichter et al., 1991, 1995, 2020; Pollet & Nettle, 2008). Similar trends have been observed in Mexico (Parrado & Zenteno, 2002) and Europe (Inoue et al., 2013; Klein & Stauder, 2015; Stauder, 2008, 2011; Stauder & Eckhard, 2016), where imbalanced partner markets contribute to reduced union formation rates.

Second, it has been suggested that a scarcity of available partners in the market could impact matching quality. Increased competition and limited options may lead individuals to select a partner quickly, without fully knowing the person's characteristics (Oppenheimer, 1988). Research exploring the impact of partner availability on matching quality has indicated that educational mating is influenced by the opportunity structure within the partner market (Grow & Van Bavel, 2015; Stauder & Kossow, 2021; Van Bavel & Nitsche, 2013; Van Bavel et al., 2018). As well as increasing the risk of relationship dissolution, lower matching quality may reduce the likelihood of transitioning to parenthood (Rijken & Liefbroer, 2009).

However, partner markets can have also the opposite effect, as an excess of available partner can disrupt existing partnerships through several mechanisms. As Becker (1973) has argued, an abundance of potential partners in a region can destabilize partnerships, as having alternative mating options has been identified as a primary reason for union dissolution. Several studies, such as Rapp et al. (2015), have found that increased partner availability and interactions with the opposite sex elevate the risk of separation. Additionally, according to exchange theory, the partner of the scarcer gender may possess heightened bargaining power within the union, and could leverage this advantage (Guttentag & Secord, 1982; South et al., 2001; Stauder & Röhlke, 2022). This power dynamic increases the risk of union dissolution (Lyngstad, 2011; South & Lloyd, 1995), and may decrease the likelihood of having children (Fostik et al., 2023), thus representing a mechanism in the opposite direction. However, the empirical results regarding the relationship

between union dissolution and partner availability in the regional context are mixed (Lyngstad, 2011; Obersneider et al., 2019).

Finally, unbalanced partner markets may alter the socioeconomic gradient of childlessness rendering groups with fewer resources childless. By benefiting from their increased market value, members of the scarcer sex can seek higher-value partners (Becker, 1981), while members of the abundant sex have to contend with intensified competition. Unbalanced partner markets tilt the scale in favor of individuals with greater resources and higher market value, thus contributing to an elevated prevalence of childlessness, especially among men with lower educational and income levels. Empirical studies have consistently supported the notion of amplified selection for members of the abundant sex (Pedersen, 1991; Schacht & Kramer, 2016). For example, Van Bavel and Nitsche (2013) and Grow and Van Bavel (2015) discovered that the reversal of the educational inequality gap reduced partnering opportunities for low educated men. Consequently, we hypothesize a deepening of the socio-economic gradient in male childlessness in areas with a surplus of men.

6.1.3 Previous research

As early as the 1970s, demographers were discussing disparities in the sizes of male and female populations, which coincided with the divergence of fertility rates between the genders at the national level. These discrepancies resulted from imbalances in sex ratios, which were influenced by events such as World Wars I and II, as well as abrupt shifts in cohort sizes during the transition from the baby boom to the baby bust era (Akers, 1967; Brouard, 1977; Muhsam, 1974; Schoen, 1983, 1985). While these observations prompted speculations that variations in age-sex structures would inevitably lead to sex-specific differences in reproduction, scholars primarily focused on fertility rates, rather than specifically exploring childlessness.

The few existing studies on childlessness support the assumption that the further the sex distribution is from equilibrium, the higher the levels of childlessness in the

larger gender group will be. Across most countries, men are more likely than women to remain childless. Chudnovskaya and Ueda (2021) have estimated that 10-20% of the sex-difference in childlessness in Sweden is due to population imbalances. Similarly, it has been shown that the higher levels of male childlessness in Norway can be largely attributed to population imbalances (Kravdal, 2021). However, these results are based on national-level data, which may overlook substantial subnational heterogeneity in partner availability. Existing studies on Finland have shown that male childlessness is higher in regions, where men outnumber women (Lainiala & Miettinen, 2013), and, conversely, that there is a positive association between female childbearing and a surplus of men (Pettay et al., 2021).

6.2 Trends in Finland

6.2.1 Partner markets in Finland

We argue that the impact of population imbalances on partner markets is likely to be specifically large in Finland due to its population sparseness. Low population densities may reinforce the effect of unbalanced partner markets because the impact of sex-selective migration is amplified when the overall numbers of inhabitants are low. When one person moves out, the impact on the population structure is larger in areas with sparse population. This claim is further supported by previous research indicating that a low population density strengthens the link between imbalanced partner markets and union formation, possibly due to the reduced visibility of potential partners (Stauder & Röhlke, 2022). Finland's 5.5 million inhabitants are spread over an area of 338.445 km^2 , which translates into a population density of around 16 inhabitants per km^2 . This makes Finland the third least densely populated country in Europe.

Beyond its geographic setup, recent macro-sociological trends may affected partner markets in Finland - and, by extension, the childbearing opportunities of Finnish men. First, the number of women has exceed the number of men in the

highest educational category since the cohort born 1955-1959. Moreover, this gender gap in education has been widening, as shown in Figure D.1 in the supplementary materials. The reversal of the gender gap in education may have had two implications for the partner search of men. First, as universities are located in urban areas, the reversal of the gender gap might have resulted in sex-selective migration, assuming that students move to the areas where the educational institutions are placed. Gulczynski (2023) found that the higher the population density is in Finland, the less male skewed the population is. Second, as education hypergamy and homogamy (the woman has the same or lower level of education than the partner) have long been prevailing pattern, the reversal of educational inequality could produce a mismatch in the population, which might further squeezes the partner market.

Second, the economic structure may affect regional partner markets in Finland given the uneven sex distribution across occupations. Women tend to concentrate in the service sectors, while men are more heavily represented in industrial sectors, as depicted in Figure D.2 in the supplementary materials. For instance, large shares of women are working in human health and social work activities (15%), trade (5%) and education (5%), while substantial shares of men are employed in manufacturing (9%) and construction (6%). These sex differences in the occupational distribution may also have an imprint on the geographic distribution of the two sexes, as female-dominated branches are mainly located in urban areas, producing sex-selective migration.

6.2.2 Childlessness in Finland

Childlessness in Finland is higher than that in other countries, and it has been increasing over recent decades, particularly among men (Jalovaara & Fasang, 2017; Jalovaara et al., 2022; Rotkirch & Miettinen, 2017). Childlessness among women at age 45 increased from 13% in 1990 to 19% in 2022. The levels for men at the same age surpass those for women by 10 percentage points, with childlessness among men

increasing from 19% to 29% in the same period. At least for men, increasing fertility postponement may inflate these findings, given that male childlessness levels might be lower at older levels. Nonetheless, the numbers show a clear trend. Studies that have investigated this phenomenon have found that among the strongest predictors of childlessness are the late entry into a union and unstable unions (Jalovaara & Fasang, 2017; Saarela & Skirbekk, 2020).

A recent study by Jalovaara et al. (2022) found two types of polarisation in childbearing behaviour in Finland. First, there is a polarisation in childlessness between individuals with low and high education, with childlessness being less common among highly educated men and women (Jalovaara et al., 2019, 2022; Nisén et al., 2014). The second polarisation occurs within the low educated stratum, in which both childless people and people with many children are becoming more numerous. This form of polarisation may point to a strong selection into union and mating for men with low SES. Among low-educated women and men with many children, multi-partner fertility is a frequent phenomenon (Jalovaara et al., 2022).

6.2.3 Research questions and expectations

The study mainly aims to examine *the relationship between lifetime partner market exposure and childlessness among men*. To do so, we assess the development of partner markets in Finland between 1990 and 2018. The male share in the population may be increasing, because both more men than women are born on average and overall sex differences in mortality at young ages have vanished. This trend might be heterogenous across regions because of sex-selective migration. Hence, we look at *the trend in the ratio of men to women, examining whether this trend is accentuated particularly in rural areas that continue to have a male-dominated demographic composition*. Partner markets affect the probability of union formation, the quality of matches and relationship stability. Therefore, we investigate whether *the probability of men remaining childless increases in areas with excess men*. Furthermore, partner

market imbalances increase the competition for partners. Therefore, we expect to find that *in areas where men outnumber women, men's transition into fatherhood is more selective depending on their socio-economic characteristics.*

6.3 Data & Methods

6.3.1 Administrative registers

Throughout the analysis, we use Finnish register data provided by Statistics Finland covering the period between 1987 and 2020. The data contains all individuals who are registered in Finland on the last day of each year. We restrict our sample to Finnish cohorts born in the years 1968-1975 because we can observe their full reproductive and residential histories from age 18 to age 45. The final data form a pooled cross-section of these cohorts, which consists of Finnish-born men aged 45. The cumulative sample contains 194,080 men.

We restrict our analysis to Finnish-born men for three major reasons. First, childbirth outside of Finland is not captured in the data; thus, for men who enter Finland after the beginning of the reproductive phase, it is not clear whether they are childless, even if they have no birth in Finland. This issue also applies to Finnish-born men if they leave the country and return at a later time, but it is much less likely to be relevant for them. Second, homogamous partner preferences with respect to country of birth or nationality might be perceived as particularly important by migrants, which implies that regional partner markets could work differently for migrants than for natives (Elwert, 2020). Finally, it may be assumed that some migrants maintain relationships to their country of origin, which makes partner markets outside of Finland more relevant for them.

6.3.2 Measuring regional partner markets

In looking at how regional partner markets relate to childlessness, we need to assess a person's exposure to partner opportunities over the life course. This involves

making some important decisions. First, we have to select an indicator for partner availability and decide what it considers (e.g., education). Second, we have to decide what “regional” means by setting clear boundaries when creating the indicator. Lastly, we have to find a way of aggregating the indicator over the entire life course. The following sections explain these steps in more detail.

Our focus in this study is on the relationship between lifetime partner market exposure and childlessness. The lifetime exposure is captured by aggregating the age-specific partner market indicator over the life course. This approach is less volatile than including age-specific partner market measures. In addition, it more closely reflects the theoretical argument that the partner search unfolds over the life course. Nonetheless, a potential disadvantage of this approach is that the partner market condition during periods when an individual is in a relationship affect the outcome. Moreover, it is a crude measure of the partner market. We estimate the average value of the partner market indicator for the ages between 18 and the age at first conception (the year before first childbirth), or between ages 18 and 45.

When measuring partner market indicators, we need to define the spatial boundaries of the area we are measuring, and who is counted within these boundaries. Previous research on regional partner markets relied on administrative boundaries to define the borders for partner markets. However, this approach, which is illustrated by the grey dashed line in Figure 6.1, can lead to measurement error when individuals reside close to the border of the administrative unit, because neighbouring regions may serve as partner markets for them. Thus, partner markets based on large administrative units do not reflect the spatial proximity. This is a case of the modifiable areal unit problem (MAUP), which states that while spatial units are modifiable and subject to whoever did the aggregating, they can have a strong impact on results (Openshaw, 1983).

To overcome this limitation, we move the analysis to the lowest spatial granularity in the data, which is the level of municipalities ($n = 309$). We aggregate the

population data for the specific municipality and all others with a border within a certain distance to the municipality of interest. This yields a spatial pattern, as visualized by the solid black line in Figure 6.1. We selected a distance of 9.2 kilometers for the aggregation based on the study by Haandrikman (2019), which reflects the average distance of partner choice in a study on Sweden. Although we are examining Finland, not Sweden, the cultural and geographic similarities between the two countries lead us to use believe that the value may serve as a reasonable approximation of the geographic distance for partner selection. To account for the uncertainty embedded in this decision, we have re-estimated the models using 0 kilometer (which encompasses all neighbouring municipalities) and 20 kilometers as alternative distances, which yielded similar results (see also supplementary materials D.9).

The main partner market indicator in our analysis is based on the availability ratio of Goldman et al. (1984), see also Stauder (2008) and Eckhard and Stauder (2019). It is defined as follows:

$$\text{AR}(x, e) = \frac{\sum_y \sum_b w_{x,e}(y, b) F(y, b)}{\sum_y \sum_b w_{x,e}(y, b) \cdot \sum_x \sum_e w_{y,b}(x, e) M(x, e)}. \quad (6.1)$$

$w_{x,e}(y, b)$ is the partner preference of men in age x with education level e for women with education b in age y . These are standardized weights conditional on the male characteristics such that $\sum_y \sum_b w_{x,e}(y, b) = 1$. The calculation of these preference weights is discussed below. $w_{y,b}(x, e)$ is the partner preference of women in age y with educational level b for men in age x and with educational attainment e . $F(y, b)$ is the number of women at age y with education b in the partner market and $M(x, e)$ is the corresponding number of men with at age y with education e , which have been drawn from the population registers. We use the following educational levels: basic (ISCED 2011: 0-2), medium (ISCED 2011: 3-4), and high education (ISCED 2011: 5-8) and group single ages into 5-year age categories (18-24, 25-29, 30-34, 35-39, 40-44, 45-49, 50-54). These components reflect the availability of potential

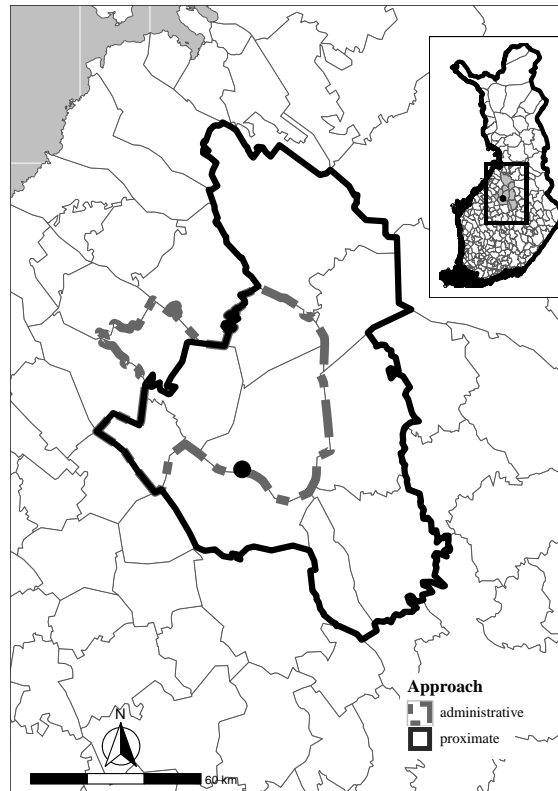


Figure 6.1: This graph illustrates through an example the difference between the administrative boundary approach and the spatial proximity approach used in the analysis. The red point in the graph illustrates the exact residence of a person, which is not given in the data. The area marked with the green dashed line corresponds to the partner market based on the administrative boundaries; in this case, the subnational economic unit (Seutukunta) the person lives in. The area surrounded by the solid yellow line illustrates the spatial partner based on the spatial proximity approach. **Interpretation:** when a person lives near the border of a subnational economic unit, the partner market involves a large measurement error, which is reduced in the spatial proximity approach.

partners (the number of women) and the number of competitors (the number of men). If the indicator takes values higher than one, the partner market exhibits a surplus of women relative to men in age x and with educational attainment e , while values below one indicate a lack of potential partners and increased competition.

The estimation of the availability ratio relies on weights that account for partner preferences, $w_{x,e}(y,b)$. We estimate these weights based on observed parental constellations at birth of their child. More concrete, the weights are estimated as the conditional distribution of characteristics of the mother dependent on the characteristics of the father from the national birth statistics for the period

between 1994 and 2020; i.e., only among childbearing couples. This procedure has some benefits and potential drawbacks compared with other approaches used in the literature, which often rely on surveys and stated preferences. Such stated preferences might deviate from actual behavior. Moreover, survey questions often ask respondents about their partner preferences, and not about the partners with whom they would consider having children (e.g., Stone et al., 2007). In contrast, our approach is based on revealed and realized preferences, and thus avoids these issues. It might, however, be affected by circularity (De Hauw et al., 2017), as realized preferences depend on the partner market situation, and may not fully reflect the true underlying preferences. This might be less relevant for the national-level data we use, which averages over regional partner markets with imbalances in both directions. Moreover, our approach assumes that childless people have, on average, the same preferences as individuals with children.

In our robustness checks we use two alternative partner market measures, which indicate to what extent the results might depend on the measurement of the partner market (for an overview, see Table D.1 in supplementary materials D.1). Previous research found evidence that the choice of indicator might be relevant for the results and their interpretation (Eckhard & Stauder, 2019; Filser & Preetz, 2021). The first alternative is an age-specific sex ratio that relates the number of women at a particular age, $F(y)$, to the number of men at the same age, $M(x)$. While this measure is simple and does not rely on assumptions regarding preferences, it ignores the existence of age and educational preferences (Buss & Schmitt, 2018; Skopek et al., 2011). Moreover, it excludes the impact of varying cohort sizes on partnering behavior, because the potential partners are from the same cohort. As a second alternative, we have estimated a preference ratio that weights the availability by preferences as shown in equation 6.2. In the denominator is the sum of the weighted number of women across ages in the specific region, while in the numerator is the number of men at age x . The measure is more stable than the

availability ratio, because it reflects only age preferences, which are found to be relatively robust over time and across countries (Ausubel et al., 2022; Dudel, 2021; Skopek et al., 2009), and because it reflects mating behaviour more realistically than the sex-ratio which ignores preferences completely (Filser & Preetz, 2021). The availability index is estimated in the following way:

$$\text{Preference ratio}(x) = \frac{\sum_{y=18}^{55} w_x(y) \cdot F_i(y)}{M(x)}. \quad (6.2)$$

6.3.3 Outcome: Childlessness

The outcome of interest is being childless at age 45 (*childless* = 1, *father* = 0). Childlessness is derived from not being listed as a parent in the birth registers, while fatherhood is inferred from being listed as a parent in the birth registers. Age 45 represents almost the end of the reproductive period, as our data on previous cohorts indicate that less than 5% of all births are to men older than 45. Thus, childlessness at age 45 provides a good approximation of ultimate childlessness. Furthermore, the number of first births after age 45 is even smaller. We experimented with different age cut-off points and the results remained largely stable. If a person becomes a father before age 45, the year of conception is used as the last observation, which is the year of birth minus one. Moreover, we account for evidence indicating that migration and fertility are interrelated processes (Kulu & Steele, 2013). Studies have shown that the probability of movement is particularly high between conception and childbirth, and thus that the birth might not occur in the region where the parents originally met, which introduces reversed causality. The rich micro-level data we use allow us to tackle this issue by dating the timing of the birth a year back to provide an estimate of the time of conception.

6.3.4 Control variables

Several control variables accounting for individual characteristics and contextual factors are included in the regression models, which are described in the next section. The variables are summarized in Table 6.1.

Household economic theory and research on fertility consistently point to the relevance of socio-economic characteristics (Becker, 1981; Kreyenfeld & Konietzka, 2017). Hence, we include disposable income in the last spell grouped into quantiles, which accounts for inflation. This variable is only available from 1995-2020. Moreover, we account for education by including the highest educational attainment. We group the education variable in the following way: basic (ISCED 2011: 0-2), medium (ISCED 2011: 3-4), and high education (ISCED 2011: 5-8). Moreover, men's employment is crucial for the partner market (Bolano & Vignoli, 2021; Bukodi, 2012), and unemployment creates uncertainty affecting fertility (Miettinen & Jalovaara, 2020). For that reason, we add the duration of unemployment as a control variable. This measure also functions as an approximation of the level of labour market attachment (Oppenheimer et al., 1997).

A set of controls on the regional context is added to the models as well, since contextual factors might confound the relationship, because structural possibilities and economic uncertainty might be correlated with partner markets and fertility (Campisi et al., 2022). Therefore, the general unemployment rate, the average income, the share of tertiary educated, and the share of poor individuals, which together approximates the income inequality in the region, are calculated for all regions and years, and are linked to the individual data via the residence biography. Subsequently, the contextual information throughout the life course are aggregated in a manner similar to the procedure for the availability indices.

Table 6.1: Summary statistics of indicators in the cumulative data.

Statistic	N	Mean	St. Dev.	Min	Max
<i>Outcome:</i>					
Childlessness	194,080	0.3167	0.465	0	1
<i>Demographic:</i>					
Max age	194,080	34,08	7.923	18	45
Cohort	194,080	1972.16	2.017	1969	1,975
<i>Availability indicators:</i>					
Availability Ratio (near)	194,080	0.09	0.21	-1.019	0.638
Preference Ratio (near)	194,080	0.006	0.069	-0.718	0.253
Sex Ratio (near)	194,080	-0.03	0.071	-0.942	0.449
<i>Individual characteristics:</i>					
Log Income	194,080	9.616	8.923	0	11.565
Education	194,080	2.192	0.884	1	3
Duration unemployment	194,080	1.528	3.038	0	25
<i>Regional context:</i>					
% Unemployed	194,080	10.941	2.533	0.834	23.017
% Tertiary: high	194,080	54.04	0.498	0	1
Inequality: high	194,080	50.00	0.500	0	1
Urban:	194,080	0.647	0.415	0	1

6.3.5 Methods: Main analysis

As our main model, we use logistic regression with childlessness as the outcome and the average of the logged partner market measure over the life course as our main predictor. We use the log of the partner market measure, because it is a ratio, which is not symmetric around one. This becomes evident when looking at the range. In the case of a lack of females, the numerator is higher than the denominator and can range from one to infinity, while the surplus of females can range from zero to 1. Taking the log of the measure yields a symmetric and linear relationship centered around zero. Furthermore, we account for spatially-clustered standard errors due to nested treatment assignment within regional partner markets (Abadie et al., 2022). Specifically, we cluster the standard errors of the main model by region and estimate a generalized mixed linear model with region random effects (Table D.2). This method leads to wider confidence intervals compared to a model without clustered

standard errors. The clustered standard errors produce a conservative estimate, because treatment assignment is only partially clustered (Abadie et al., 2022).

To enhance interpretation and ensure the comparability of effect sizes across models, we generate counterfactual predictions based on the model coefficients. For instance, Karlson et al. (2012) demonstrated that coefficients in logit models can change not only due to confounding but also as a result of rescaling. Hence, we utilized logistic regression for calculating counterfactual scenarios. This approach allows us to assess the population-level impact of unbalanced partner markets by envisioning a scenario in which they do not exist. In a two-step process, we transform unbalanced markets into balanced ones by setting negative log availability values to zero. Subsequently, using model estimates, we predict the probability of being childless for all individuals in the sample and aggregate the share of childlessness in this counterfactual population. The disparity between model predictions for observed and counterfactual data highlights the population-level influence of partner market imbalances on male childlessness. Nevertheless, we acknowledge and address other model limitations through robustness checks.

Furthermore, we investigate the direct and indirect effects (via ever being partnered or married) of partner markets (measured by the availability ratio) on childlessness using a mediation analysis at the aggregate level. We perform a mediation analysis following Baron and Kenny (1986) using the availability ratio at age 30-35 in year $t - 10$ as the exposure (a), the share ever partnered or married at age 35-40 in year $t - 5$ as the mediator (m), and childlessness at age 45 in year t as the main outcome (y), and using regional average income, unemployment rate, share of tertiary education, and share of poverty as control variables. The results are based on two regressions:

$$E(M | A = a, C = c) = \beta_0 + \beta_1 a + \beta c \quad (6.3)$$

$$E(Y | A = a, M = m, C = c) = \theta_0 + \theta_1 a + \theta_2 m + \theta_4 c \quad (6.4)$$

The direct effect of the partner market on childlessness is given by θ_1 , the indirect effect via the share ever partnered is provided by $\beta_1 \times \theta_2$, and the total effect is simply the sum of the direct and the indirect effect. It should be noted that the mediation analysis is performed at the partner market level and not at the individual level, and it assumes linear effects.

6.3.6 Methods: Robustness checks

In our robustness checks, we use alternative regression approaches that account for model limitations. First, we estimate a sibling fixed effects model (sibling FE) to account for unobserved, time-constant confounders that are shared among siblings, such as upbringing and genetic factors (Barclay & Kolk, 2020). We use a logistic FE model for the estimation (Stammann et al., 2016). This model corrects for the incidental parameter bias. A caveat of the sibling FE approach is the limited generalisability, as it restricts the sample to men who have at least one male sibling born between 1968 and 1975. The sibling data used for the sibling fixed effects models are composed of 65,000 men, who belong to 32,000 sibling groups. Second, we estimate a discrete time event-history model (Allison, 2009), which builds on the temporal structure of the events to estimate a causal effect. The model assesses how the partner market affects the transition to first childbirth, instead of the association between lifetime partner markets and childlessness at the end of the reproductive period. Third, we follow the matching procedure suggested by Ho et al. (2007) to reduce the sensitivity of results with respect to assumptions regarding the functional form. First, we create a dichotomous treatment variable by transforming the availability index into two categories: 1. lack of potential partners; and 2. excess potential partners. We then perform *exact matching* based on siblings, which reduces model dependency and reduces bias from selection into treatment. This pre-processing ensures that the treatment and control groups are similar, which reduces the relevance of the parametric specification for the

results (Ho et al., 2007). A logistic regression model is then run using the new treatment variable along with the control variables.

6.4 Results

6.4.1 Descriptive results

Figure 6.2 shows the regional levels of childlessness in Finland for the male cohorts born between 1968 and 1975 across subnational economic units (*fin.* Seutukunta). The brighter the colours, the higher the level of childlessness among men. Childlessness varies considerably by region, ranging from 24% to 41%. Moreover, there is a geographic pattern, with childlessness levels being low in the west and particularly high in the north, but also in the east. In the capital region of Helsinki, 29.6% of men are childless, placing it in the middle of the range.

The spatial pattern of the availability ratio for 30-year old men is displayed for three years (cross-sectional data) and educational levels in Figure 6.3, which confirms hypothesis 1 that the availability of potential partners has declined over time. The emerging unfavorable position for men on local mating markets is indicated by a growing number of white regions, which correspond to balanced or unfavorable local partner markets. In 1987, all municipalities exhibit an excess in availability in the partner markets. However, just 18 years later, the map changes, showing more regions with a lack of available partners. This trend is particularly strong for lower educated men. In 2019, the spatial distribution of partner availability changes partially, as some regions in the south and in the middle of Finland also have favorable partner markets for men, while the east of Finland remains unbalanced to the disadvantage of men, which confirms hypothesis 2. Values of the availability ratio range from 0.27 to 2.00. The lowest value indicates that four men are competing for one women in the preferred range, while the highest value indicates that there are on average two women per man. Intriguingly, comparing the figures 6.2 and 6.3 reveals some overlap of the regions exhibiting high levels of childlessness and

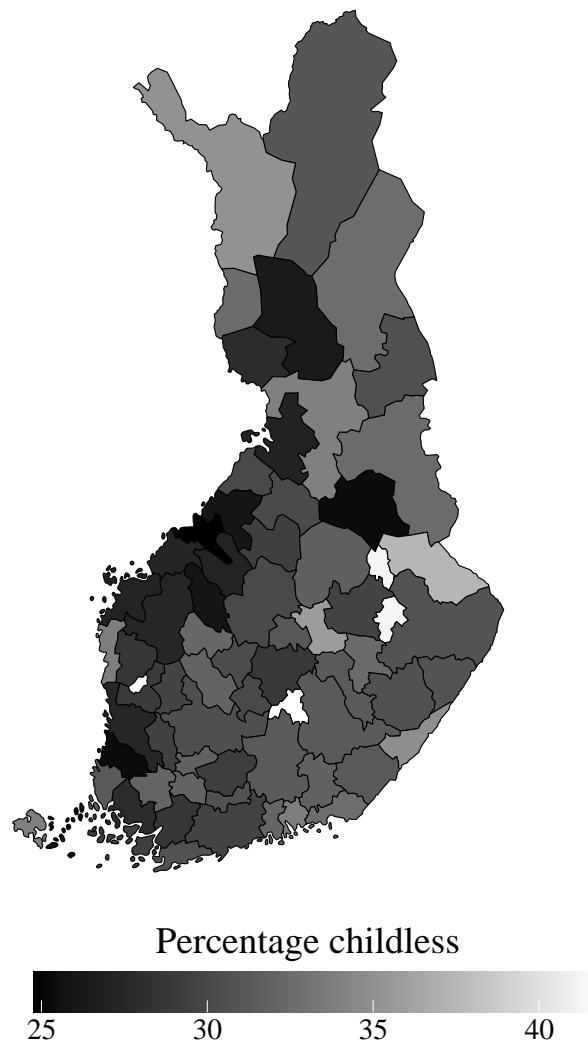


Figure 6.2: This graph illustrates the percentage of childless men at age 45 across subnational economic units (*fin.* Seutukunta) for the cohorts born in 1968-1975. **Note:** Men who enter fatherhood before age 45 are counted in the region where they were residing one year before the birth in order to avoid reversed causality resulting from moves related to family formation.

unfavorable partner markets, which provides some initial support for the hypothesis that partner markets affect childlessness.

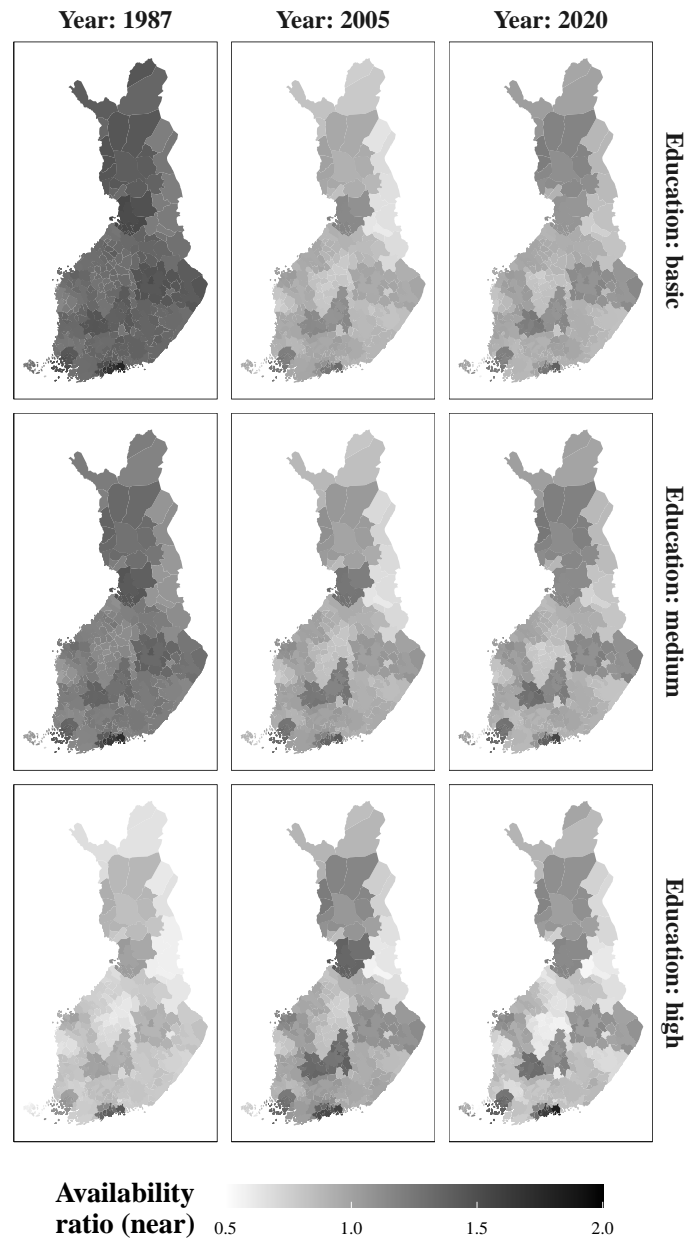


Figure 6.3: Cross-sectional data on partner availability for men at age 30. **Interpretation:** Lighter colours indicate a weak partner market situation at age 30, while darker regions exhibit an excess of potential partners.

Figure 6.4 shows the bi-variate association between life-time partner availability and childlessness in our sample. It indicates the proportion of childless people for the categorised cumulative exposure to the partner market measured using the

availability ratio. The cumulative exposure is the mean availability ratio across the life course until the year before childbirth (conception), or until age 45, if the men remain childless. Figure 6.4 indicates that the better the partner market situation is over the life course, the lower the share of childless men is, supporting hypothesis 3. Of the group of men with excess partner availability over their life-time, the share who are childless is 25%, which is 20 percentage points lower than that of men experiencing balanced partner markets (45%), and is 26 percentage points lower than that of men residing in a region where men outnumber women (51% childless).

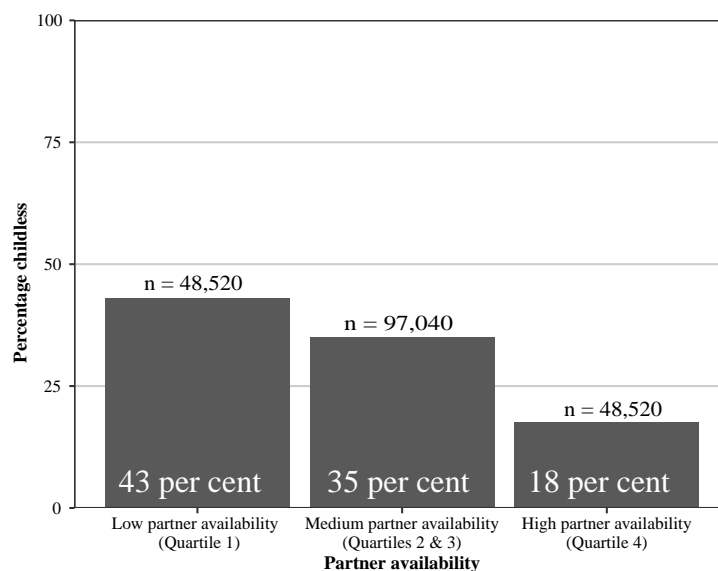


Figure 6.4: Percent childless across groups with different lifetime partner market situations. The groups are based on quartiles of the mean availability ratio between age 18 and the age at conception of childbirth or age 45. The sample contains Finnish men born between 1968 and 1975.

6.4.2 The association between regional partner markets and male childlessness

We present the results from the logistic regression models of being childless at age 45 on the cumulative availability ratio in Table 6.2 and the full table is displayed in Table D.3 in the supplementary materials. The top part of each column shows the logit-coefficients for a different set of model specifications. The middle part of the table shows the difference in childlessness levels between the model prediction

and the counterfactual scenario (*population-level effect*), which indicates the level of male childlessness if there was no lack of availability. In the simple logistic regression without any control variables (Model 1), a one point increase in the life-time availability of females is associated with a decline in the probability of remaining childless as a male, as indicated by the negative sign for the coefficient, -2.413 (CI: -2.836 and -1.991). This suggests that an increase in the availability of women with preferred characteristics is inversely associated with childlessness.

Table 6.2: Logit-binomial regression of childlessness at age 45 on the cumulative partner market exposure using the availability ratio (near) as the predictor variable. The availability ratio is the average log availability ratio over the period between age 18 and conception or age 45. This table displays logit coefficients, which represent the average response in the log-odds of childlessness to a value change of 1. The full table, including all the control variables, can be seen in Table D.3 in the appendix.

	<i>Dependent variable:</i>			
	Childless at age 45			
	(1)	(2)	(3)	(4)
Availability ratio	-2.413***	-2.191***	-5.058***	-5.716***
Observed (% childless)	32.6	32.6	32.6	32.6
Counterfactual (% childless)	32.1	32.2	32.0	32.0
Population level effect	-0.467	-0.441	-0.587	-0.585
Observations	194,080	194,080	194,080	194,080
Log Likelihood	-119,316.500	-106,999.400	-85,200.000	-85,072.720
Akaike Inf. Crit.	238,637.100	214,016.700	170,426.000	170,177.400

Note: *p<0.1; **p<0.05; ***p<0.01

Model 2 in Table 6.2 adds individual control variables and Model 3 adds contextual control variables. After adding to the model individual control variables for cohort, income quantile and duration of unemployment, the results remain stable and in accordance with hypothesis 3. In Model 2, the coefficient for the logged-availability ratio is -2.191 (CI: -2.817 and -1.566), indicating a reduction in the probability of being childless when partner availability increases. Therefore, the effect remains constant after controlling for socio-economic and demographic characteristics.

Moreover, when adding contextual control variables for the share of tertiary educated persons in the population, the regional unemployment rate and income inequality measured as the standard deviation of the average monthly income the effect remains significant and in the expected direction (Model 3). Thus, when we take self-selection into regions with specific economic and educational characteristics into account, the results remain stable. After controlling for these contextual variables, the relationship remains significant and does not show a change in direction, indicating that an increase in partner availability decrease the probability of being childless. The coefficient of the log availability ratio is -5.058% (CI: -5.857% and -4.260%).

The middle section of Table D.3 presents the anticipated childlessness rates derived from both observed and counterfactual data, along with the resulting difference representing the population-level effect. The findings highlight a significant influence of partner markets. The population-wide childlessness would be reduced by 0.4 to 0.6 percentage points if no men were exposed to unbalanced partner markets.

6.4.3 The steepening of the socio-economic gradient in childlessness

Model 4 in Table D.3 and Figure 6.5 demonstrate a pronounced amplification of the socio-economic gradient in male childlessness within unfavorable partner market conditions. This confirms that partner markets have a substantial impact on low-income groups, positioning them unfavorably in unbalanced partner markets. The model incorporates the independent effects of partner availability and its interaction with income quantiles, presenting compelling evidence for an intensified income gradient in imbalanced partner markets. The statistical significance of the interaction between income and partner availability is underscored, leading to an enhanced model fit, as evidenced by a reduction in AIC. Noteworthy is the designation of the lowest income quantile as the reference value, with subsequent quantiles revealing

progressively escalating positive coefficients. This suggests that the link between partner market conditions and childlessness weakens in higher income groups. Employing estimates from Model 4, we predict the probability of childlessness across various partner market indicator values within distinct income groups. At lower levels of partner availability, childlessness diverges significantly across income groups, gradually contracting as partner availability improves. Conversely, in favorable partner markets, the economic gradient in childlessness diminishes and ultimately disappears. For example, the difference in the predicted probability of childlessness between the lowest and the highest income quantiles is 17 percentage points in the 25% quantile of the availability indicator distribution. This difference is reduced to 11 percentage points in a balanced partner market, and narrows even further to six percentage points in the 75%-quantile of the availability indicator.

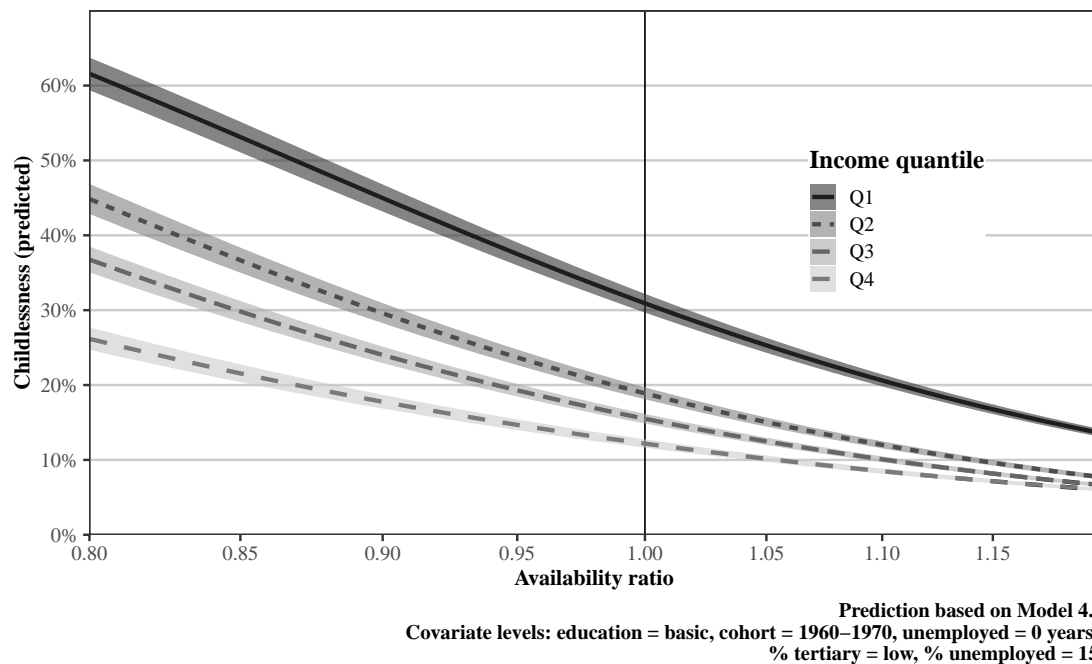


Figure 6.5: Interaction effect of the availability ratio and income quartile on the probability of being childless at age 45: men in Finland. Prediction based on Model 4. Covariate levels: education = basic; cohort = 1960–70; duration unemployed = 0 years; percentage tertiary = low; percentage unemployed = 15. Shaded areas show 95 per cent confidence intervals. The solid vertical line represents the balanced partner market (AR = 1).

6.4.4 Mediation analysis

Our mediation analysis reveals that the direct effect of partner markets on childlessness accounts for three-quarters of the total effect, while the indirect effect through partnership formation accounts for only one-quarter. A one-point rise in the availability ratio (e.g., from 1 to 1.1) is associated with a reduction in childlessness of 0.27 percentage points. This reduction can be attributed to the direct effect (0.19 percentage points, or 72%), which may be driven by the quality of the partnership matches (Lichter et al., 1995, 2020), and the indirect effect (0.07 percentage points, or 28%), which is postulated to occur through changes in partnership formation and stability (Becker, 1977; Eckhard & Stauder, 2018).

6.4.5 Robustness checks

Several robustness checks are conducted to assess the sensitivity of our main findings. This includes the use of several different modeling approaches, model specifications, and partner market indicators. The population-level effects of all robustness checks are summarised in Figure 6.6 (the matching model is excluded for readability, but can be found in Figure D.8 in the supplementary materials). For each analysis, it shows the difference in aggregate childlessness between average fitted values and the counterfactual analysis with balanced or good partner markets, similar to our main results. A negative value indicates that in the absence of a lack of partners, the population level of childlessness would be lower.

The quantification of partner preferences based on observed data, drawn from partner constellations from parental constellations at birth of their child, might be subject to endogeneity because both preferences and population imbalances affect these patterns (De Hauw et al., 2017). In order to quantify the potential impact on our findings, we estimate preferences based on data that are unlikely to be affected by population imbalances. Specifically, we compare the conditional distribution of the age of mothers in the regions 1) with an excess of women and 2) the distribution

for all births (for a detailed description of the estimation, see Section D.7). In the former, imbalances should not affect male fertility outcomes, while in the latter regional imbalances might cancel out. Tables D.4 and D.5 in the supplementary materials present the results from the comparison of the two distributions, which point to a strong overlap. This supports the argument that the estimate of partner preferences is not strongly distorted by partner markets. Moreover, we compare the estimated partner preferences to results from the literature. Studies from dating websites (Skopek et al., 2009) and from surveys (Buss & Schmitt, 2018) yield patterns similar to those found in our data.

In addition, we estimate sibling fixed effects to account for selection based on parental background. The results are in line with the pattern observed in the main model. Model 2 in Table D.6 shows the coefficients for the within-effects model, which are similar to those based on the between-effects regression in Model 1. We find that a 10% increase in partner availability decreases the probability of being childless by 10.36% (CI: 10.00% and 10.82%).

Furthermore, using discrete time event history models, we estimate the effect of partner availability on the transition to fatherhood (results are displayed in Table D.7). The results are largely robust. The population-level effect in the discrete time event history models is a decline of about 0.198 in childlessness if partner market imbalances did exist. The results remain consistent when using different temporal lags (two and three years), which confirms the lasting impact of partner markets on childbearing (see Figure D.9). The only result that is not in line with our hypothesis comes from the model using the age-specific sex ratios as measures of the partner market (see Table D.8), which has a statistically significant negative effect of increased partner availability on the transition to the first birth (-0.405; CI: -0.480; -0.330).

Moreover, using dichotomisation and matching, we aim to relax the assumption regarding the parametric shape of the effect. The results displayed in Table D.9 are

largely consistent with the main results, indicating that the effect is not dependent on the assumption regarding the parametric shape. The effect sizes are larger, because the population level effect refers to a qualitative rather than a gradual change due to the binary coding of the treatment variable.

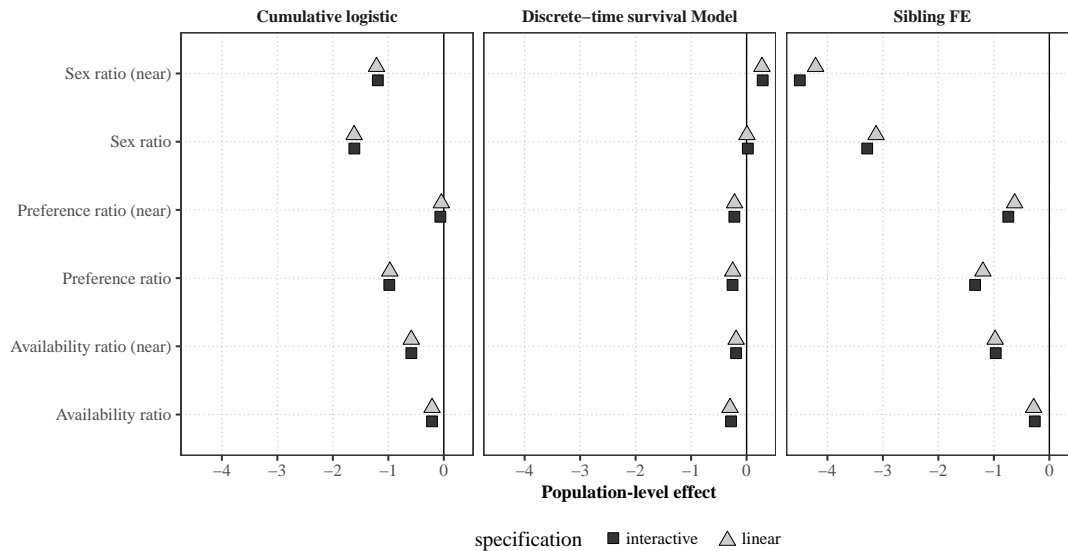


Figure 6.6: This figure summarises the results across models (except for the matching models), control variable selections and availability indicators. The different panels distinguish the model type; the different shape of the points highlight the variable specification (**linear** effect of partner market or **interactive** effect with income quantile) and the different symbols and rows display the results for the different availability indicators. The same figure including the matching model can be found in the supplementary materials B Figure D.8.

Capital regions are very different from other regions in terms of population composition and fertility behaviour, which may distort our findings. This issue is important given the large number of people residing in Helsinki. Therefore, we re-estimated the main model on a subset of the population who never resided in Helsinki between age 18 and 45 or before their first birth. The results, which are summarised in Table D.10 in the supplementary materials, correspond to the main findings.

Finally, we find preliminary evidence supporting the role of partnership formation as a mechanism that mediates the relationship between partner markets and childlessness. Using the sample from the main analysis, we conducted an analysis using singlehood at age 45 instead of childlessness as the primary outcome, to

explore this mechanism further. Remarkably, the results, as detailed in Table D.11, mirror those obtained in our primary analysis. Furthermore, we investigate the direct and indirect effects (via ever being partnered or married) of partner markets (measured by the availability ratio) on childlessness using aggregate data. We apply a mediation analysis following Baron and Kenny (1986), controlling for regional average income, unemployment rate, share of tertiary education, and share of poverty. The overall impact of a one-point rise in the availability ratio (for example, from 1 to 1.1) is related to a reduction in childlessness by 0.27 percentage points. Of this reduction, 0.19 percentage points (72%) can be attributed to the direct effect, while the remaining 0.07 percentage points (28%) are attributable to the indirect effect through the share of individuals who have ever been partnered or married. This mediation analysis is predicated on the assumption of linear effects and the measurement of confounding factors.

6.5 Discussion

6.5.1 Main findings

In this study, we have investigated the relationship between regional partner markets and childlessness among men in Finland. Descriptive analyses using municipality-level data show that indicators of the number of women relative to the number of men correlate negatively with the level of childlessness; that is, the fewer women there are relative to the number of men, the higher the probability is that men will remain childless. Individual-level regression analysis confirms this finding and indicates that around 0.587 percentage points of male childlessness can be attributed to regional imbalances in partner availability. Our findings are robust to changes in the indicators of the regional availability of partners, to the regression method used for the analysis, and to model specification. Overall, our results indicate that the partner market is likely an important component for explaining the recent fertility declines among men in Finland.

Our descriptive analyses show that the average availability of partners for men across regions has declined over time. This finding is robust across partner market indicators, but is strongest when only looking at age and sex structures. Declining partner availability mirrors changes in the subnational population and education structures, which may be related to cohort sizes, sex ratios at birth, and/or mortality. In addition, the number of men residing in unbalanced partner markets increased between 1987 and 2010, followed by some declines in the 2010s (see Figure D.10). Moreover, the overall shift has been accompanied by increasing heterogeneity in partner availability across regions, probably driven by internal migration (Gulczynski, 2023). This highlights the importance of regional conditions for men's partnership formation opportunities, which have previously been studied mostly at the national level (Van Bavel & Nitsche, 2013).

We find that the probability of being childless at age 45 is negatively associated with lifetime exposure to adverse partner market conditions. Using a counterfactual prediction, we show that if no men in Finland experienced a lack of partner availability, levels of childlessness would decline by around 0.6 percentage points. This corresponds to findings of previous research. Chudnovskaya and Ueda (2021) found for Sweden that inequalities in the sex ratio can explain about 20% to 34% of the sex gap in childlessness depending on cohort.

Our findings reveal variations in the impact of partner markets across socio-economic groups. The socioeconomic gradient in childlessness is most pronounced in unbalanced partner market situations, and diminishes as partner market conditions improve. This has two key implications. First, income operates as an asset in attracting and securing partners, gaining significance in unbalanced partner markets. This insight may help to explain simultaneous trends of deteriorating partner markets and an escalating socio-economic gradient in childlessness (Jalovaara et al., 2019). Second, childlessness tends to concentrate among males with low income in rural areas, leaving this group without sufficient kin relationships, economic resources,

and institutional support in old age. This situation may have repercussions for levels of loneliness, care needs, and health in the future. Consequently, we recommend that policymakers plan for this triple disadvantaged group.

Several potential mechanisms that could explain our findings have been proposed in the literature, such as partnership formation and relationship stability (see Section 6.1.2). We conducted additional analyses reported in the supplementary materials, which indicate that partnership formation is indeed a major link between regional partner markets and childlessness. We find for the same sample of men that not just childlessness, but also the probability of being single (e.g. not married or cohabiting) at age 45 is related to the lifetime exposure to partner markets.

Our findings are related to a stream of literature on fertility variation at the subnational level. It is well-established that the fertility level can vary considerably at the subnational level (e.g., Campisi et al., 2020; Nisén et al., 2021), mainly due to the characteristics of the subnational units. For instance, Fox et al. (2019) demonstrated that subnational variations in income play an important role in fertility, while Campisi et al. (2022) showed that regional unemployment and union formation levels are associated with recent fertility declines. Moreover, rural-urban disparities have been well documented, with fertility rates generally being lower in urban areas and higher in rural areas (Campisi et al., 2020; Kulu & González-Ferrer, 2014). Intriguingly, this implies that High male childlessness levels and low fertility among women do not necessarily coexist. Several regions have high levels of childlessness among men, but only low or modest childlessness among women (see Figure D.11 in the supplementary materials). Therefore, we reiterate a call to "bring men back in" to fertility research (Coleman, 2000; Goldscheider & Kaufman, 1996; Keilman et al., 2014; Lappegård & Rønsen, 2013).

A subject of discussion is the role of online dating in past and future partnership formation and stability, as advances in internet dating may mitigate the impact of regional partner markets over the long-term. Hence, it would be interesting

to investigate the role of internet dating in childlessness. Internet dating might change the relationship between partner markets and childlessness by making geographic proximity less important. However, according to existing studies, the residential location remains crucial for the mate selection even in online dating (Rosenfeld & Thomas, 2012).

6.5.2 Strengths and limitations

The impact of partner markets on childlessness is robust across partner market measures. Using a simple sex ratio, a preference ratio, and a sophisticated partner availability ratio yields similar results. Moreover, we use a proximate approach to measure partner markets, which reduces potential measurement error that has been an issue in previous research using administrative units. However, using both spatially narrower and wider definitions of partner markets leads to similar results. Overall, these findings provide some evidence that even simple measures can serve as good proxies for local partner markets.

We are aware of four methodological limitations of our study. First, the analysis may suffer from selection bias because decisions to live in regions with high and low partner availability are not random, as both men and women with certain characteristics may actively migrate because of a lack of partners. However, this bias is difficult to address empirically. Second, our findings may be influenced by spatial autocorrelation, which has the potential to bias the resulting estimates. The maps and Moran's I statistic indicate the presence of weak spatial autocorrelation with regard to childlessness. Second, our findings, in particular the standard errors in the regression models, may be influenced by spatial autocorrelation. The maps and Moran's I statistic indicate the presence of weak spatial autocorrelation with respect to partner markets and childlessness. Third, the majority of men are conscripted into the military, which delays their education careers to some degree. This may affect both the partner market measures and the preference measures.

In a robustness check, we accounted for these effects indirectly by limiting the analysis to men over age 25, which yielded similar results. Finally, the residence information in the data before 1994 was not perfectly accurate, because students often remained registered at their parents' address, rather than registering at the place where they were studying (p. 76 Jalovaara, 2012). In a robustness check presented in Table D.12, we accounted for the data quality issue by limiting the data to the 1995-2018 period, which did not change the results.

Moreover, our study is subject to a conceptual limitation. The partner market indicators differentiate individuals solely based on their socio-economic characteristics, while neglecting other factors that are crucial for partnership formation and childlessness. For example, the inclusion of respondents who are homosexual, not seeking a partner, or uninterested in childbearing may obscure the analysis. While constrained by the available data, a more nuanced categorization could enhance the accuracy of our distinctions.

Advancing gender equality and equity and the empowerment of women, and the elimination of all kinds of violence against women, and ensuring women's ability to control their own fertility, are cornerstones of population and development-related programmes.

United Nations - Population and Development
(Cairo, 1994)

7

Discussion

Contents

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The objective of this thesis was to provide a granular account of fertility patterns and trends by examining men's and women's fertility using subnational administrative register data. Structural and biological factors have received less attention in the debate on the drivers of fertility, but this thesis has demonstrated their relevance. Each study focused on a different aspect of this objective. The chapters in Part I examined the biological, structural, and cultural factors contributing to fertility trends, with a particular focus on fertility decline. Although all of these factors were found to be robustly related to fertility, none of them alone accounted for the majority of the fertility decline in the last decade in the Nordic and Anglo-Saxon

countries. These results suggest that fertility, in general, and the recent fertility decline, in particular, are not driven by a single factor, but rather by multiple factors interacting simultaneously. Therefore, I propose that fertility is a complex trait that requires multifaceted, multivariate, and interdisciplinary explanations. The studies in Part II focused on the fertility of men, in particular the differences between male and female fertility and the drivers of male childlessness. These chapters showed that the predictors of fertility for men differ from those for women, and that men's fertility can differ from that of women. Thus, the fertility of men is a research topic in its own right. In what follows, I summarise the main findings of each chapter.

7.1 Summary of the main results

In Chapter 2, we examined the relationship between human development and fertility in the United States at the subnational level and provided new insights regarding a major debate in population research. Using several methods, indicators, and models, we aimed to resolve the discussion about the existence of fertility decline reversals. The results pointed towards fertility decline reversals at high levels of development, confirming the inverse J-shape hypothesis for historical periods. However, we found evidence for a structural break during the Great Recession in 2007/2008. No association between human development and fertility was observed during the subsequent decade. Moreover, the J-shape's existence and timing were highly dependent on the development indicators. We also disentangled some mechanisms behind the fertility decline reversals, showing that gender attitudes and economic outlook were key components of these reversals. The research is relevant for the field of demography. These findings are particularly interesting because the US stands out as a somehow special case, given that US fertility rebounded at high levels (Luci-Greulich & Thévenon, 2014), though it has recently declined (Kearney et al., 2022).

In Chapter 3, we examined the relationship between secularisation and fertility decline, and provided new insights into a major debate in sociology. While the impact

of secularisation and religious affiliation has been a contested topic in sociology for decades, this debate has recently lost momentum due to the assumption that secularisation plays a minor role in modern high-income countries. We demonstrated the contemporary relevance of religious affiliation in the area of couple formation and fertility. We found that accelerations in secularisation can have a non-negligible impact on societal processes even in modern industrialized and secularised high-income countries. Combining individual and couple perspectives, we examined the relevance of declining religious affiliation for the probability of being in a couple relationship, the religious composition of couples, and the relevance of this composition for childbearing. The results pointed to a significant role of secularisation in couple composition and couples' fertility. The results indicated that the decline in church membership has played a pivotal role in the Finnish fertility decline. Declining church membership has affected fertility, through the lower average fertility of individuals who are not church members on the one hand, and through indirect effects acting on couple formation and couple composition on the other. Finland is also an interesting case because of its high level of secularisation and gender equality, which are typical of Nordic societies. However, the results are also relevant for other contexts, such as the United States, which are undergoing similar accelerations of secularisation and fertility declines.

Chapter 4 aimed to predict fecundity in couples, a crucial determinant of fertility trends. Claims about declining fecundity are usually based on small samples with large margins of error. Hence, this chapter provided a more reliable assessment of fecundity at the population level (Guzick et al., 2001). We used innovative machine learning methods and two large-scale datasets, the Norwegian Mother and Child Birth Cohort (MoBa) and Norwegian administrative registers. The main objective was to predict prolonged time-to-pregnancy in couples based on socioeconomic, behavioural, biological, and genetic factors. We demonstrated that subfecundity is predictable using the expansive data source and advanced machine learning tools.

The utilised data combined Norwegian medical, population, and income registers with survey indicators and biomarkers from the MoBa data, which together provided an unprecedentedly rich resource. We used several machine learning models to enhance prediction accuracy. Moreover, the chapter highlighted the main predictors of time-to-pregnancy, which were both partners' age, BMI, and reproductive diseases. While most existing research mainly focused predominantly on biological factors, this chapter offered an expanded perspective by also considering social factors. We posited that biological factors should also be viewed as social realities, as they are strongly related to socioeconomic factors. Finally, we found that the best performing model can distinguish couples who conceive instantaneously from those who have longer time-to-pregnancies or unplanned conceptions. This showed that highly fecund couples are a structurally well determined and distinct group.

Chapter 5 described differences between the TFR for men and the TFR for women at the subnational level over time across eight countries and provided new evidence about factors that affect the TFR. We explained male-female fertility differences in different contexts, which are related to age-sex population structures. Moreover, we discussed the birth squeeze concept and suggested different approaches for detection. In particular, we suggested several thresholds for assessing what level of gender difference in the TFR of men to the TFR of women can be considered large. In the empirical analysis, we provided comparative evidence of the relevance of the birth squeeze, and of fertility differentials more broadly, at the subnational level, in middle-income countries as well as in high-income countries. For that purpose, we collected, harmonised, and compared subnational data on male and female fertility from Australia, Colombia, Finland, France, Germany, Mexico, and the United States. We concluded that the TFR for women provides an incomplete and distorted picture of a fertility regime, as it is affected by population age-sex structures. Hence, we suggested reporting the TFR for men alongside the TFR for women.

Chapter 6 examined the relationship between regional partner markets and childlessness among Finnish men and provided new insights into recent increases and the growing socio-economic polarisation in childless among men. Using several methods, indicators, and models, we undertook a thorough investigation of the research question. The results pointed to a significant role of partner markets. Moreover, we found that lower socio-economic groups are particularly sensitive to the impact of partner markets, which may explain the steepening socio-economic gradient in male childlessness. Drawing on the model results, we estimated the population-level effects of partner markets and the contributions of changing partner markets to the population-level increase in childlessness observed in Finland since the 1990s. Finally, the chapter is interesting from a methodological perspective, as we tackled issues related to reverse causality and the modifiable area unit problem.

The fertility decline in the 2010s in the Anglo-Saxon and Nordic countries remains a puzzle, but this thesis has contributed several relevant findings to the understanding of the decline. Primarily, the thesis has focused on biological and structural factors, which have received relatively less attention in the debate. Structural factors include partner markets, which have become increasingly unbalanced for men in rural areas and for women in urban and capital areas due to sex-selective mobility. This trend may reinforce challenges to forming and maintaining stable relationships, which are essential for childbearing. For example, estimates from Chapter 6 show that male childlessness would have been approximately 1 percentage point lower if men were exposed to balanced partner markets. Moreover, this translates into lower fertility rates for men. In Finland, the total fertility rate (TFR) of men would be 10% higher than the TFR of women if partner markets were balanced. In addition, human development has been largely decoupled from fertility increases, which raises questions about the potential of progress in development to increase fertility. Furthermore, recent accelerations in secularization appear to have played a non-negligible role in the fertility decline. The decline in total fertility

rate of the Finnish-born population would be by 0.08 children per woman smaller if the religious population had not shrunk. Moreover, secularization has changed the composition of partnerships, leading to fewer homogeneous religious couples, which has reduced the total first birth rate by approximately 5%. Finally, biological factors may also contribute to the decline, as fertility has been increasingly postponed to later ages, and fathers' and mothers' ages are strongly negatively related to fecundity. For instance, declining birth rates at young ages have been partially offset by increasing childbearing at older ages, but these increases are constrained.

7.2 Strengths and weaknesses

This thesis drew on administrative register data, a two-sex perspective, and subnational research designs. While these designs have been described in Chapter 1 and separately in each chapter, the overall benefits and drawbacks of these approaches will be elaborated below.

Generally, the findings in the thesis pertain primarily to the Nordic- and Anglo-Saxon countries, and may or may not be extended to other country groups like the Central- and Eastern European countries. At least the different patterns and trends in period fertility point to some fundamental differences, see Figure 1. Research on the Central- and Eastern-European countries highlights their idiosyncrasies (Fanelli & Profeta, 2021; Németh et al., 2025; Sobotka, 2016; Sobotka & Fürnkranz-Prskawetz, 2020). The institutional context in the German-speaking countries is less conducive to the reconciliation of career and family compared to the Nordic countries, which may mute the pro-cyclical fertility pattern to some extent, and the fertility intentions are lower in the German-speaking countries (Sobotka, 2011a). The relevance of structural and biological factors to childbearing in those contexts may be a subject for future research.

7.2.1 Including men and women in fertility research

This thesis has given particular attention to men and their role in fertility, which is a research topic that has been woefully understudied despite frequent calls to “bring men back in” (Coleman, 1993; Lappegård & Rønsen, 2013). I concur with these calls and emphasise the importance of research on male fertility, as it has the potential to provide additional insights, better descriptions, and more robust results. For instance, my research has shown that male fertility can differ significantly from female fertility in various contexts, as demonstrated in Chapters 2, 3, and 5. This difference led me to conclude in Chapter 5 that the total fertility rate for women is insufficient, as it reflects not only childbearing behaviour, but also the age-sex population structure to some degree. Keilman et al. (2014) proposed two-sex measures to account for this insufficiency. However, these measures come with their own set of disadvantages, such as being harder to interpret. Therefore, I suggest that statistical agencies and the UN population division report estimates for male fertility alongside those for female fertility.

Predictors of childbearing exhibit distinct patterns in men and women, and may interact. The robustness checks performed in Chapter 2 demonstrated that the relationship between human development and fertility is more pronounced among men than among women. Furthermore, Chapter 3 investigated the role of state church membership in the transition to the first birth and found that the religiosity of the female partner has a stronger impact on couple childbearing than that of the male partner. These findings contrast with evidence for Italy showing that the employment characteristics of the male partner have a stronger impact on subsequent childbearing than those of the female partner (Vignoli et al., 2012). Moreover, Chapter 3 revealed that the effects of both partners’ religiosity are not additive, but are interactive, underscoring the importance of including men in the analysis of childbearing. These results highlight the potential benefits of combining

the male and female perspectives, as well as examining the interactions between them, in future research on childbearing.

Nonetheless, including men in fertility research presents several challenges. First, data on male fertility are not always available and are usually of lower quality. Data from surveys are often of lower quality due to unit non-responses and recall bias issues (Joyner et al., 2012). Vital statistics data have a substantial share of item non-response on father's age and education. While substantial methodological progress in addressing these issues has been made (Dudel & Klüsener, 2019a; Schoumaker, 2019), the data continue to be of lower quality. In this thesis, I have circumvented these problems by drawing largely on high-quality data sources that have only minor item and unit non-response issues. Second, population projections for men and women lead to the two-sex problem, which is not yet solved. The two-sex problem describes the inconsistency between male and female-based population projections (Karmel, 1947). Unless the fertility, mortality, and population of men and women are exactly the same, the differences will translate into differences in projections. Differences in projections are problematic, as one would assume that projections based on men and women should produce consistent results, because men's and women's reproduction are dependent on each other. Therefore, male fertility data may not be used further in population projections, constraining their applications. Third, studying fertility from a dyadic perspective, which includes both the male and female partner, complicates the identification of causal effects. Selection into union due to assortative mating will lead to some associations of the partner's characteristics. It can be difficult to disentangle the impact of selection from the effect of the characteristics. This may complicate the identification of causal effects of partner characteristics. However, Trimarchi and Van Bavel (2017) proposed a solution to this issue using a multiprocess survival model by Lillard and Waite (1993).

7.2.2 Subnational demographic analysis

This thesis used subnational analysis, which comes with advantages and limitations. My decision to focus on the subnational level was driven by methodological considerations. First, according to the principle of spatial data science, “everything that is close is more relevant”. For instance, it has been shown that the fertility transition in Europe spread from the forerunner regions to the neighbouring regions, and then onwards (Coale & Watkins, 1986; Goldstein & Cassidy, 2014). Second, subnational analysis accounts for the impact of the institutional and cultural context by holding it constant, making it easier to identify causal effects. Finally, subnational analysis provides larger samples sizes than country comparisons. The United Nations have 193 member states, which constrains empirical investigations at the country-level. This problem becomes even more severe for regional groups. For instance, Bryan and Jenkins (2016) demonstrated that European data sets do not include a sufficient number of countries to estimate country effects in multilevel models.

While subnational data adds new perspectives and are becoming increasingly available to researchers, subnational analysis poses different challenges, especially in terms of data analysis. First, subnational boundaries are less stable than country boundaries. Countries revise their spatial divisions regularly due to changes in population distribution, new administrative procedures, or supranational rulings. Hence, spatial units change over time. For instance, England revised its local government structures five times in the period between 2000 and 2023 (Office for National Statistics, 2023). Changing boundaries can affect longitudinal analysis, as the units are not constant over time. This can, however, be addressed using spatial interpolation to form constant units (Elhorst, 2014). Second, comparisons of subnational units across countries is hampered by the different sizes of the spatial units in terms of surface area and population size (as an example, see Chapter 5). For example, comparing US states with Australia states is hardly justifiable, given their different characteristics. Even comparing states within the U.S. has

been questioned by one of the reviewers of Chapter 2. In the state of New York, 20.2 million people live in an area of 141,299 km^2 , while in Alaska, only 733,406 people live in an area of 1.7 million km^2 . Supranational efforts to harmonise regional units may mitigate this problem, and are crucial for future research. The NUTS system developed by the European Union is a good example. However, these harmonised systems are not global and usually include specific countries only. This will limit cross-country comparisons of subnational units to selective countries that collaborate in areas of policy and law.

7.2.3 Register data for social and demographic research

Much of the analysis throughout the thesis drew on administrative register data, which are broadly defined as process-generated secondary data from state agencies. Health records, vital statistics, and tax reports are different kinds of administrative register data. These data have strengths and limitations, which warrant a discussion. A critical account is needed, particularly as register data are becoming increasingly popular in demography and other social sciences. Hence, I will discuss the potential advantages and disadvantages of using register data in research below. The advantages pertain to scientific advancement and the potential for societal progress. The disadvantages are related to statistical, ethical, and reproducibility concerns.

The large size of register data sets ensures statistical significance for the weakest effects and allows researchers to do subgroup analysis. In a *Frequentist* setting, statistical significance depends on the sample size, as it means that an identical statistical test repeated multiple times would yield an effect different from zero, which is more likely for larger sample sizes (Efron & Hastie, 2016). However, the advantage associated with the size of the data are less straightforward than they may initially appear. First, while the *Frequentist* paradigm refers to uncertainty arising from random sampling, population registers do not qualify as random samples, but instead represent the full sample of the administered population (for

a discussion, see Spiegelhalter, 2019). This is demonstrated by the statistical investigation by Meng (2018), who compared small random samples with high response rates with large population registers with selectivity. He concluded that population registers are the preferable option only when 1) their size approaches the completeness of the target population; and 2) the selection into registers is not based on important characteristics. Both conditions are fulfilled in the empirical investigations throughout the thesis. For instance, in Finland, the coverage of births in the register data is nearly complete. However, German health claims data are often selective based on socio-economic characteristics (Taylor et al., 2009). Therefore, register data may represent a good additional resource for research, but survey data also have value and should continue to exist.

As administrative register data draw on information available to governments and civil servants, research results based on these data are simpler to translate into policy legislation (Penner & Dodge, 2019). When both state agencies and researchers draw on the same set of information, the research findings can be easily converted into policy measures. For instance, vulnerable groups or strong correlations identified in register data can be directly targeted and altered. When policies address the vulnerabilities of certain groups or group inequalities, research can evaluate them based on the same data. Hence, administrative register data may be ideally suited for implementing and later evaluating policy reforms. Therefore, register-based research and policymaking may create a positive spiral of social progress.

However, the scientific use of administrative register data also raises several concerns, including regarding the repurposing of the data, the potential conflicts between data protection and the principles of open science, and selectivity. Public agencies collect data primarily for administrative purposes, such as to inform policy decisions and allocate resources (Poulain & Herm, 2013). In contrast, researchers seek to repurpose these data for scientific inquiry, often without the explicit consent of the respondents. This raises concerns about the legitimacy of

using administrative data for research purposes, particularly in light of the General Data Protection Regulation (GDPR) and the principles of scientific ethics. While implicit consent may be assumed in some cases, especially in those in which the research is deemed to contribute to the public good and improve the well-being of the respondents, this assumption is not without controversy. The use of administrative data for research purposes without explicit consent can be seen as a grey area in which, the benefits of research must be weighed against the potential risks to individual privacy and autonomy.

The use of administrative register data in research may also be contested based on the principles of open science (Connelly et al., 2016). Open science is a scientific movement that aims to improve scientific quality through transparency. The movement started to gather steam when the credibility of science suffered from the reproducibility crises in the early 2010s. The crises originated in failed replications of many research publications and experiments. Proponents of open science argue that for science to move forward from the reproducibility crises and to regain the trust of the public, research should be transparent. Transparency in research implies making the code and the data accessible to others. However, ensuring the reproducibility of research conflicts with the data confidentiality protections that are part of the access agreements that users of administrative register data must consent to. Therefore, research using administrative register data often does not adhere to the principles of reproducibility. Some researchers do not even share the code because, as Kravdal (2020) argues, “[t]he code has no value without access to the data”. The code used in the empirical analysis in the different chapters is available or will be made available upon publication.

To conclude, the use of administrative register data opens up new avenues for scientific research that have the potential to contribute to the public good. However, researchers should ensure the confidentiality of the respondents and come up with new solutions for reproducibility that reconcile data access restrictions with the principles of open-science.

7.3 Outlook on fertility

7.3.1 The future of fertility

In Chapter 1, I noted that among my motivations in writing this dissertation was to improve predictions of future fertility. Therefore, I provide a quick outlook on fertility in the next decades for Finland and the United States. I draw on the substantial findings of the thesis, present the forecasts from the UN population division, and review two scenarios from the literature.

Thesis forecast:

The findings of the thesis suggest that fertility is likely to stay at around the level where it currently is, although it is possible that fertility will continue to decline followed by slight reversals due to fertility postponement and recuperation (see below). While Chapter 2 showed that progress in development at advanced development stages may lead to fertility reversals, the structural break starting in 2007/08 could undermine any potential reversals in the near future. Chapter 3 showed that secularisation has been a strong driver of fertility decline at the individual and the couple level in Finland. As secularisation is unlikely to decelerate or reverse, fertility may continue to decline. Furthermore, the age and BMI of both partners can have strong negative effects on a couple's fecundity, as Chapter 4 has established. Both effects are likely to become more influential, given the increase in fertility postponement (Beaujouan, 2020) and the spread of obesity in Western countries (Lingvay et al., 2024). Therefore, the different chapters have shown that, *summa summarum*, the total fertility rates in the Nordic and Anglo-Saxon countries are likely to remain at their current levels between 1.1 and 1.7, albeit with some fluctuations.

Forecasting scenario:

The United Nations population division publishes biannually the World Population Prospects, which include fertility forecasts, that could inform us about future trends (United Nations Department of Economic and Social Affairs, 2024). These probabilistic forecasts are based on Bayesian hierarchical models that rely on assumptions about fertility and data from the past (Alkema et al., 2011; Liu et al., 2023; Ševčíková et al., 2011). The population division models three different fertility settings: high fertility (phase I), fertility decline (phase II), and low fertility (phase III). Finland and the U.S. are currently in phase III, which begins when a country has experienced two consecutive increases in the TFR after the TFR has fallen below the replacement level. Phase III is modelled as an autoregressive Bayesian hierarchical model, which implies that each country has an individual level of convergence in the low-fertility state, estimated from prior observations of fertility, and fertility is expected to fluctuate around this point, dependent on past fluctuations. Figure 7.1 shows these forecasts for Finland, the United States and Germany. The median prediction for the United States suggests a decline that gradually levels off in 2025, and a flat trend until 2100. The UN population division forecasts different fertility futures for Finland and Germany. In Finland, fertility is expected to increase to 1.5 by 2100. In Germany, fertility is predicted to reach an even higher fertility level.

Review scenarios:

Nisén et al. (2020) proposed a fertility forecast for Finland that centres around fertility postponement and its recuperation. According to this scenario, fertility will continue to decline for a few years as long as postponement takes place, but this decline will stop after a few years, and fertility will recover marginally. This model assumes that fertility postponement is the main secular driver of fertility trends in low fertility settings. For instance, the current fertility declines are partially driven by postponement (Hellstrand et al., 2021). This suggests that when the postponement

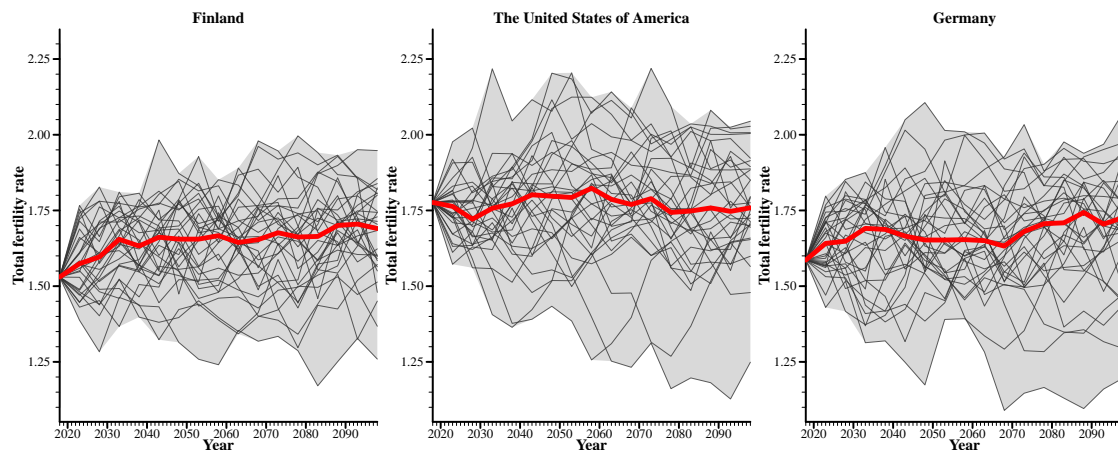


Figure 7.1: This figure displays the median, minimum, maximum and Monte Carlo forecasts of the total fertility rate by the United Nations population division.

comes to an end, there might be some fertility postponement recuperation. In their prediction scenario, the authors assume that fertility postponement gradually diminishes until the year 2050. In a similar vein, Sobotka (2017a, 2021) proposed a scenario for low fertility contexts in which the total fertility rate remains at low levels, but undergoes ups, downs, and reversals. He argued that fertility postponement has depressed period fertility rates for decades. Once fertility postponement comes to an end, fertility recovers temporarily due to fertility recuperation. Afterwards, fertility is expected to fluctuate at below the replacement level (up to 2.1). These fluctuations will be structurally determined by factors that dampen fertility, such as economic recessions (Sobotka et al., 2011) and periods of uncertainty (Comolli, 2017; Vignoli et al., 2020), or by factors that spur fertility, such as progress in gender equality (McDonald, 2000; Myrskylä et al., 2009) and positive economic conditions (Fox et al., 2019).

I conclude that, based on the different scenarios, fertility will very likely stay below the replacement level in Finland, Germany, and the United States. Although the decline in fertility may continue as the aforementioned economic, subjective, biological, cultural and structural factors continue to have a negative impact, the decline will likely slow down and possibly even reverse slightly, as fertility

postponement may eventually come to an end. Given the complexity of fertility behaviour, it is difficult to provide exact numbers on fertility in Finland, the United States and Germany over the next two decades. Moreover, the unexpected sudden fertility decline in the Nordic countries in the 2010s should make us cautious and the uncertainty bounds in future predictions may need to be artificially large. Nevertheless, I would expect future TFRs to range between 1.1 and 1.7 in Finland, Germany and the United States over the next two decades. Furthermore, I would like to draw attention to the discrepancy between the substantial research on past fertility trends, as illustrated in this thesis, and the fertility projections. Projections remain largely based on extrapolations of aggregate trends, whereby past fertility trends are projected forward with some incorporation of trends in similar countries. However, this methodology could be replaced by micro-simulation methods that systematically incorporate substantial knowledge of the factors influencing fertility.

7.3.2 The relevance of fertility

Low and declining fertility is often discussed due to its potential impact on the economy and welfare systems. Fertility affects the age structure of the population, which is relevant for the economy, as consumption and production follow robust age curves (Lee et al., 2014). Children and the elderly consume more than they produce, while the working-age population produce more than they consume. However, the productivity of a population is determined not only by the age structure, but also by the educational levels and the institutional support for its employees (Lutz, 2023). Regardless, I will use a reduced measure, which only describes the population age structure. In this section, I will examine the implications of fertility, comparing the future trend of the share of the workforce in two scenarios, e.g., replacement level fertility versus current fertility. The outcome is the proportion of the population aged 18-65 in the total population, e.g., share at working age: $\frac{p_{18 < x < 65}}{p}$.

I employ a freeze rate and a replacement level fertility cohort component projection to quantify the impact of fertility on the size of the workforce in low fertility settings (Preston et al., 2008). Figures 7.2 present the results from two projections, with the orange lines representing the freeze rate scenario and the purple lines representing the replacement scenario (counterfactual). The gap between the lines illustrates the impact of fertility on the workforce in the entire world, the United States, Germany, and Finland. In the freeze rate scenario, the age-specific fertility rates in 2023 are held constant for the rest of the century. In contrast, the replacement level fertility scenario, indicated by the dashed line, shows the population size if fertility were set to replacement level immediately ($\text{NRR} = 1$). In both scenarios, the migration and mortality data are the same, and are taken from the World Population Prospects (United Nations Department of Economic and Social Affairs, 2024).

Figure 7.2 clearly shows that replacement level fertility cannot prevent the shrinking of the workforce in the short term. Instead, replacement level fertility would even accelerate the decline in the workforce in the coming years. This is due to the fact that higher fertility will increase the number of children, who are also dependent. However, over the long term, the replacement level fertility scenario leads to a rebound of the workforce, while the relative size of the workforce remains constant in the freeze rate scenario. The impact of fertility on the workforce differs across geographic regions, as is indicated by the different panels. In 2023, the global fertility rate was 2.25 children per woman, which is slightly above the replacement level (top left panel in Figure 7.2). Adjusting the total fertility rate downward to a TFR of 2.17, which leads to a net reproduction rate of one, will increase the workforce in the near future. Thus, fertility declines contribute to the growth of the workforce at the global level. In the United States, Finland and Germany, fertility exerts a marginal impact on the future size of the workforce, see top right and bottom panels in Figure 7.2. The workforce is expected to shrink, while replacement

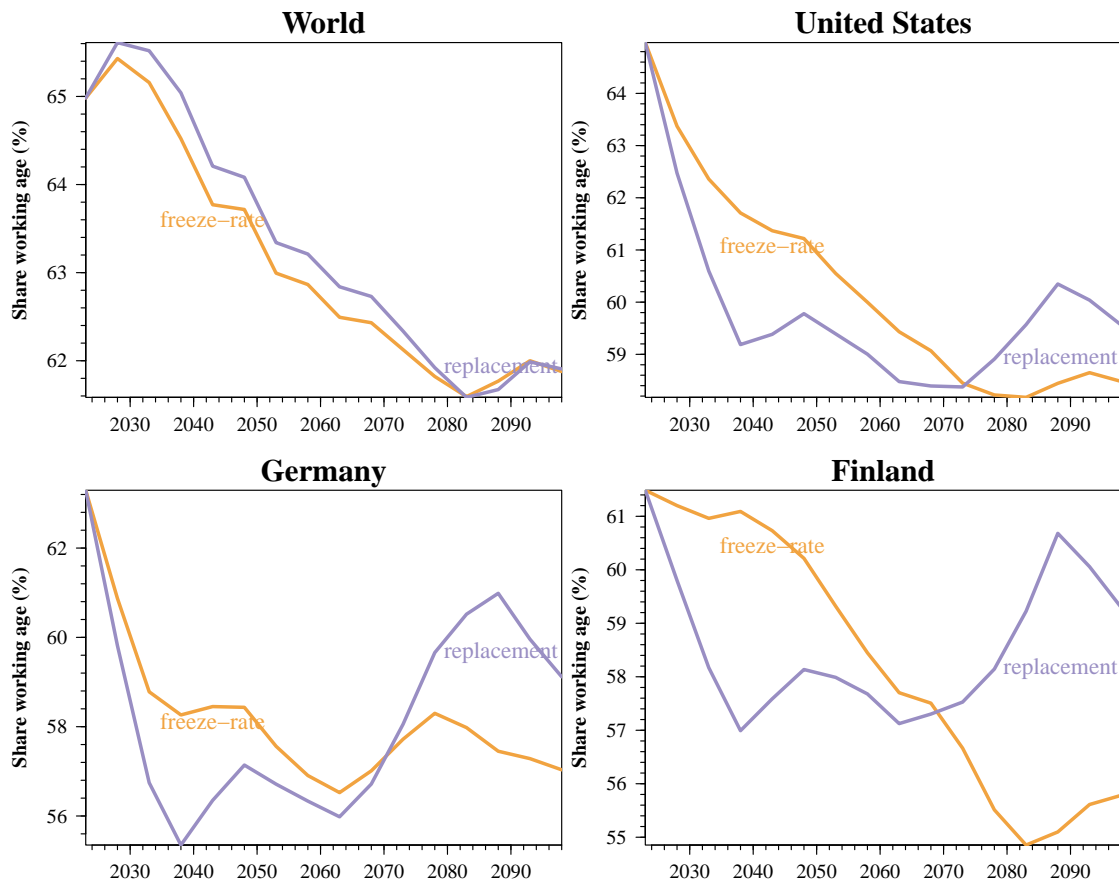


Figure 7.2: This figure illustrates the size of the workforce expressed as population share in % according to current mortality and fertility rates (*freeze rate scenario*) and when fertility would be set to a level that produces a net reproduction rate of one (*replacement level fertility*) in the world, United States, Germany and Finland. Migration is taken from the World Population Prospects. The results are generated using the cohort component method to data from the World Population Prospect.

level fertility would accelerate this trend in the short term. Thus, the workforce will decline irrespective of the fertility scenario, which is related to the age structure that carries population momentum. Therefore, countries with sustained low fertility cannot rely on fertility rebounds alone to avoid workforces declines. In the long term, however, the replacement level fertility scenario points to a consolidation of the size of the workforce at a somewhat higher level compared to that in the freeze rate scenario. This suggests that, while fertility may not be able to prevent the initial decline of the workforce in the short term, it could have long-term benefits. To conclude, fertility is a key driver of population ageing (see also Lee and Zhou, 2017),

but it does not directly drive the shrinkage of the workforce in the short-term, due to population momentum, the impending retirement of the baby boomer generation, and the economic dependence of children. Therefore, policy-makers should not target fertility as a means to address economic concerns. Furthermore, research has shown that the stock of human capital in populations plays a more significant role in the sustainability of economies and welfare states, and, ultimately, the standard of living, than fertility does (Lee et al., 2014; Lutz, 2023; Myrskylä et al., 2024).

7.3.3 Innovative policy suggestions

The thesis contends that the recent fertility trends are multifactorial, and that the drivers of these declines are structural, biological, economic, and cultural factors. Therefore, the potential of policies to stop or even reverse fertility declines is limited because they would need to address a multitude of factors. Moreover, some of the factors are not reversible, like declining fecundity with age; or targeting them might conflict with certain fundamental human rights, like the freedom of residence in the case of regional partner markets. Therefore, I strongly oppose any pronatalist policies that target low fertility directly. “Such policy responses have questionable justifications, limited effect on fertility, and potentially harmful effects on sexual and reproductive health, human rights, and gender equality” (p. 1 Gietel-Basten et al., 2022). The only justifiable reasons to pursue active family and reproductive policies would be to address health concerns or individual needs, or to support individual opportunities and foster equality. Therefore, empowerment, and not persuasion, should be the core of family policies.

Nevertheless, some policies that support parents and strengthen children’s rights may still be justified. One justification for this approach is the persistence of the gap between intended and realised childbearing, which highlights structural constraints on childbearing (Harknett et al., 2014). The realised number of children often falls short of the intended number of children, a phenomenon sometimes referred to as

the *fertility intention gap*. This gap points to structural barriers to childbearing, which policies can actively address to facilitate the realisation of life goals. A recent study by Vanhuysse et al. (2023) showed that even in countries with generous family policies such as Sweden and Finland, parents face high costs when raising children, which shifts the cost-benefit rationale of childbearing. In particular, parents transfer time and goods to the next generation that they are not compensated for. Compensation for these additional costs of parenthood can be seen as fair. In addition, while childbearing itself may not be associated with monetary benefits, caring for children is a form of work that deserves recognition, similar to employment or civic work. For these reasons, I propose several innovative policy measures.

Invest in education

Instead of addressing fertility itself, the consequences of low fertility may be targeted. The greatest concern regarding low fertility is the shrinkage of the workforce, which was analysed in Section 7.3.2. However, a smaller workforce may not be a problem if it is accompanied by a growth in per capita productivity. Productivity is an economic concept that describes the value produced per unit of time. Productivity is generally higher among higher educated individuals, who tend to produce more value. Thus, increasing the education of the workers may mitigate the effects of the decline in the size of the workforce (Lutz, 2021). But how much investment in education is necessary? Myrskylä et al. (2024) estimated for Finland, the second-fastest ageing country globally, that keeping the investment in education constant, e.g., increasing the investment per capita as the cohorts are shrinking, can more than offset the impact of declining cohorts on economic output. Hence, in the face of shrinking cohorts, funds should not be redistributed from education to other sectors, but the investments in education may be kept constant instead.

Prepare care systems for more childless older people

A future-oriented policy should prepare for a growing number of childless elderly people, who will need affordable care options. In many societies, some care is provided by professional care services, but much of it is provided by family members. However, childlessness and declining fertility will affect the number of relatives who are able to provide care for the elderly (Alburez-Gutierrez et al., 2023). As a result, people will increasingly rely on professional care, leading to a growing demand for professional care services. It is essential to note that this increasing demand is related not just to ageing, but also to growing childlessness. Moreover, Chapter 6 showed that low-income individuals, and especially men, are more likely to be childless (Jalovaara et al., 2019). These individuals not only lack relatives capable of providing elderly care, but also lack sufficient economic resources to afford professional care services. This double disadvantage may create a new dimension of social inequality. Therefore, I encourage policy-makers and care-insurance systems to prepare for these demographic shifts.

Let children vote in elections

I propose that children should be given the right to vote in all political elections from birth, as this could enhance the position of children in society, and the degree to which their interests are taken into account in political decision-making. In most democracies, minimum voting age laws exclude children from society and politics by drawing a qualitative line between adults and children. This boundary is artificial and deprives children of their rights as citizens. In Germany, for example, the minimum age for voting in federal elections is 18 and in European elections is 16. Removing the minimum age for voting is a fundamental step towards achieving the principle of “one man, one vote” in democracies, and towards recognising the rights and interests of children. Allowing children to vote may improve the representation of the interests of the youngest members of society in politics. In

addition, giving children the right to vote from birth can be a fundamental step towards the development of a demand-driven family policy, as members of the family can express their political will.

7.4 Conclusion

Fertility trends are complex. Particularly the declines in the Anglo-Saxon and Nordic countries in the 2010s remain puzzling. They will have an impact on completed cohort fertility (Hellstrand et al., 2020), even though they were accompanied by fertility postponement. In Chapter 1, I argued that only a multifactorial explanation can shed light on fertility trends, and that both structural and biological determinants of fertility are important. The chapters provided empirical evidence to support this thesis. Human development (Chapter 2), secularisation (Chapter 3), fecundity (Chapter 4), partner markets (Chapters 5 and 6), economic characteristics (Hellstrand et al., 2024), value change (Kearney et al., 2022) and uncertainty (Comolli, 2021) are associated with the recent fertility decline. It is likely that these factors had interacting effects on the fertility decline, making it impossible to explain this trend by citing a single factor. This observation has important implications for research, policy, and society.

The epistemological implications for research are that it is essential to develop a more nuanced understanding of the factors contributing to the fertility decline. This requires researchers to go beyond establishing a systematic relationship between variables. Instead, I suggest quantifying the contribution of each factor to the overall fertility change at the population level. This makes the effects comparable across dimensions and studies, which will facilitate the scholarly discussion. In other words, I suggest shifting the focus from $\hat{\beta}$ (coefficient) to a perspective that uses the estimates to obtain a population-level effect ($\tau_{T=[1-0]|\hat{\beta}} = E[\hat{y}_{T=1|\hat{\beta}}] - E[\hat{y}_{T=0|\hat{\beta}}]$). Demography has a comparative advantage to do so. Approaches like multi-state modelling with counterfactual intervention (Hellstrand et al., 2021) or the G-formula

may be useful tools for this purpose (Bijlsma & Wilson, 2020; Gueltzow et al., 2022, 2023; Keil et al., 2014; Sudharsanan & Bijlsma, 2022). This perspective is exemplified in this thesis and in the work of Julia Hellstrand (2020, 2021, 2024). I suggest quantifying the impact of each of the above-mentioned factors on fertility and fertility trends using an integrative approach.

The results of this research carry an important message for policymakers, as they suggest that no single policy will be able to reverse the fertility decline. Instead, policymakers should focus on addressing the consequences of low fertility, such as the impact on economic output. Research has shown that investments in education can mitigate the impact of low fertility on economic output (Myrskylä et al., 2024), as more educated individuals are healthier and more productive on average (Lutz, 2021). Moreover, as old-age support networks are expected to shrink due to increasing childlessness, the professional care infrastructure will need to adapt to the growing demand. Therefore, I suggest that policymakers prioritize education and other investments that can help to mitigate the consequences of low fertility and childlessness.

The fertility decline has significant implications for society, as it means that there will be fewer children. As Section 7.3.1 showed, fertility is unlikely to increase in the near future. Therefore, it is essential that the society at large prioritises the well-being and education of children. From an economic perspective, the value of children should increase, as goods that are rare increase in price. Therefore, I hope that societies will adapt by acknowledging the dignity of children and investing in their future.

Appendices

A

Appendix to Chapter 2

A.1 Variance estimation for the inversion point

Formula for the inversion point:

$$I = \frac{-\beta_1}{2\beta_2} \quad (\text{A.1})$$

Delta method:

$$\text{Var}(I) = \frac{\delta I}{\delta \beta'} \text{Var}(\beta) \frac{\delta I}{\delta \beta'} \quad (\text{A.2})$$

$$= \left(\frac{\delta I}{\delta \beta_1} \right)^2 \text{Var}(\beta_1) + \left(\frac{\delta I}{\delta \beta_2} \right)^2 \text{Var}(\beta_2) + 2 \frac{\delta I}{\delta \beta_1} \frac{\delta I}{\delta \beta_2} \text{Cov}(\beta_1, \beta_2) \quad (\text{A.3})$$

with

$$\frac{\delta I}{\delta \beta_1} = -\frac{1}{2\beta_2} \quad (\text{A.4})$$

and

$$\frac{\delta I}{\delta \beta_2} = \frac{2\beta_1}{4\beta_2^2} \quad (\text{A.5})$$

which can be evaluated at parameter estimates. Using the $\text{Var}(I)$ estimate and the estimated turning point, the 95%-confidence interval was estimated in the following way:

$$ci_{95}(I) = I \pm 1.96 * \frac{\text{Var}(I)}{\sqrt{n}}$$

A.2 Equations

Estimation of tempo-adjusted TFR

$$TFR_{tempo-adjusted} = \sum_{parity=1} \frac{TFR_{parity}}{(1-r)} \quad (A.6)$$

with

$$r = 0.5 * [MAB(t+1, parity) - MAB(t-1, parity)] \quad (A.7)$$

Estimation of the Human Life indicator

$$\text{Human Life indicator} = \prod_{i=1}^N (age_i + a_i)^{d_i} \quad (A.8)$$

Estimation of the Gini-coefficient for the life table

$$G_0 = 1 - \frac{1}{e(0)[\ell(0)]^2} \cdot \sum_0^{\infty} [l(x)]^2 \quad (A.9)$$

A.3 Additional Tables

Treatment	Outcome	Model	State FE	Year FE	Controls	inv. J-shape?	Turning point
HLI	TFR	Std.	Yes	No	No	Yes	71.6
HLI	TFR	Std.	Yes	Yes	No	Yes	88.5
HLI	TFR	FEIS	Yes	Yes	No	Yes	76.82
HLI	TFR	RE	No	No	No	Yes	86.4
HLI	TFR	Census	No	No	Yes	Yes	64.19
HLI	TFR	Smooth	Yes	Yes	No	Yes	102.36
HLI	aTFR	Std.	Yes	Yes	No	Yes	101.49
HLI	mTFR	Std.	Yes	Yes	No	Yes	83.64
HLI	TFR	Std.	Yes	Yes	Unemp.	No	75.8
HLI	TFR	Std.	Yes	Yes	Service	Yes	58.61
HLI	TFR	Std.	Yes	Yes	Age diff.	No	74.84
HLI	TFR	Std.	Yes	Yes	Rec.	Yes	79.18
HLI	TFR	Std.	Yes	No	Δ MAB	Yes	72.63
HLI	TFR	Std.	Yes	Yes	Δ MAB	Yes	88.23
HLI	TFR	Std.	Yes	No	MAB	Yes	76.48
HLI	TFR	Std.	Yes	Yes	MAB	Yes	104.21
HDI	TFR	Std.	Yes	No	No	No	0.82
HDI	TFR	Std.	Yes	Yes	No	No	1.04
HDI	TFR	FEIS	Yes	Yes	No	No	-0.5
HDI	TFR	RE	No	No	No	No	0.96
HDI	TFR	Census	No	No	No	No	0.92
HDI	TFR	Smooth	Yes	Yes	No	No	1.03
HDI	aTFR	Std.	Yes	Yes	No	Yes	0.76
HDI	mTFR	Std.	Yes	Yes	No	Yes	1.15
HDI	TFR	Std.	Yes	Yes	Rec.	No	1
LE	TFR	Std.	Yes	No	No	Yes	78.46
LE	TFR	Std.	Yes	Yes	No	Yes	89.03
LE	TFR	FEIS	Yes	Yes	No	Yes	116.71
LE	TFR	RE	No	No	No	Yes	88.04
LE	TFR	Census	No	No	No	Yes	38.37
LE	TFR	Smooth	Yes	Yes	No	Yes	94.2
LE	aTFR	Std.	Yes	Yes	No	No	62.42
LE	mTFR	Std.	Yes	Yes	No	No	84.8
LE	TFR	Std.	Yes	Yes	Rec.	Yes	84.51

Tempo-adjusted TFR

Table A.1: State fixed effects regression on tempo-adjusted TFR using lagged values of the Human Life indicator (HLI), Human Development Index (HDI) and life expectancy (LE).

	lag.HLI	lag.HDI	lag.LE
Linear	-0.708*** (0.040)	-44.092** (21.577)	-2.140*** (0.145)
Squared	0.005*** (0.0003)	26.764** (12.227)	0.014*** (0.001)
State fixed effects	Yes	Yes	Yes
Year fixed effects	No	No	No
Years	1969 - 2004	1990 - 2004	1969 - 2004
Observations	1,836	714	1,836
R ²	0.142	0.114	0.123
J shape	Yes	Yes	Yes
Turning point	71.6	0.82	78.46
Confidence interval	(71.45, 71.76)	(0.79, 0.86)	(78.25, 78.66)
<i>Note:</i>	*p<0.1; **p<0.05; ***p<0.01		

Table A.2: Two-way fixed effects regression on tempo-adjusted TFR using lagged values of the Human Life indicator (HLI), Human Development Index (HDI) and life expectancy (LE).

	lag.HLI	lag.HDI	lag.LE
Linear	-0.025 (0.031)	-39.756** (18.318)	0.026 (0.108)
Squared	0.0001 (0.0002)	26.168** (10.325)	-0.0002 (0.001)
State fixed effects	Yes	Yes	Yes
Year fixed effects	Yes	Yes	Yes
Years	1969 - 2004	1990 - 2004	1969 - 2004
Observations	1,836	714	1,836
R ²	0.011	0.476	0.002
J shape	Yes	Yes	No
Turning point	101.49	0.76	62.42
Confidence interval	(94.46, 108.51)	(0.73, 0.79)	(54.34, 70.49)
<i>Note:</i>		*p<0.1; **p<0.05; ***p<0.01	

Table A.3: Two-way fixed effects regression on male TFR using lagged values of the Human Life indicator (HLI), Human Development Index (HDI) and life expectancy (LE).

	lag.HLI	lag.HDI	lag.LE
Linear	-0.108*** (0.015)	-6.844 (12.787)	-0.243*** (0.042)
Squared	0.001*** (0.0001)	2.970 (7.208)	0.001*** (0.0003)
State fixed effects	Yes	Yes	Yes
Year fixed effects	Yes	Yes	Yes
Years	1969 - 2004	1990 - 2004	1969 - 2004
Observations	1,836	1,428	1,836
R ²	0.184	0.621	0.158
J shape	Yes	Yes	Yes
Turning point	83.64	1.15	84.8
Confidence interval	(83.02, 84.25)	(0.92, 1.38)	(84.11, 85.48)
<i>Note:</i>		*p<0.1; **p<0.05; ***p<0.01	

The effect of state-level controls

Table A.4: Two-way fixed effects regression with controls of female TFR on lagged values of the Human Life indicator (HLI), Human Development Index (HDI) and life expectancy (LE).

	(1)	(2)	(3)
HLI	0.213*** (0.033)	-0.131*** (0.046)	0.235*** (0.034)
HLI ²	-0.001*** (0.0002)	0.001*** (0.0003)	-0.002*** (0.0002)
Unemployment Rate	-0.011*** (0.002)		
% in Service		-0.012 (0.016)	
Age Difference			0.181** (0.086)
State fixed effects	Yes	Yes	Yes
Year fixed effects	Yes	Yes	Yes
Observations	2,193	1,479	2,193
Years	1976 - 2018	1976 - 2018	1976 - 2004
J shape	No	Yes	No
Turning point	75.8	58.61	74.84
Confidence interval	(75.37, 76.23)	(57.88, 59.34)	(74.44, 75.24)

Note:

*p<0.1; **p<0.05; ***p<0.01

A.3.1 Controlling for fertility postponement

Table A.5: State fixed effects regression of female TFR on lagged values of the Human Life indicator (HLI), Human Development Index (HDI) and life expectancy (LE).

	TFR female			
	Myrskylä 1	Myrskylä 2	Greulich 1	Greulich 2
lag.HLI	-0.327*** (0.025)	-0.076*** (0.020)	-0.415*** (0.029)	-0.081*** (0.022)
lag.HLI ²	0.002*** (0.0002)	0.0004*** (0.0001)	0.003*** (0.0002)	0.0004** (0.0002)
Δ MAB	-0.503*** (0.046)	0.026 (0.042)		
ΔΔ MAB	-0.215*** (0.035)	0.027 (0.028)		
MAB			1.871*** (0.097)	0.369*** (0.090)
MAB ²			-0.034*** (0.002)	-0.005*** (0.002)
State fixed effects	Yes	Yes	Yes	Yes
Year fixed effects	No	Yes	No	Yes
Years	1969 - 2018	1969 - 2018	1969 - 2018	1969 - 2018
Observations	2,550	2,550	2,550	2,550
R ²	0.09	0.049	0.165	0.101
J shape	Yes	Yes	Yes	Yes
Turning point	72.63	88.23	76.48	104.21
Confidence bands	(72.44, 72.81)	(87.31, 89.15)	(76.29, 76.67)	(102.84, 105.58)

Note:

*p<0.1; **p<0.05; ***p<0.01

A.3.2 Random effects models

Table A.6: State random effects regression of female TFR on lagged values of the Human Life indicator (HLI), Human Development Index (HDI) and life expectancy (LE).

	lag.HLI	lag.HDI	lag.LE
Linear	-0.335*** (0.025)	49.369*** (6.425)	-0.908*** (0.081)
Squared	0.002*** (0.0002)	-28.862*** (3.578)	0.006*** (0.001)
Constant	14.354*** (0.885)	-19.076*** (2.884)	38.489*** (3.162)
State random effects	Yes	Yes	Yes
Year random effects	No	No	No
Observations	2,550	1,428	2,550
Years	1969 - 2018	1990 - 2018	1969 - 2018
R ²	0.078	0.107	0.076
J shape	Yes	No	Yes
Turning point	74.34	0.86	80.55
Confidence bands	(64.79, 83.89)	(0.57, 1.14)	(68.3, 92.79)
<i>Note:</i>	*p<0.1; **p<0.05; ***p<0.01		

Table A.7: Two-way random effects regression of female TFR on lagged values of the Human Life indicator (HLI), Human Development Index (HDI) and life expectancy (LE).

	lag.HLI	lag.HDI	lag.LE
Linear	-0.079*** (0.019)	34.196*** (6.080)	-0.184*** (0.065)
Squared	0.0005*** (0.0001)	-17.766*** (3.343)	0.001** (0.0004)
	(0.697)	(2.774)	(2.552)
Constant	5.290***	-14.405***	9.954***
State random effects	Yes	Yes	Yes
Year random effects	Yes	Yes	Yes
Observations	2,550	1,428	2,550
Years	1969 - 2018	1990 - 2018	1969 - 2018
R ²	0.046	0.094	0.032
J shape	Yes	No	Yes
Turning point	86.4	0.96	88.04
Confidence interval	(85.56, 87.24)	(0.95, 0.97)	(86.9, 89.17)
<i>Note:</i>	*p<0.1; **p<0.05; ***p<0.01		

Table A.8: State fixed effects regression with smoothed time-series of lagged values of the Human Life indicator (HLI), Human Development Index (HDI) and life expectancy (LE).

	Smoothed female TFR		
	(1)	(2)	(3)
HLI.smooth	-0.240*** (0.018)		
HLI.smooth ²	0.002*** (0.0001)		
HDI.smooth		212.042*** (11.684)	
HDI.smooth ²		-116.906*** (6.375)	
LE.smooth			-0.631*** (0.060)
LE.smooth ²			0.004*** (0.0004)
Year fixed effects	No	No	No
State fixed effects	Yes	Yes	Yes
Years	1969 - 2018	1990 - 2018	1969 - 2018
Observations	2,550	1,428	2,550
R ²	0.221	0.520	0.221
J shape	Yes	Yes	Yes
Turning point	76.28	0.91	82.12
Confidence interval	(76.07, 76.48)	(0.9, 0.91)	(81.85, 82.39)

Note:

*p<0.1; **p<0.05; ***p<0.01

Table A.9: Two-way fixed effects regression with smoothed time-series.

<i>Dependent variable:</i>			
Smoothed female TFR			
	(1)	(2)	(3)
HLL.smooth	-0.053*** (0.017)		
HLL.smooth ²	0.0003** (0.0001)		
HDI.smooth		45.519*** (4.828)	
HDI.smooth ²		-22.139*** (2.628)	
LE.smooth			-0.103* (0.057)
LE.smooth ²			0.001 (0.0004)
Year fixed effects	Yes	Yes	Yes
State fixed effects	Yes	Yes	Yes
Years	1969 - 2018	1990 - 2018	1969 - 2018
Observations	2,550	1,428	2,550
R ²	0.021	0.133	0.010
J shape	Yes	No	Yes
Turning point	102.36	1.03	94.2
Confidence interval	(100.8, 103.91)	(1.02, 1.04)	(92.17, 96.23)

Note:

*p<0.1; **p<0.05; ***p<0.01

Table A.10: Census-division fixed effects regression of female TFR on lagged values of development indicators.

Dependent Variable:	TFR female		
Model:	(1)	(2)	(3)
lag HLI	-0.0419 (0.0385)		
lag HLI ²	0.0003 (0.0003)		
lag HDI		23.01** (9.226)	
lag HDI ²		-12.53** (5.157)	
lag LE			-0.0127 (0.0963)
lag LE ²			0.0002 (0.0006)
Census division	Yes	Yes	Yes
Year	Yes	Yes	Yes
Years	1969 - 2018	1990 - 2018	1969 - 2018
Observations	2,550	1,428	2,550
R ²	0.68597	0.67502	0.68718
Within R ²	0.00215	0.00684	0.00598
J shape	Yes	No	No
Turning point	64.19	0.9200	38.37
Confidence bands	(62.44, 65.93)	(0.89, 0.94)	(33.69, 43.05)

Clustered (census Division-Year) standard-errors in parentheses
*Signif. Codes: ***: 0.01, **: 0.05, *: 0.1*

Table A.11: The effect of the great recession period on the fertility-development nexus.

		Female TFR	
lag HLI	-0.116*** (0.023)		
lag HLI ²	0.001*** (0.0002)		
lag HLI:Recession	0.113 (0.133)		
lag HLI ² × Recession	-0.001 (0.001)		
lag HDI		56.684*** (11.261)	
lag HDI ²		-28.395*** (6.306)	
lag HDI × Recession		-30.491** (12.747)	
lag HDI ² :Recession		17.019** (7.069)	
lag LE			-0.238*** (0.080)
lag LE ²			0.001*** (0.001)
lag LE:Recession			-0.021 (0.296)
lag LE ² × Recession			0.0001 (0.002)
State fixed effects	Yes	Yes	Yes
Year fixed effects	Yes	Yes	Yes
Observations	2,550	1,428	2,550
Years	1969-2018	1990-2018	1969-2018
J shape	Yes	No	Yes
Turning point	79.18	1	84.51
Confidence bands	(78.59, 79.76)	(0.98, 1.01)	(83.49, 85.52)
<i>Note:</i>		*p<0.1; **p<0.05; ***p<0.01	

Table A.12: State fixed effects regression on female TFR using Several Development Indicators.

	lag.HLI	lag.HDI	lag.LE
Linear	-0.349*** (0.025)	56.896*** (7.762)	-0.983*** (0.083)
Squared	0.002*** (0.0002)	-33.309*** (4.313)	0.006*** (0.001)
State fixed effects	Yes	Yes	Yes
Year fixed effects	No	No	No
Years	1969 - 2018	1990 - 2018	1969 - 2018
Observations	2,550	1,428	2,550
R ²	0.081	0.133	0.079
J shape	Yes	No	Yes
Turning point	74.18	0.85	80.33
Confidence interval	(74, 74.36)	(0.85, 0.86)	(80.1, 80.56)

Note:

*p<0.1; **p<0.05; ***p<0.01

A.3.3 Breakpoint analysis

Table A.13: Results from the fixed-effects breakpoint regression analysis of TFR female on HLI with one, two and three breakpoints. The upper panel of the table shows the slopes with the corresponding standard errors for the different intervals of the predictor variable HLI. The second panel presents the estimated breakpoints with the corresponding confidence intervals. The lowest panel shows model summary measures, including the degrees of freedom, the multiple R^2 and the adjusted R^2 .

	<i>Number of breakpoints</i>		
	1	2	3
Intercept	-0.955593*** (0.0518)	-0.930526*** (0.038875)	-0.930799*** (0.039048)
lag.HLI	-0.168370*** (0.007356)	-0.165000*** (0.005733)	-0.165036*** (0.005754)
U1.lag.HLI	0.178006 (0.007459)	0.196963 (0.006075)	0.195585 (0.006170)
U2.lag.HLI		-0.082828 (0.004861)	0.201470 (0.514187)
U2.lag.HLI			-0.283276 (0.514198)
Breakpoint 1	67.5461 (67.35, 67.74)	68.08867 (67.92, 68.26)	68.06736 (67.90, 68.24)
Breakpoint 2		74.78745 (74.56, 75.02)	74.42508 (74.05, 74.80)
Breakpoint 3			74.55215 (74.29, 74.82)
State fixed effects	Yes	Yes	Yes
Year fixed effects	No	No	No
Observations	2550	2550	2550
Years	1969-2018	1969-2018	1969-2018
R^2	0.3428	0.4186	0.4189
Adjusted R^2	0.342	0.4174	0.4173

Note: *p<0.1; **p<0.05; ***p<0.01

A.3.4 Life span inequality

I have estimated the Gini-coefficient for the life tables from the US Mortality DataBase. The estimation followed:

$$G_0 = 1 - \frac{1}{e(0)[\ell(0)]^2} \cdot \int_0^\infty [l(x)]^2 dx \quad (\text{A.10})$$

I estimated the extent to which the Human Life Indicator captures lifespan inequality by estimating the correlation between the HLI and the Gini. The results in Table A.14 show that the overall correlation is strong, pointing at a high validity of the HLI as lifespan indicator. In addition, I estimated the correlation for two periods, before 2010 and after 2010, because the literature shows that the correlation between life expectancy and lifespan inequality as vanished in recent years. The results show a continuing high correlation, although with slightly reduced strength. Thus, the HLI may capture lifespan inequality to a lesser extent than the Gini-coefficient.

Table A.14: Pearson's r correlation between 1-Gini and the Human Life Indicator in different periods.

Period	1969-2018	1969-2010	2010-2018
Correlation	0.961	0.97	0.94

Given that the HLI does not fully capture lifespan inequality, I have estimated the models with 1-Gini-coefficient. The results are presented in Table A.15 and are in line with the other results.

Table A.15: Two-way fixed effects regression with individual slope of the female TFR on $1 - Gini$.

<i>Dependent variable:</i>	
Female TFR	
1 - lag.gini	-49.264** (23.716)
1 - lag.gini	27.379** (13.336)
Observations	2,499
years	1969 - 2018
R ²	0.003
Turning point CI (TP)	0.8996591 (0.88, 0.92)

Note: *p<0.1; **p<0.05; ***p<0.01

A.3.5 Regression for the period between 2008 and 2018

Table A.16: Twoway fixed-effects regression of the female TFR on the Human Life Indicator (lag) for the period between 2008 and 2018.

<i>Dependent variable:</i>	
TFR	
HLI	-0.017*** (-0.025, -0.010)
State fixed effects	Yes
Year fixed effects	Yes
Observations	612
Years	2008 - 2018
R ²	0.036
Adjusted R ²	-0.073

Note: *p<0.1; **p<0.05; ***p<0.01

A.3.6 Ordinary least squares regression

Table A.17: Ordinary least squares regression of female TFR on Human Life Indicator (HLI), Human Development Index (HDI), and Life Expectancy (LE).

	<i>Dependent variable:</i>		
	TFR female		
	(1)	(2)	(3)
lag HLI	-0.165*** (0.034)		
lag HLI ²	0.001*** (0.0002)		
lag HDI		104.296*** (10.804)	
lag HDI ²		-59.155*** (6.028)	
lag LE			-0.424*** (0.112)
lag LE ²			0.003*** (0.001)
Intercept	8.157*** (1.226)	-43.959*** (4.839)	19.037*** (4.389)
Observations	2,601	1,479	2,601
R ²	0.027	0.103	0.018
Adjusted R ²	0.026	0.102	0.017
J-Shape	Yes	No	Yes
Turning point	75.43	0.88	80.7
CI(I)	(74.89, 75.97)	(0.88, 0.89)	(79.99, 81.42)
<i>Note:</i>	*p<0.1; **p<0.05; ***p<0.01		

A.4 Model fit

Table A.18: This table displays the number of state-year observations, state observations and positive development-TFR slopes after the turning point estimated for a certain model.

Model	Outcome	Predictor	J-Shape	Turning point	N. Obs. after TP	N. States after TP	Positive $\frac{\Delta TFR}{\Delta Development}$
FEIS	TFR adjusted	HDI	TRUE	0.698	1,479	51	539
FEIS	TFR adjusted	HLI	FALSE	68.356	2,217	51	1,025
FEIS	TFR adjusted	LE	FALSE	73.879	2,528	51	1,096
FEIS	TFR female	HDI	FALSE	-0.503	1,479	51	539
FEIS	TFR female	HLI	TRUE	76.822	365	31	155
FEIS	TFR female	LE	TRUE	116.707	2,601	51	1,122
FEIS	TFR male	HDI	FALSE	-5.020	1,479	51	539
FEIS	TFR male	HLI	TRUE	68.863	740	42	341
FEIS	TFR male	LE	TRUE	74.718	738	42	320
Division FE	TFR adjusted	HDI	FALSE	0.960	0	0	0
Division FE	TFR adjusted	HLI	TRUE	68.020	2,252	51	1,036
Division FE	TFR adjusted	LE	TRUE	74.520	2,472	51	1,092
Division FE	TFR female	HDI	FALSE	0.920	313	30	78
Division FE	TFR female	HLI	TRUE	64.190	2,514	51	1,099
Division FE	TFR female	LE	TRUE	38.370	2,601	51	1,122
Division FE	TFR male	HDI	TRUE	0.890	929	46	310
Division FE	TFR male	HLI	TRUE	64.170	1,624	51	771
Division FE	TFR male	LE	TRUE	69.760	2,004	51	974
Two-ways FE	TFR adjusted	HDI	TRUE	0.760	1,479	51	539
Two-ways FE	TFR adjusted	HLI	TRUE	101.487	2,601	51	1,129
Two-ways FE	TFR adjusted	LE	FALSE	62.417	2,601	51	1,122
Two-ways FE	TFR female	HDI	FALSE	1.038	0	0	0
Two-ways FE	TFR female	HLI	TRUE	88.502	0	0	0
Two-ways FE	TFR female	LE	TRUE	89.031	0	0	0
Two-ways FE	TFR male	HDI	TRUE	1.152	0	0	0
Two-ways FE	TFR male	HLI	TRUE	83.638	0	0	0
Two-ways FE	TFR male	LE	TRUE	84.797	0	0	0
OLS	TFR adjusted	HDI	FALSE	0.921	298	29	69
OLS	TFR adjusted	HLI	TRUE	70.635	1,930	51	896
OLS	TFR adjusted	LE	TRUE	77.517	1,930	51	891
OLS	TFR female	HDI	FALSE	0.882	1,099	50	389
OLS	TFR female	HLI	TRUE	74.274	1,049	44	465
OLS	TFR female	LE	TRUE	79.883	897	42	372
OLS	TFR male	HDI	FALSE	0.776	1,479	51	539
OLS	TFR male	HLI	TRUE	68.711	777	42	356
OLS	TFR male	LE	TRUE	74.705	740	42	321

Table A.19: Continued from previous page.

Model	Outcome	Predictor	J-Shape	Turning point	N. Obs. after TP	N. States after TP	Positive	$\frac{\Delta TFR}{\Delta Development}$
First Difference	TFR adjusted	HDI	FALSE	0.750	1,479	51	539	
First Difference	TFR adjusted	HLI	TRUE	73.212	1,338	50	597	
First Difference	TFR adjusted	LE	TRUE	79.228	1,158	43	491	
First Difference	TFR female	HDI	FALSE	0.847	1,436	51	528	
First Difference	TFR female	HLI	TRUE	74.890	872	43	380	
First Difference	TFR female	LE	TRUE	80.380	663	38	265	
First Difference	TFR male	HDI	TRUE	0.959	0	0	0	
First Difference	TFR male	HLI	TRUE	65.225	1,430	51	672	
First Difference	TFR male	LE	TRUE	71.448	1,606	51	760	
Two-ways RE	TFR adjusted	HDI	TRUE	0.807	1,479	51	539	
Two-ways RE	TFR adjusted	HLI	TRUE	79.668	13	4	5	
Two-ways RE	TFR adjusted	LE	TRUE	86.493	0	0	0	
Two-ways RE	TFR female	HDI	FALSE	0.962	0	0	0	
Two-ways RE	TFR female	HLI	TRUE	86.400	0	0	0	
Two-ways RE	TFR female	LE	TRUE	88.038	0	0	0	
Two-ways RE	TFR male	HDI	TRUE	0.982	0	0	0	
Two-ways RE	TFR male	HLI	TRUE	82.471	0	0	0	
Two-ways RE	TFR male	LE	TRUE	84.130	0	0	0	
State FE	TFR adjusted	HDI	TRUE	0.824	1,477	51	539	
State FE	TFR adjusted	HLI	TRUE	71.604	1,759	51	811	
State FE	TFR adjusted	LE	TRUE	78.456	1,491	48	654	
State FE	TFR female	HDI	FALSE	0.854	1,400	51	511	
State FE	TFR female	HLI	TRUE	74.181	1,064	44	470	
State FE	TFR female	LE	TRUE	80.329	684	38	279	
State FE	TFR male	HDI	TRUE	0.880	1,164	50	414	
State FE	TFR male	HLI	TRUE	67.442	1,020	46	464	
State FE	TFR male	LE	TRUE	74.162	882	43	406	

A.5 Additional Figures

A.5.1 The role of postponement

When looking at fertility developments using the tempo-adjusted TFR, the j-shape pattern remains visible. However, the weakening relationship points at interfering tempo distortions of the normal TFR, because the measure is biased by tempo-distortions. The initial drop in fertility was partially driven by postponement, as well as the subsequent recovery. I cannot make any statements about the impact of tempo distortions in the last phase because of data limitations. Yet, previous studies have shown that the decline resulted from decreasing childbearing intensity of teenagers and young adolescences, while fertility above age 30 remained roughly at the same level, which is visible in our data as well. Although this is not the ultimate evidence for tempo-distortions resulting from fertility postponement, it provides some preliminary support. Yet to be shown is whether the people that did not receive children between 2008 and 2018, have they only postponed or forewent childbearing altogether.

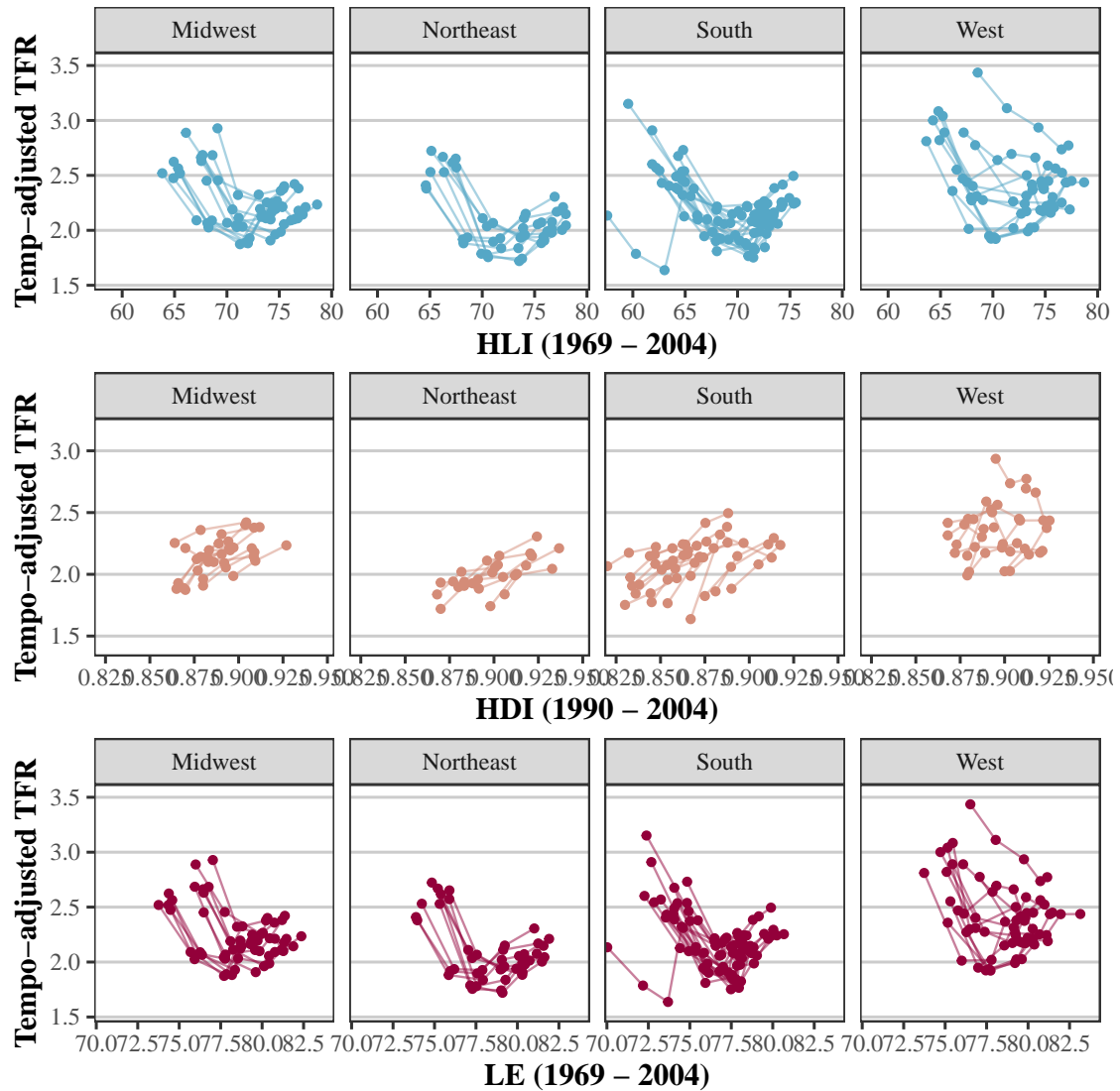


Figure A.1: Decade averages of development and fertility in the United States between 1990 and 2018

Model dependency

In the main model, the inversion point was calculated at a Human Life indicator of 77 and a life expectancy of 117 years. Yet, when calculating the models with different indicators and different specifications, the inversion point may shift slightly due to differences in the dimension of development as well as varying model assumptions, as displayed in Figure A.4. Thus, to reveal the distribution of turning points, I have calculated the point for random-effects, fixed effects, state-specific slope and OLS regression models using the different indicators, removed the values which

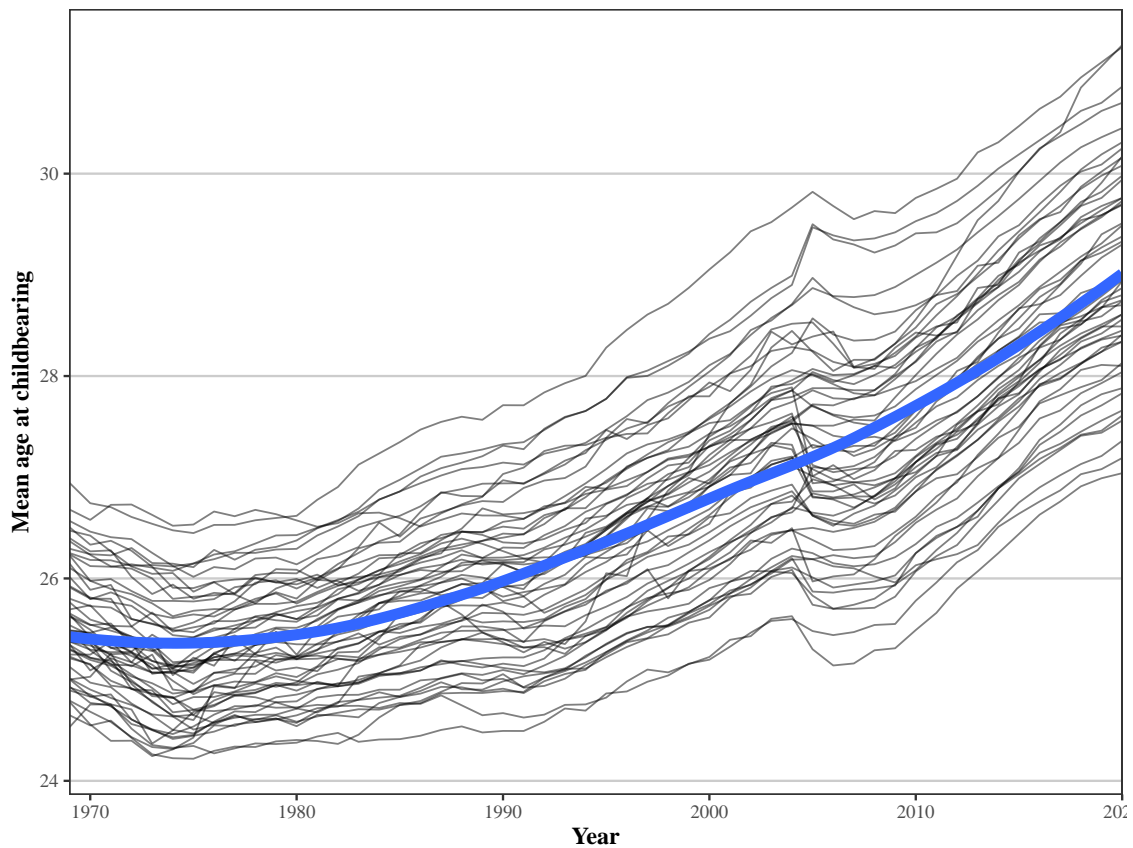


Figure A.2: The development of mean age of childbearing at the state-level between 1969 and 2020 in the U.S.

showed a concave relationship and assembled the results in the Figure A.4. The inversion point for the HDI and life expectancy is more clear-cut than for the HLI. The mean for the HLI is at 74 (HDI = 0.92, LE = 89), while the 25%- quantile is at 68 (HDI = 0.84, LE = 74) and the 75%-quantile is at 79 (HDI = 0.98, LE = 83). This shows, that the inversion point lies within the observed value range.

Yet, one result is inconsistent with our proposed hypothesis. For the HDI and the LE I see several observations that are at the far right end of the distribution. These values are strong outliers and belong to the models using the tempo-adjusted fertility rate and two-way fixed effects. I direct the reader to the section on tempo-effects.

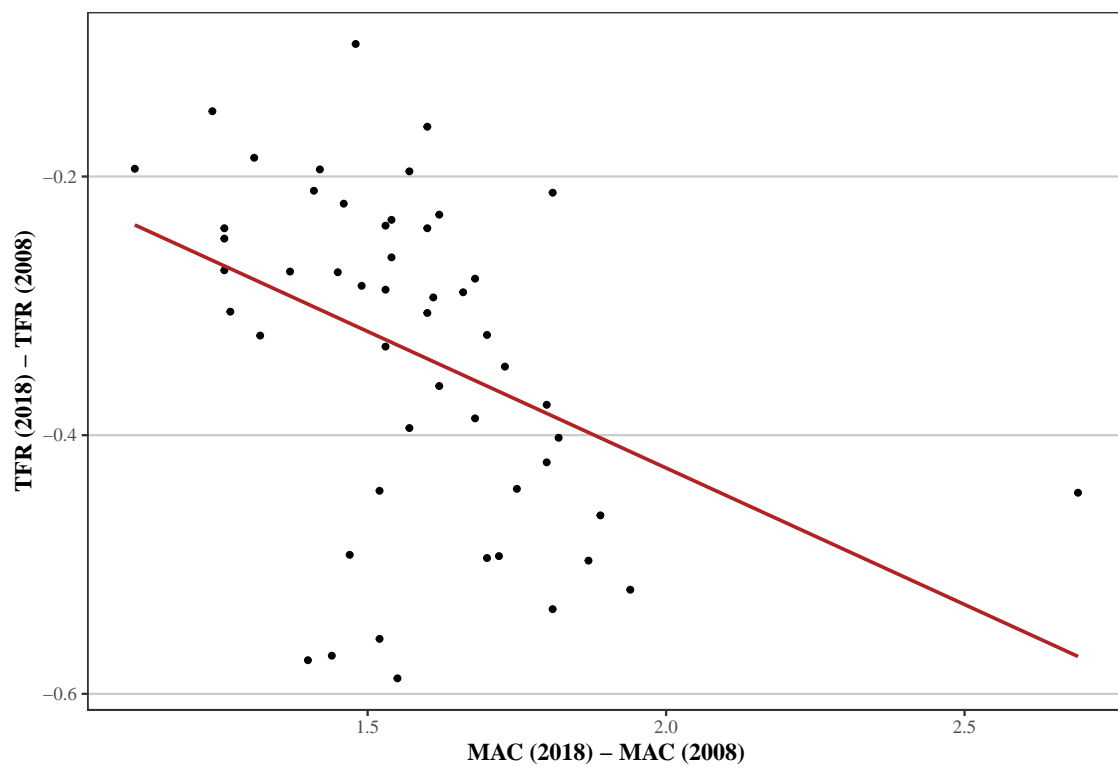


Figure A.3: The change in mean age of childbearing and the change of TFR between 2008 and 2018 at the subnational level in the U.S.

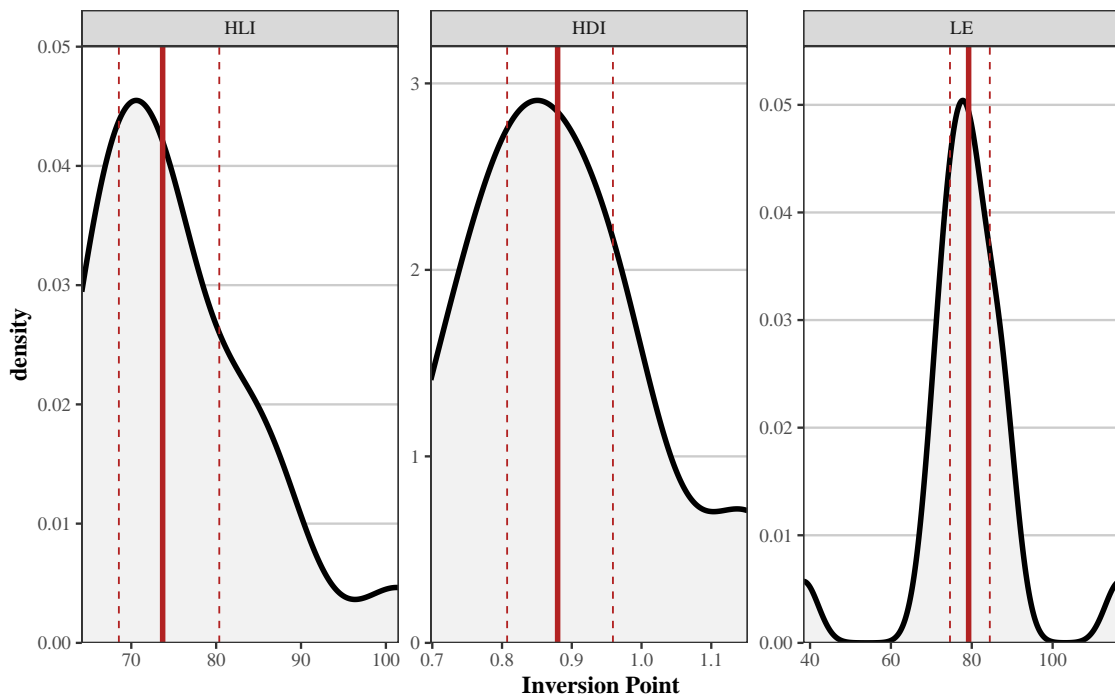


Figure A.4: The graph displays the distribution of turning points of the OLS, state FE, first-differenced, state random, two-ways random, two-way fixed effects models that show a convex relationship. Out of 63 models show 49 a convex relationship and 14 do not show the convex relationship. The thick line is the median of the turning points, and the dashed lines are the 25% quantiles.

Sensitivity

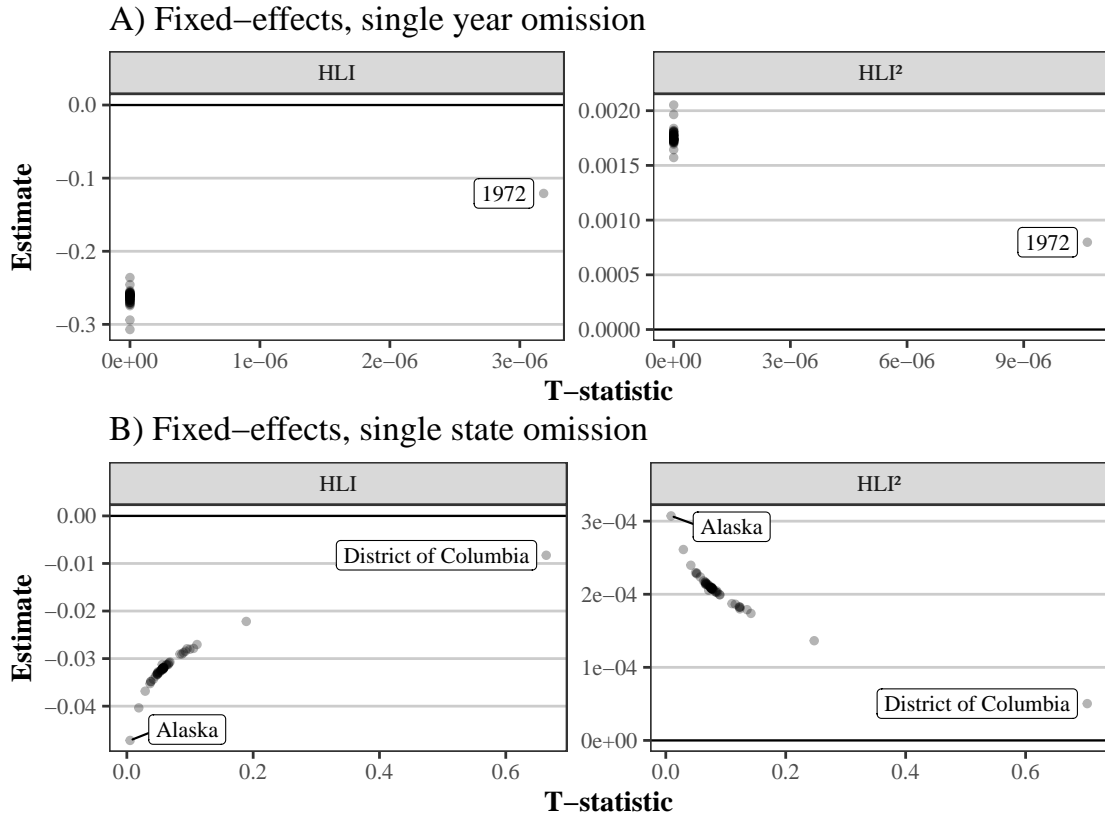


Figure A.5: This figures illustrates the coefficients and the T-statistic for HLI and HLI^2 across several two-way fixed effects individual slope regression models for different slope regression subsamples, after removing single years or single states. **Interpretation:** The results remain largely robust after removing single cases. However, omitting early years from the sample results in weaker J-shaped pattern. After removing Mississippi from the data, the relationship between development and fertility is largely flat, while the J-shape becomes more pronounced when removing Utah.

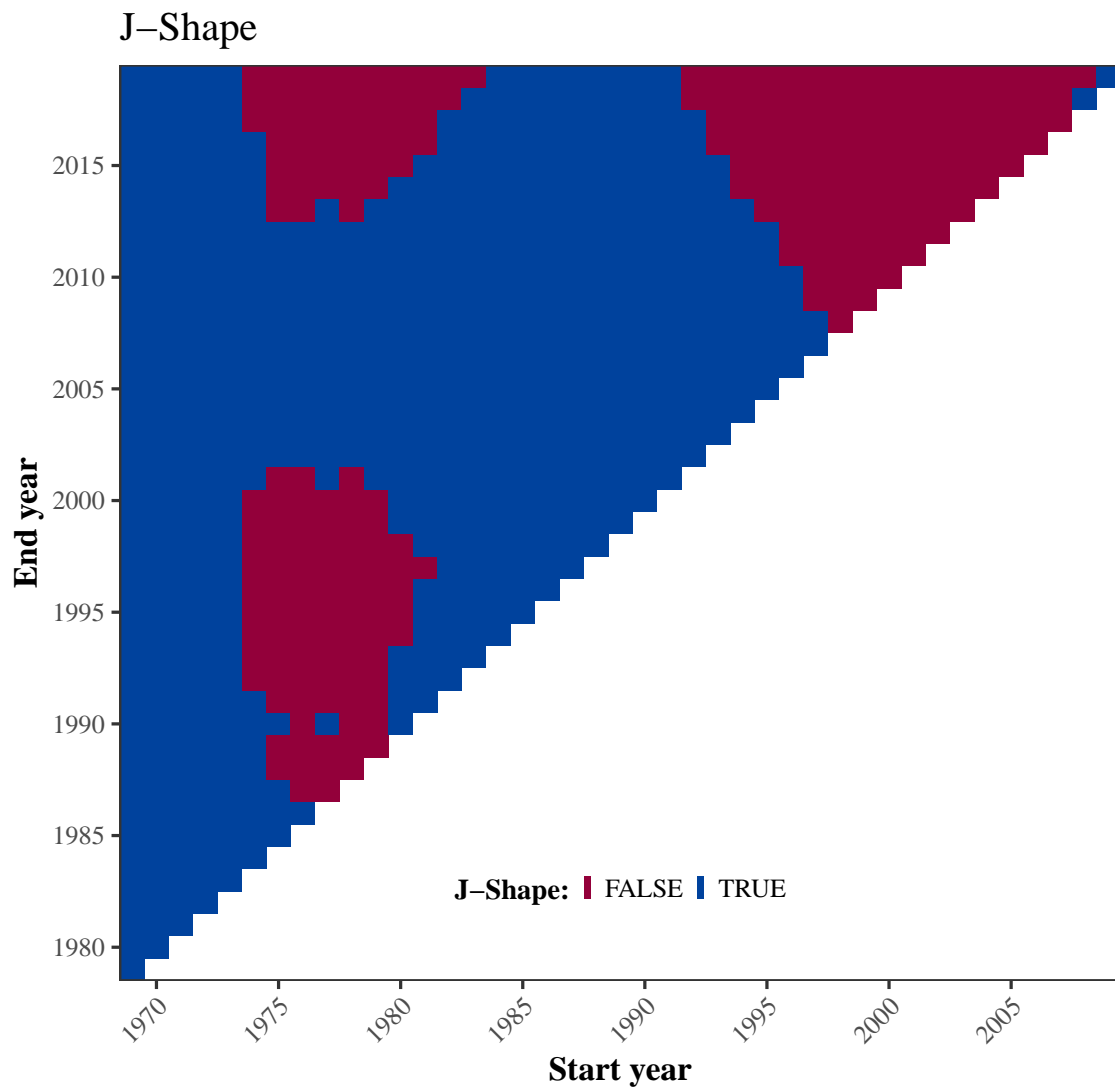


Figure A.6: Summary of two-way fixed effects regression models on different time-series lengths. The x-axis indicates the starting point of the time-series and the y-axis the end point. The colour indicates whether the coefficients align with the J-shape hypothesis ($\beta_1 < 0$ and $\beta_2 > 0$) or do not correspond to the hypothesized pattern.

A.5.2 Quantile regression

Moreover, I have calculated a longitudinal quantile regression following the suggestion by Lacalle-Calderon et al. (2016) and display the results in Figure S7 below. In this regression model, I find that the reversal of fertility does only occur for states with high levels of fertility, while low-fertility regimes experience almost no influence on development. This result reinforces previous findings indicating that contextual idiosyncrasies, such as factors related to culture and institutions, can affect fertility decline reversals.

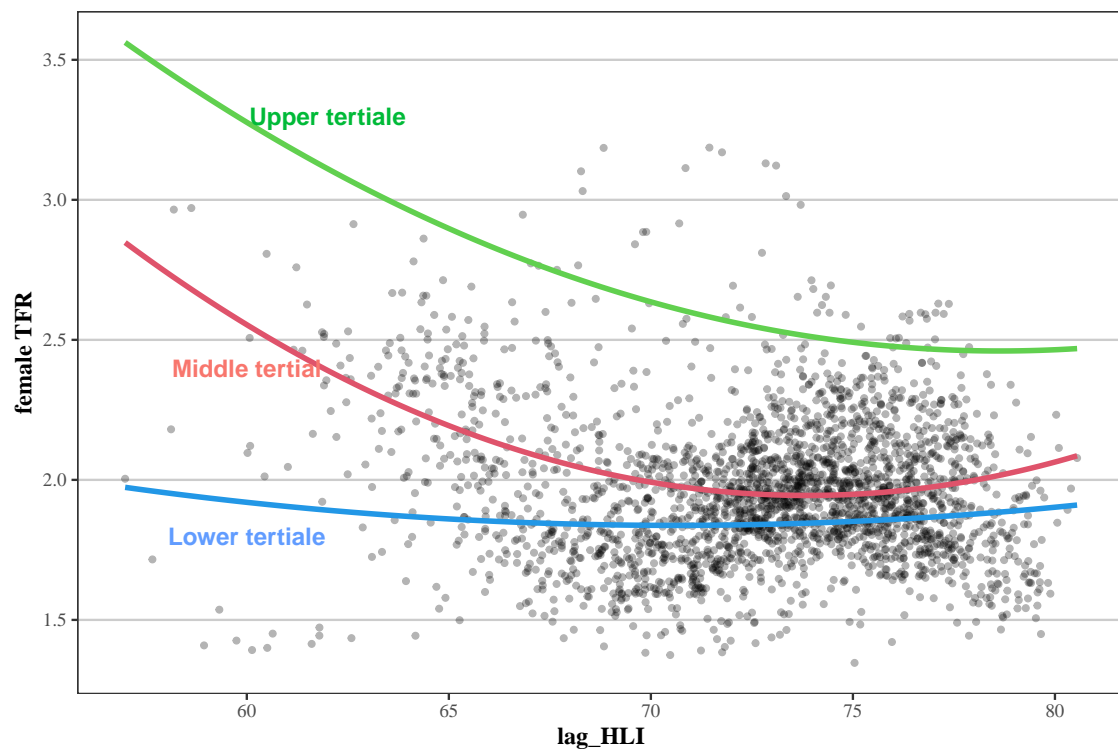


Figure A.7: Quantile regression with 33% quantiles.

A.5.3 Development and the male-female TFR ratio

When looking at the ratio of TFR of men to TFR of women in relation to development indicators, I see a strong negative relationship. The higher the development the lower the value for men compared to the female equivalent. The negative relationship holds within and between states. This observation for the subnational level corresponds to results from previous research at the national level, which shows a cross-over of male and female fertility during the demographic transition. Additionally, Dudel and colleagues (2020) have shown for the U.S, that the decline of the male to female TFR ratio is exaggerated by declining cohort size, which is framed as birth squeeze. Yet, there are some outliers in the most recent years, as Massachusetts as well as New York have a male-to-female TFR ratio that is higher than 1, although they belong to the most developed states.

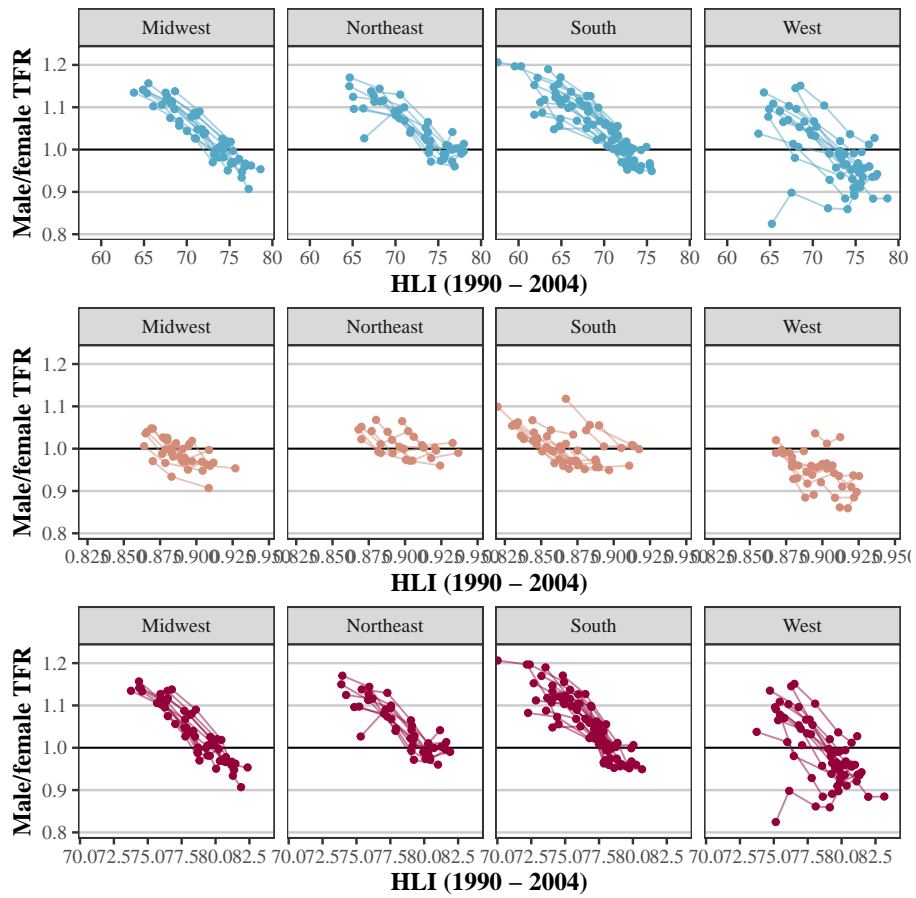


Figure A.8: Decade averages of development and male fertility in the United States between 1990 and 2018

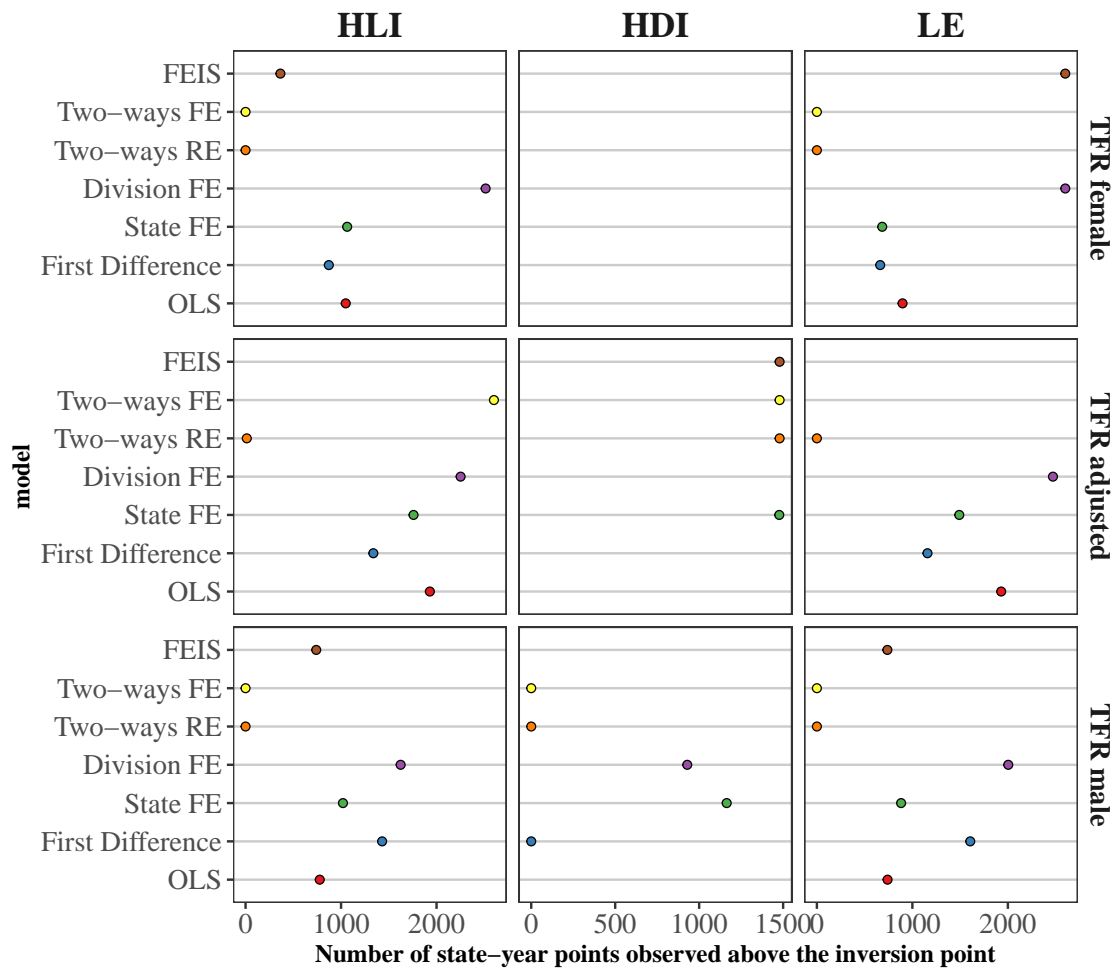


Figure A.9: This figure displays the number of state-year observations that occur after reaching the turning-point.

A.5.4 Model fit

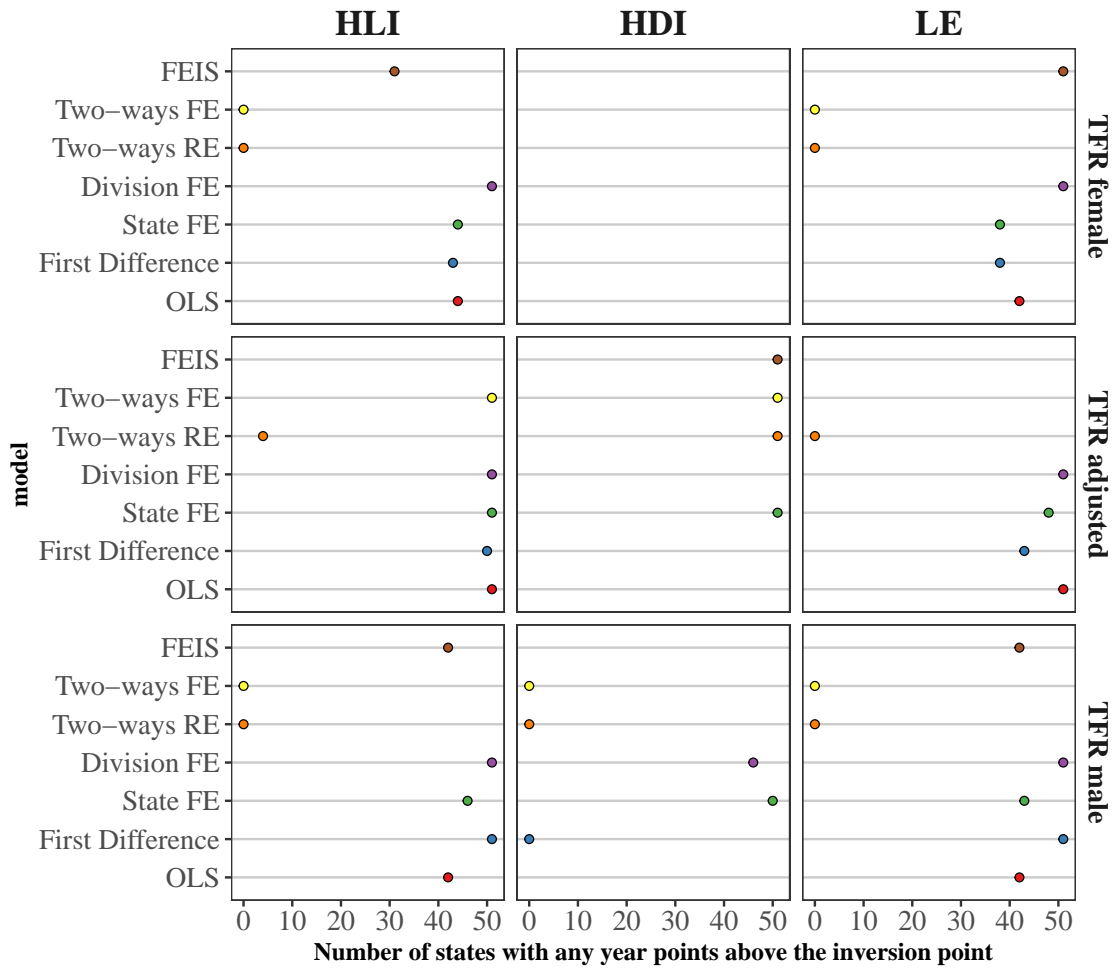


Figure A.10: This figure displays the number of state that reach the turning-point.

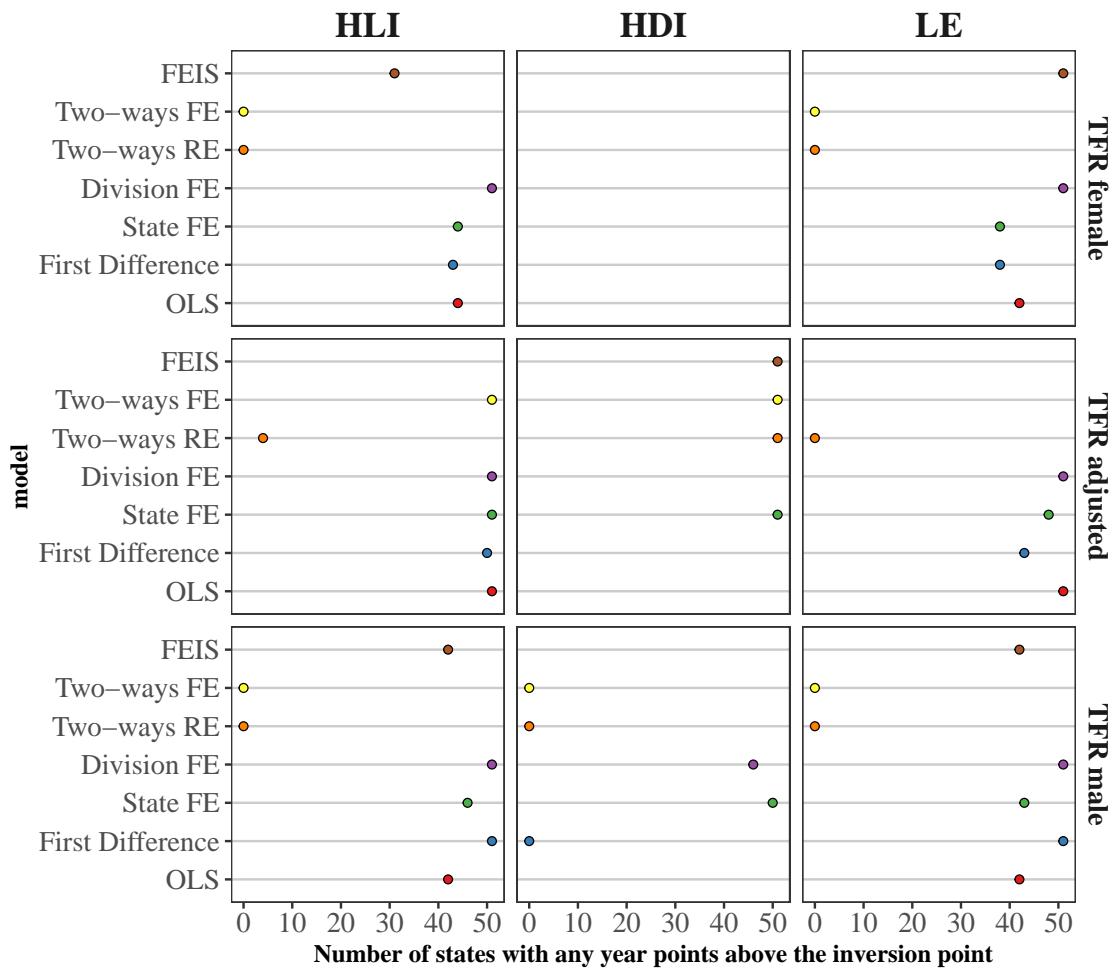


Figure A.11: This figure displays the number of positive $\Delta\text{TFR}/\Delta\text{Development}$ slopes.

B

Appendix to Chapter 4

B.1 Methodological Appendix

B.1.1 Counterfactual simulation of the total fertility rate (TFR)

I estimate the counterfactual TFR in the following way. First, I estimate the observed TFR as the cumulative sum of the weighted age-specific fertility rates. Second, the counterfactual scenario is estimated by multiplying the group-specific fertility rates with the weights from the year 2000. The estimation follows,

$$TFR = \sum f_i(x) \times w_i(x)^{counterfactual}, \quad (B.1)$$

where f is the age-specific fertility rate for the age x and the religious group i , w is the population share of group i in age-group x . Thus, the counterfactual simulation replaces the observed $w_i(x)$ with the counterfactual from year 2000.

B.1.2 Decomposition of the TFR

The TFR is defined as the sum of age specific fertility rates ($f(x)$), which is the ratio of number of births to the person-years exposed to the event,

$$f(x) = \frac{births(x)}{exposure(x)}. \quad (B.2)$$

Therefore the age-specific fertility rate can be rewritten into the population subgroups (p) that contribute to it, so that the population age-specific fertility rate is the sum over all subgroups p ,

$$f(x) = \sum_{x=15}^{55} \left[\frac{\sum_i^p \text{births}_i(x)}{\sum_i^p \text{exposure}_i(x)} \right]. \quad (\text{B.3})$$

Since the estimation is additive, I can rewrite the equation as weighted average:

$$TFR = \sum_{x=1}^{55} \sum_{i=1}^p \underbrace{f_i(x)}_{\text{Behavioral}} \times \underbrace{\text{weight}_i}_{\text{Composition}} \quad (\text{B.4})$$

The equation above can be used to decompose the difference in the TFR into the behavioral component stemming from a difference in $f_i(x)$ and a compositional component weight_i .

$$\Delta TFR = \sum_{x=1}^{55} \underbrace{\frac{\partial TFR}{\partial f(x)} \cdot (f_i(x) - f_j(x))}_{\Delta \text{Rate}} + \underbrace{\frac{\partial TFR}{\partial \text{weight}} \cdot [\text{weight}_i(x) - \text{weight}_j(x)]}_{\Delta \text{Composition}}, \quad (\text{B.5})$$

which is the observed rate difference between the two groups multiplied with the initial response of the TFR to a change in the age-specific fertility rate, and the initial change in the TFR to a change in the weight of a group.

B.1.3 Estimation and standardization of the population share

The estimation of the population share of a sub-group (m) of the population (p) follows:

$$p(m) = \frac{\text{Population}_m}{\sum_{i=1}^3 \text{Population}_i} \quad (\text{B.6})$$

However, shifts in the age structure may affect the total population shares. Standardization is used to account for structural differences in the population composition, i.e. in the age-structure, when comparing aggregate indicators over time or across populations (Preston et al., 2008). I apply the direct standardization

approach, which uses a reference population. As a "standard", I chose the Finnish population in the year 2019. The age-sex distribution for this group is displayed in Figure B.1 below.

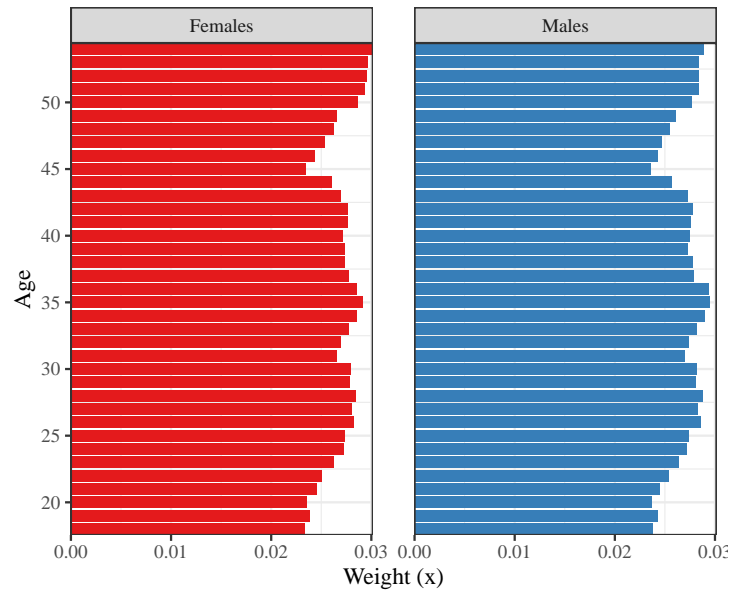


Figure B.1: This figure displays the standard population in Finland in the year 2019, which is used in the standardization.

In standardization, I sum the product of population share and the weight. The standardized population shares is known in epidemiology as *standardized prevalence*. The estimation follows:

$$p(m)_{\text{standardized}} = \sum_x p_x(m) \times w_x, \quad (\text{B.7})$$

where x stands for the age group, $p_x(m)$ is the population share of group m in the age group x in a specific year, and w_x is the weight, which is the share of the age-group in the year 2019. The weight is estimated as the population share of the group x in the year 2019:

$$w_x = \frac{pop_x}{\sum_{x=18}^{50} pop_x}. \quad (\text{B.8})$$

B.1.4 Iterative Proportional Fitting (IPF)

Iterative proportional fitting (also known as Stephen-Rephson algorithm) is an iterative method used in the marriage-market literature (homogamy-heterogamy) to assess the impact of changing population shares with respect to certain characteristics on mating pattern along these dimensions. The method disentangles the impact of preferences and availability through holding the preferences constant from a certain reference point. The method requires a contingency table for the reference year and a contingency table for any other year under investigation t . The contingency table from the reference year is iteratively scaled to fit the margin-totals of the contingency table of the year t , while maintaining the cell distributions, until the difference is below a certain threshold.

Given the contingency table in Table B.1 for the reference year 2000 and the observed contingency table in Table B.2 for the year 2010, where * shows that this is the year under investigation.

Table B.1: Table for the reference year 2000.

		Men	Men
		Religiously unaffiliated	Religiously affiliated
Women	Religiously unaffiliated	a=42405	b=23127
Women	Religiously affiliated	c=69420	d=525118

Table B.2: Table for the year 2010, which is the year under investigation.

		Men	Men
		Religiously unaffiliated	Religiously affiliated
Women	Religiously unaffiliated	a*=52990	b*=26833
Women	Religiously affiliated	c*=77711	d*=424938

I scale the values a, b, c, d from the first table so that they yield the same marginal distribution as in the second table (a^*, b^*, c^*, d^*). I reach this aim through iteratively performing two steps, which scale according to the row totals (I.) and according to the column totals (II.).

$$a + b = a^* + b^* \quad (\text{B.9})$$

$$c + d = c^* + d^* \quad (\text{B.10})$$

$$a + c = a^* + c^* \quad (\text{B.11})$$

$$b + d = b^* + d^* \quad (\text{B.12})$$

I. I reach this goal by multiplying the reference contingency table cell values with the relative difference of the target row-sums to the reference contingency table, which yields a new reference table:

$$a_{i=1,1} = a \times \frac{(a^* + b^*)}{(a + b)} \quad (\text{B.13})$$

$$b_{i=1,1} = b \times \frac{(a^* + b^*)}{(a + b)} \quad (\text{B.14})$$

$$c_{i=1,1} = c \times \frac{(c^* + d^*)}{(c + d)} \quad (\text{B.15})$$

$$d_{i=1,1} = d \times \frac{(c^* + d^*)}{(c + d)} \quad (\text{B.16})$$

II. I reach this goal by multiplying the reference contingency table cell values with the relative difference of the target row-sums to the reference contingency table, which yields a new reference table:

$$a_{i=1,2} = a_{i=1,1} \times \frac{(a^* + b^*)}{(a + b)} \quad (\text{B.17})$$

$$b_{i=1,2} = b_{i=1,1} \times \frac{(a^* + b^*)}{(a + b)} \quad (\text{B.18})$$

$$c_{i=1,2} = c_{i=1,1} \times \frac{(c^* + d^*)}{(c + d)} \quad (\text{B.19})$$

$$d_{i=1,2} = d_{i=1,1} \times \frac{(c^* + d^*)}{(c + d)} \quad (\text{B.20})$$

Step I. and II. form one iteration of the algorithm, which is repeated several times. The algorithm stops either after a certain number of iterations (max-iterations) or after the difference between the observed column totals for year t

and the counterfactual column as well as the observed row totals for year t and the counterfactual column totals is below a certain threshold value. For our example, the counterfactual values are displayed in table B.3:

Table B.3: Counterfactual table for the year 2010, which is the year under investigation.

		Men	Men
		Religiously unaffiliated	Religiously affiliated
Women	Religiously unaffiliated	a*=59277.25	b*=20571.51
Women	Religiously affiliated	c*=71423.75	d*=431199.49

B.1.5 Random matching algorithm

The primary objective of the simulation is to assess the plausibility that the increase in mixed religious couples is entirely the result of changing population distributions, assuming random matching. The random pairing algorithm summarized in algorithm 1 creates randomly matched couples. In the next step, I estimate the share of religiously homogeneous and heterogeneous couples among them. This process is repeated 100 times to account for the Monte Carlo error, e.g. the between simulation variability. If the trends of the randomly formed matches parallels the trend of the observed data, I may conclude that the partner availability may account for changing couple formation. I carry out annual simulations of the randomly matched couples for the period from 1995 to 2019. To create such a simulated population of couples, I start with the population of reproductive age and present in Finland and keep only those who are in a union ($n_{couples}$), thus removing all singles. Then, I virtually separate the male partners from the female partners and assign them to a randomly chosen new partner. So I have $n_{couples}$ simulated couples. Then I estimate the proportion of the religious composition of the population of simulated couples. I repeat this simulation 150 times. (I draw the Finnish couple population, separate the original couples, and randomly assign new partners). In this way, I create a probability distribution for the religious affiliation of the partners if the couples were randomly matched.

Algorithm 1 Simulation of the random matches based on register data for different cohorts.

1. Obtain the distribution of religiosity in couples in a specific year. Get $N_{m,r}$, $N_{f,r}$, $N_{m,n}$, $N_{f,n}$. The subscripts m and f indicate the sex, and r and n stand for religious and non-religious.
 2. Use the random sort process to form matches between men and women.
 3. Estimate the share of couples with the following composition: religious_f-religious_m, religious_f-non religious_m, non religious_f-religious_m, non religious_f- non religious_m
 4. Compare the observed distribution of matches and the expected distribution of matches given random matching.
-

B.1.6 Estimation of first birth and couple hazard rates

I estimated first-birth and couple hazard rates using a Poisson model with splines. The model specification follows below:

$$\log(y \mid \mathbf{X}) = \beta_1 \text{religious}_m + \beta_2 \text{religious}_f + \beta_3 \text{religious}_{\text{both}} + \beta_4 \mathbf{X} + \log(\text{exposure}) + \epsilon_{i,t}, \quad (\text{B.21})$$

where y is the number of events. In order to get the events and exposures, I aggregated the spell data by summing events per religious-age combination and counting the spells.

B.1.7 Estimation of the twin model

I estimate twin fixed effects models to account for selection on family-related time-constant unobserved factors, such as religious background, education, neighbourhood, childhood living and family network. For these models, I reduced the data to females or males having a twin of the same sex. Twins are identified in the registers through identical parental IDs and dates of birth. Removing all none twin pairs from the data leaves us with 1,700 individuals clustered within 431 twin groups.

Using this data, I estimate whether the religious composition of the couple affects whether the couple transitions to first-birth within the first 5 years, condensing the multi-spell data to a single-spell data file. If the couple has a child within the period, the outcome is one, if the couple is dissolved or did not transition to childbirth, the outcome is zero.

I estimate the twin-fixed effects model in the following way, where r indicates the dummy for religious affiliation,

$$(Y_{ij} - \bar{Y}_{ij}) = \beta_1 (r_{ij}^f - \bar{r}_i^f) + \beta_2 (r_{ij}^m - \bar{r}_i^m) + \beta_3 (r_{ij}^b - \bar{r}_i^B), \quad (\text{B.22})$$

where i is the index for the twin group and j refers to the individual within the twin group. \bar{Y}_{ij} , \bar{r}_i^f and \bar{r}_i^m refer to the twin-group averages of childbirth-occurrence, female religious and male religious partner.

B.1.8 Regional panel regression models

I use macro-data at the regional level in Finland to ensure the robustness of the main findings. Essentially, I exploit regional variation in secularisation to estimate the impact on fertility. Panel regression models remove the impact of time-constant unobserved variables c_i through first-differences. I created a balanced panel of 69 regions ($i = 1, \dots, N$ units) observed over 19 years ($t = 1, \dots, T$ years), the data contains 1254 observations.

$$y_{i,t} - y_{i,t-1} = (x_{i,t} - x_{i,t-1})\beta + (c_{i,t} - c_{i,t-1}) + u_{i,t} - u_{i,t-1}, \quad (\text{B.23})$$

which drops the impact of c_i through differencing. First differencing is less efficient than standard fixed effects regression using demeaning, because it loses the observations for the first year, yet, the pooled regression on first-differenced data removes serial autocorrelation and provides valid statistics, including F statistics based on sums of squared residuals (p. 281 Wooldridge, 2010). The first differencing, similar to the fixed effects model, assumes the exogeneity of x_{it} conditional on the unobserved effect.

B.2 Additional Figures

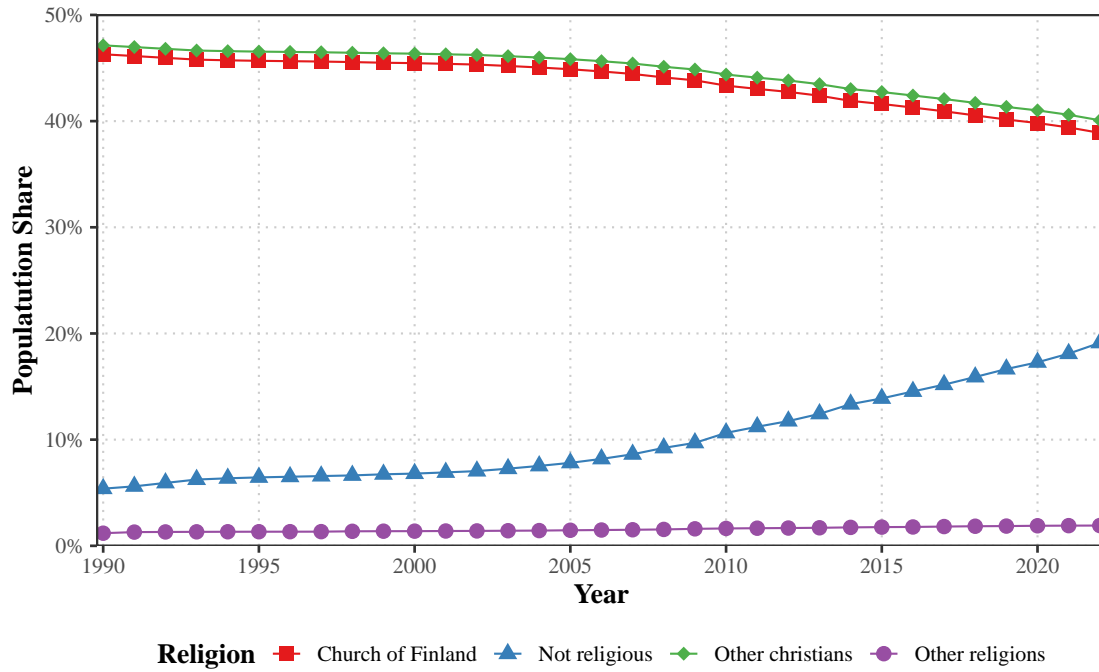


Figure B.2: The share of religious groups according to official statistics provided by Statistics Finland.

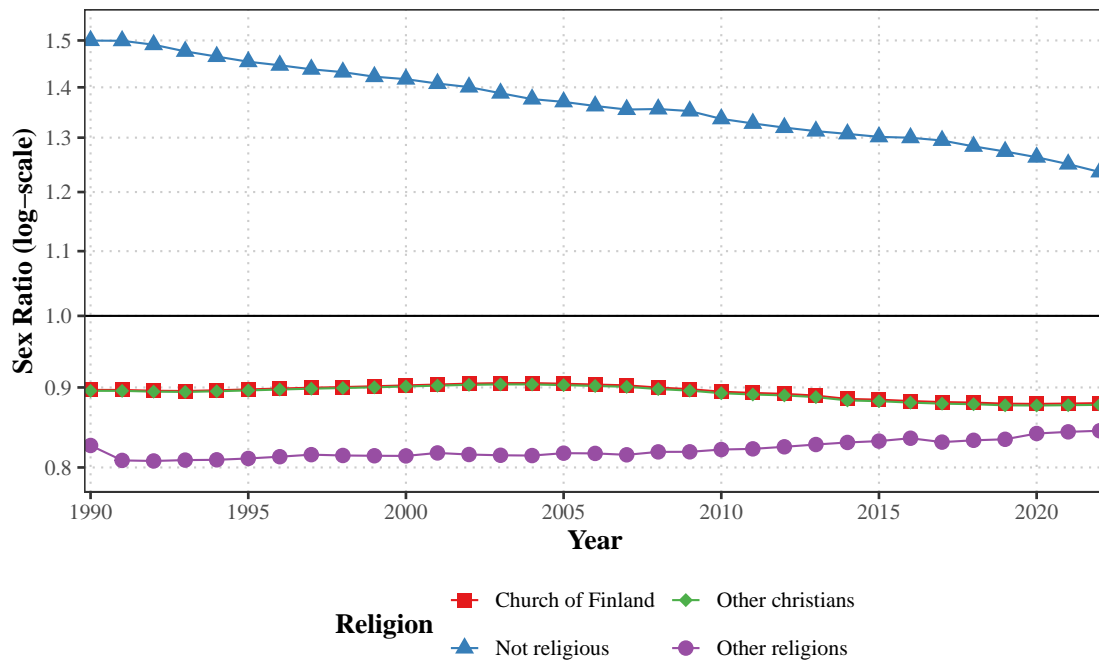


Figure B.3: The sex ratio in the main religious groups in Finland in the period between 1990 and 2022. Note: the y-axis is log transformed to create symmetrical distributions around 1.

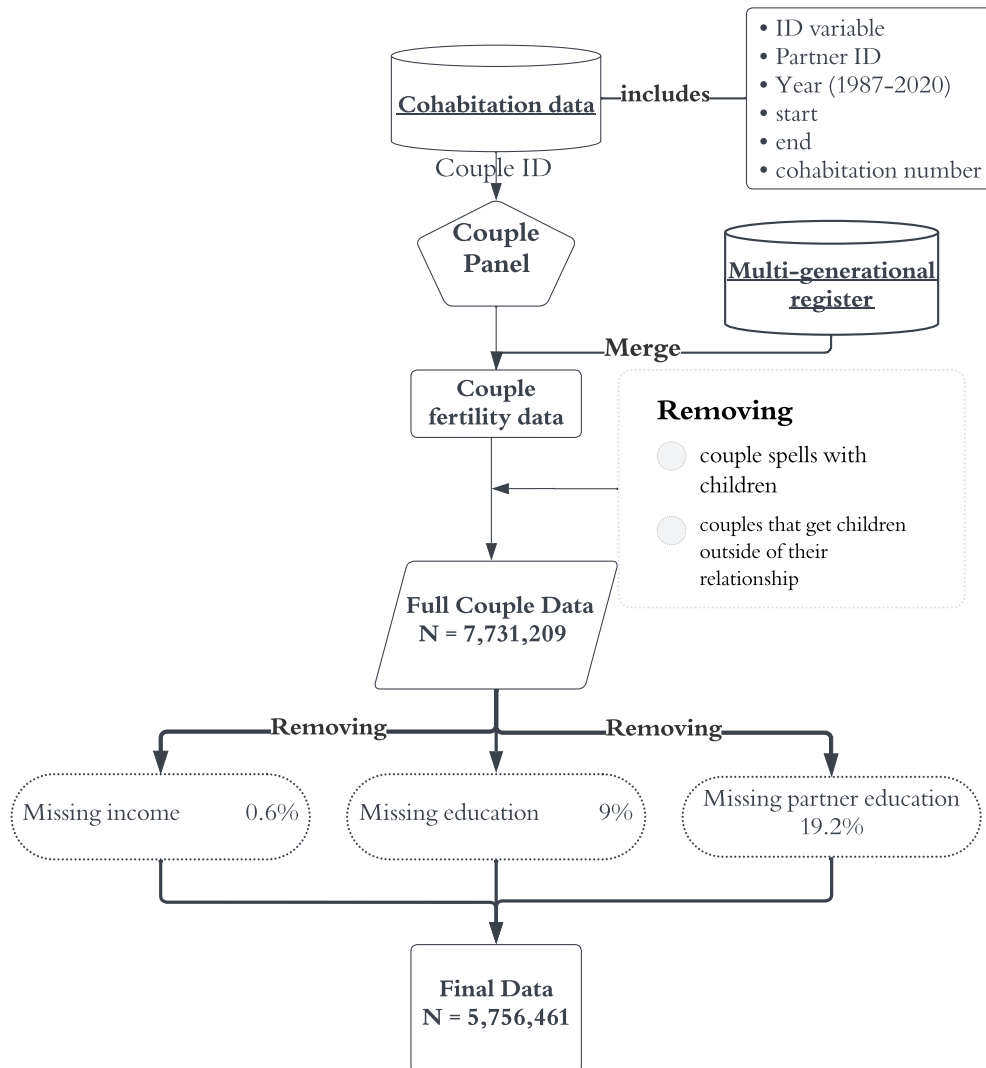


Figure B.4: This figure displays the share of missing information in the register data that have been removed from the analysis.

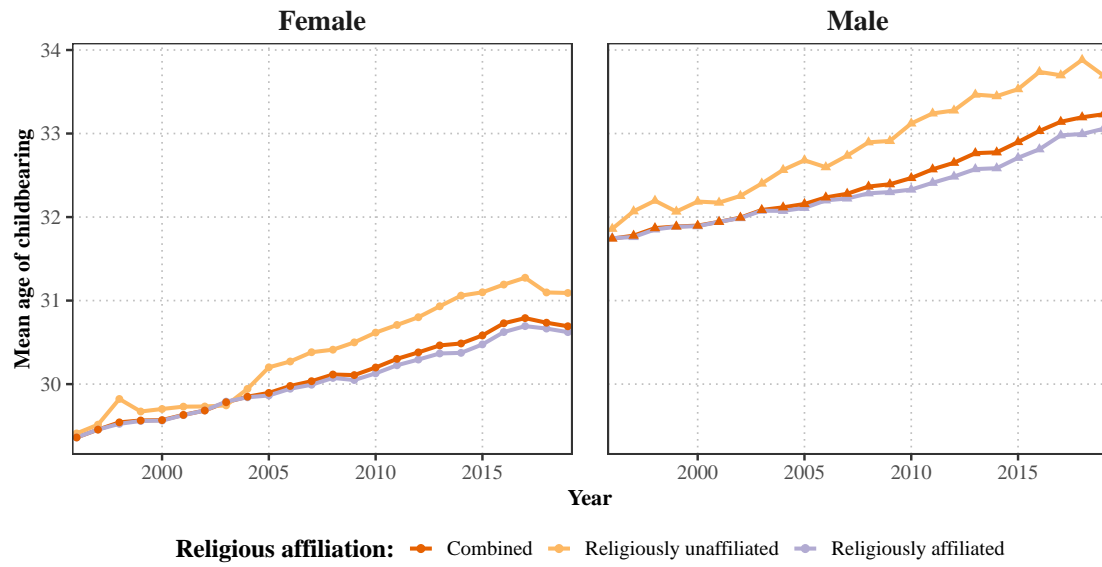


Figure B.5: The mean age of childbearing for men and for women in the period between 1995 and 2019.

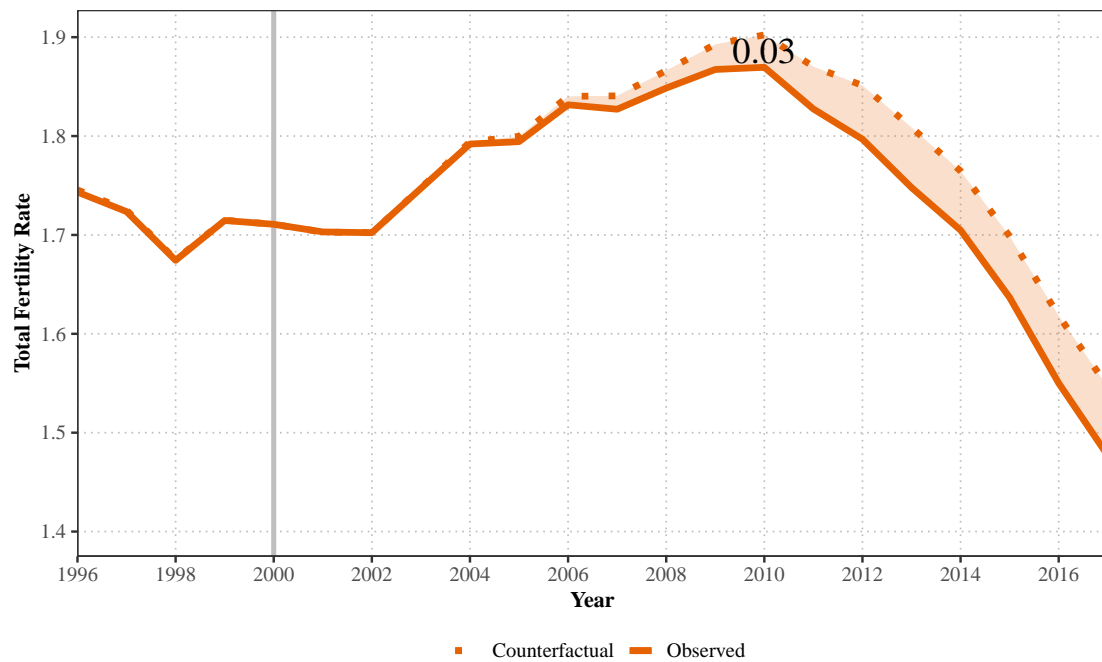


Figure B.6: Time-trend of the observed and counterfactual total fertility rate (TFR) of the Finnish population between 1990 and 2019. The dotted line marks the Finnish TFR if the composition of the population remained constant from 2000 onward. The solid line represents the observed TFR for the same period. The shaded area marks the difference between the counterfactual and observed TFR. The numbers are the difference between counterfactual and observed TFR ($TFR_{counterfactual} - TFR_{observed}$).

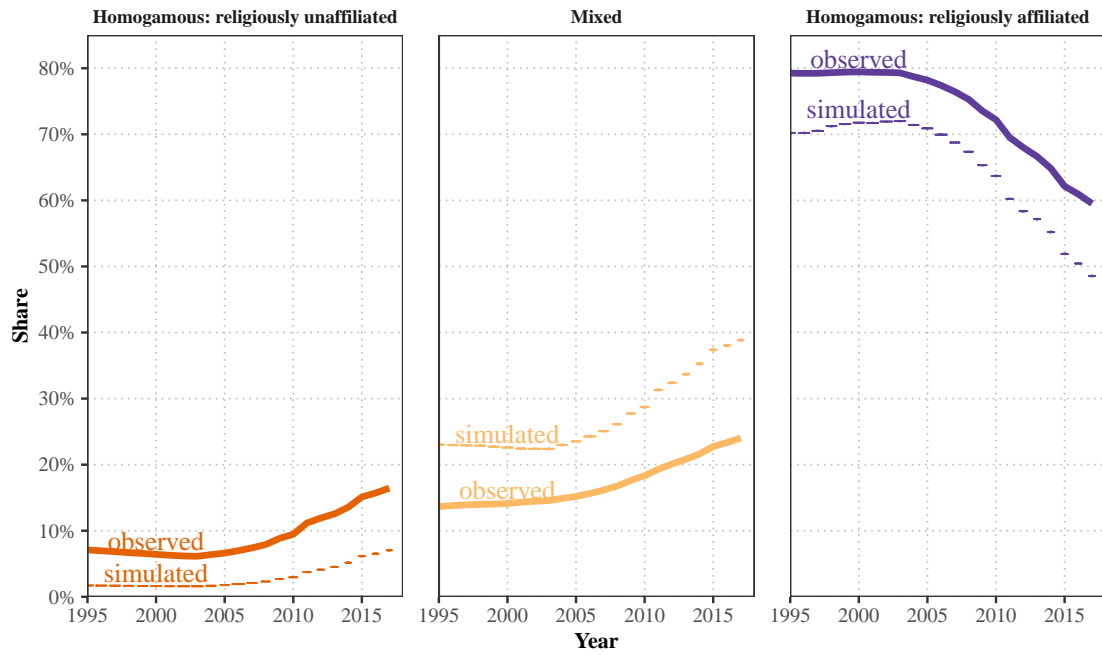


Figure B.7: This figure displays the simulation results described in Section B.1.5. The line represents the observed share of the partnership type in the Finnish population of reproductive age. The annual boxplots represent the distribution of simulated shares.

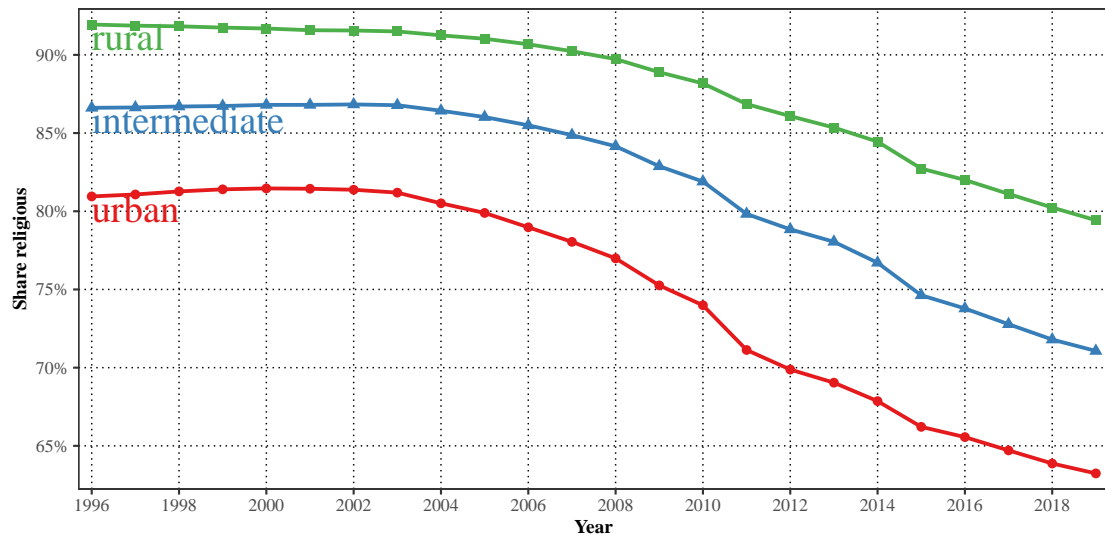


Figure B.8: Trend in state-church membership across different urban classifications.

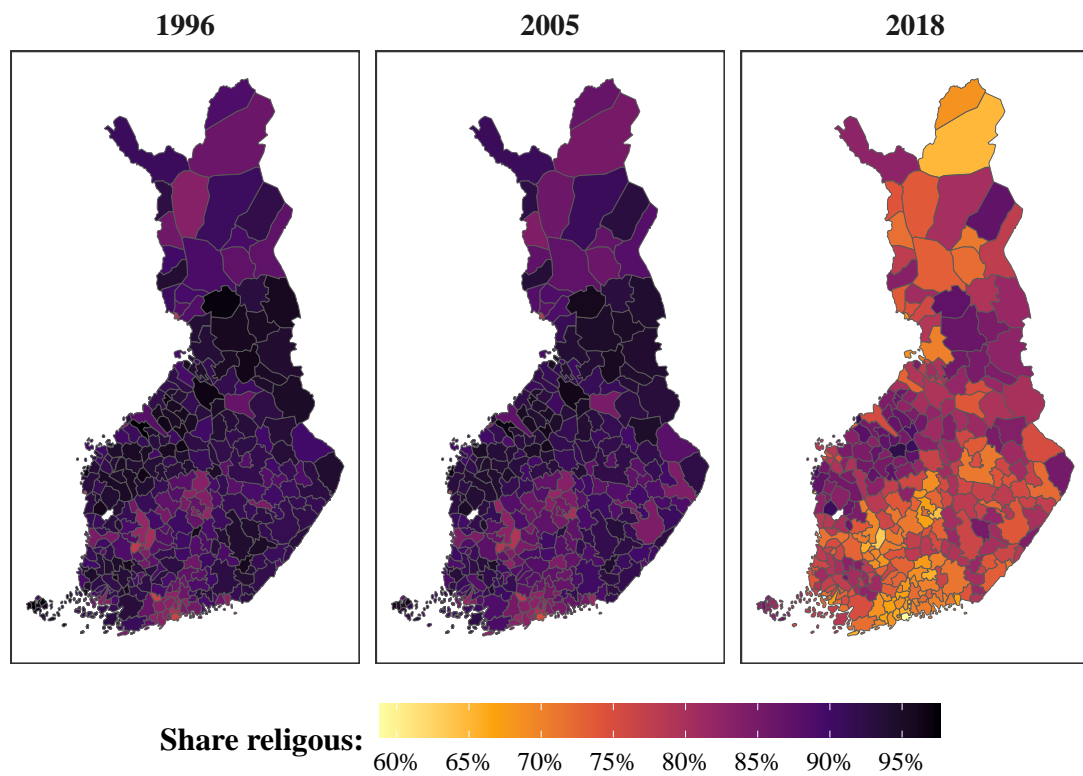


Figure B.9: Map of the regional share of state-church members in Finland in the years 1996, 2005 and 2019.

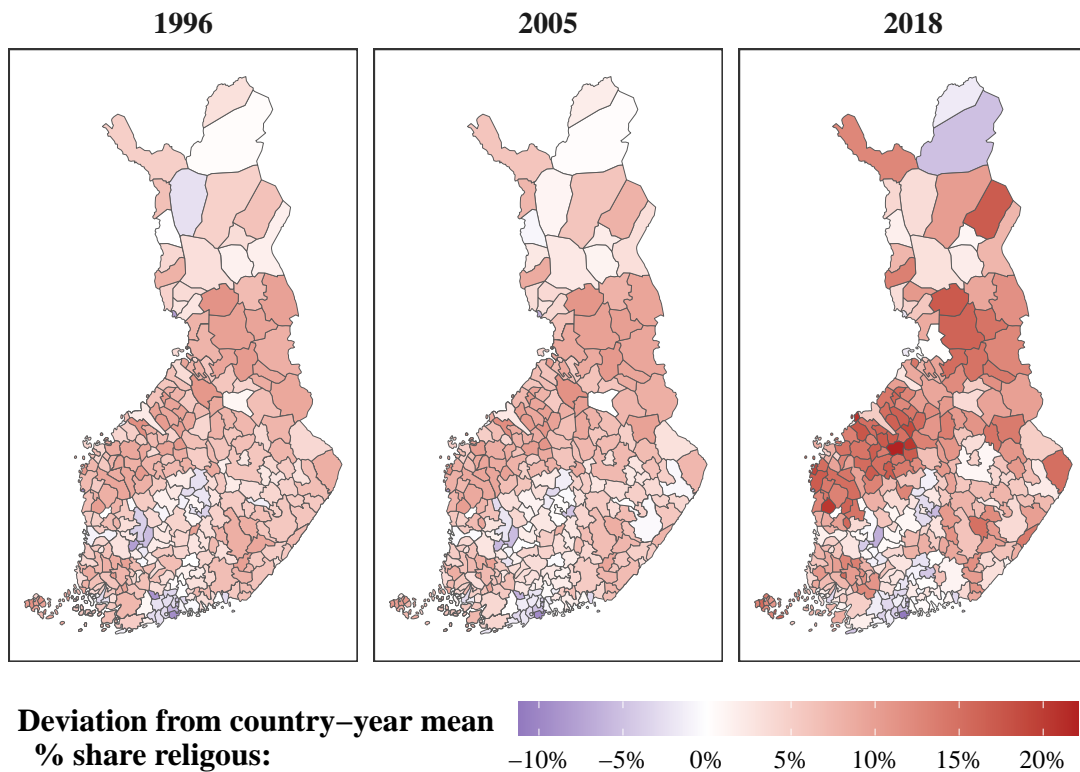


Figure B.10: Absolute difference of share of religious people to the average of the regional share of state-church members in Finland in the years 1996, 2005 and 2019.

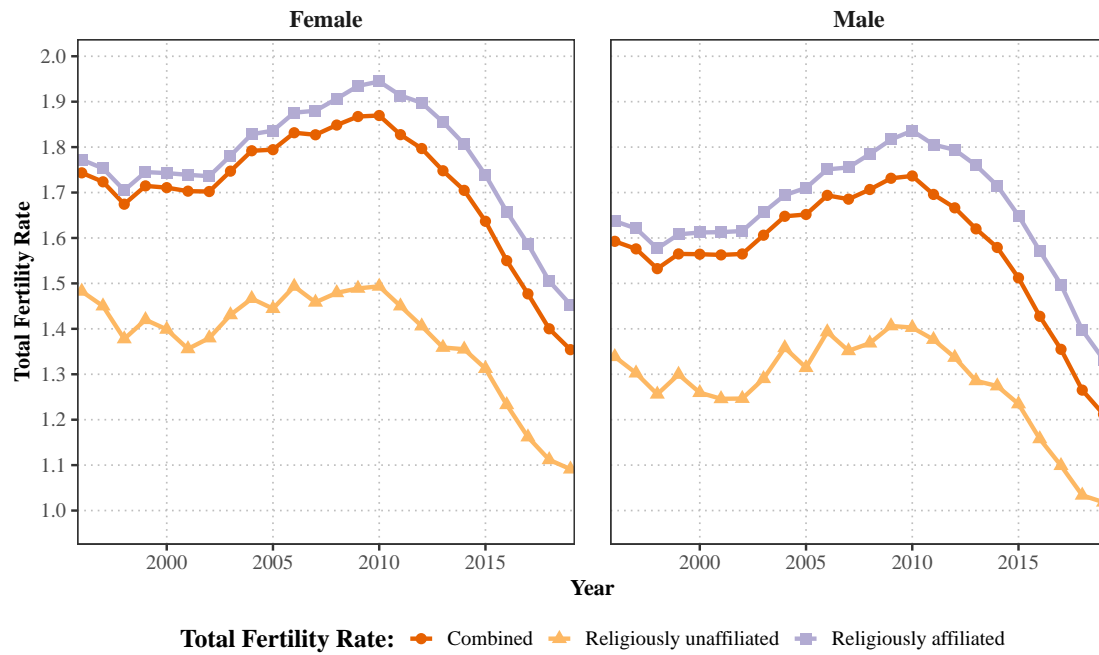


Figure B.11: Female and male TFRs for the religious, non-religious and the entire Finnish population in the period between 1995 and 2019. The left panel displays the rates for females and the right panel displays the corresponding numbers for males.



Figure B.12: Counterfactual and observed female and male TFR for the Finnish population between 1995 and 2019 if the population structure had remained constant from 2000. The left panel displays the rates for females and the right panel displays the results for males.

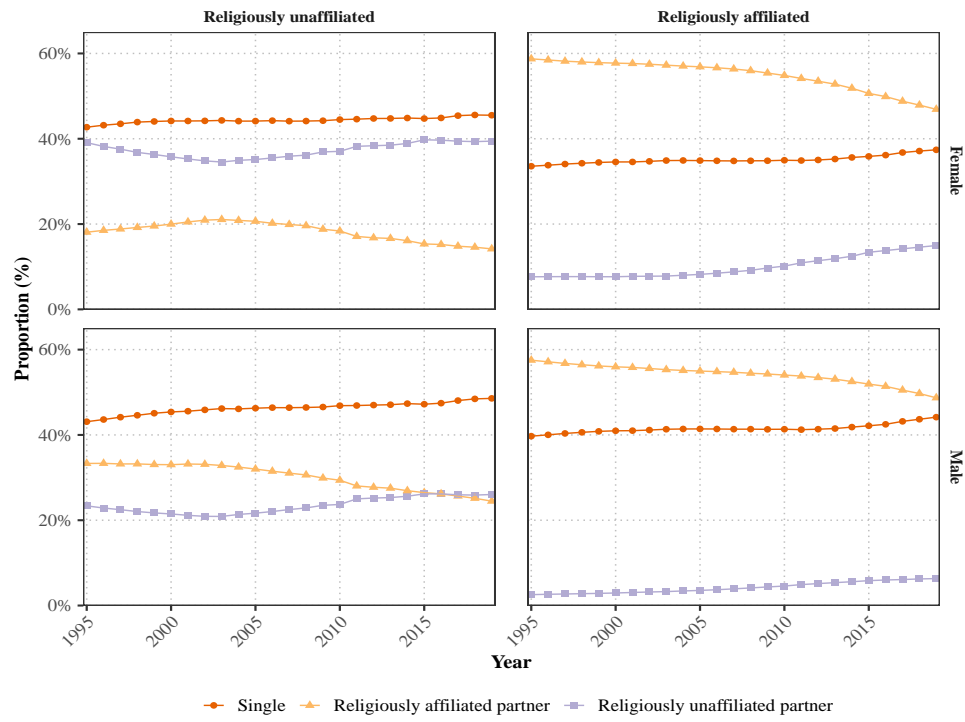


Figure B.13: This graph illustrates the age-standardized prevalence of partnership status by sex and religious status.

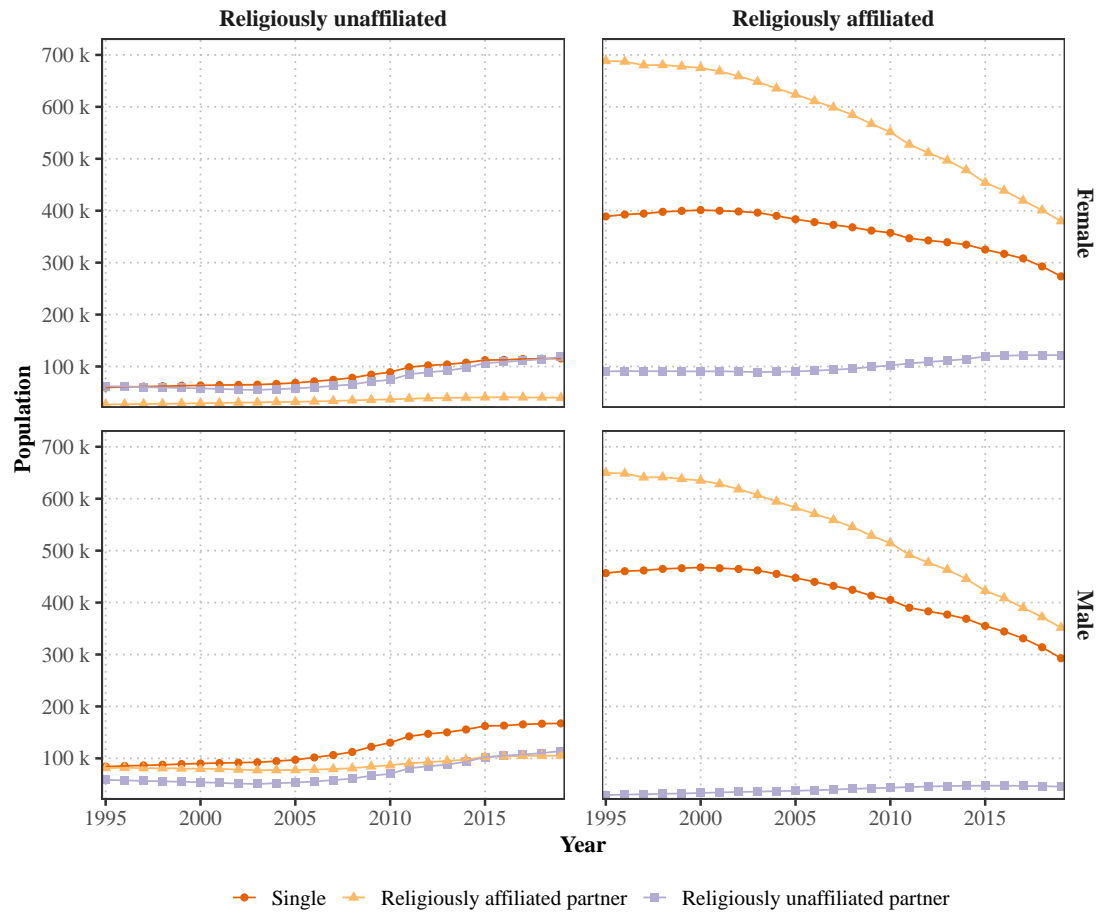


Figure B.14: This graph illustrates the population counts of people with a certain partnership status stratified by sex and religious status.

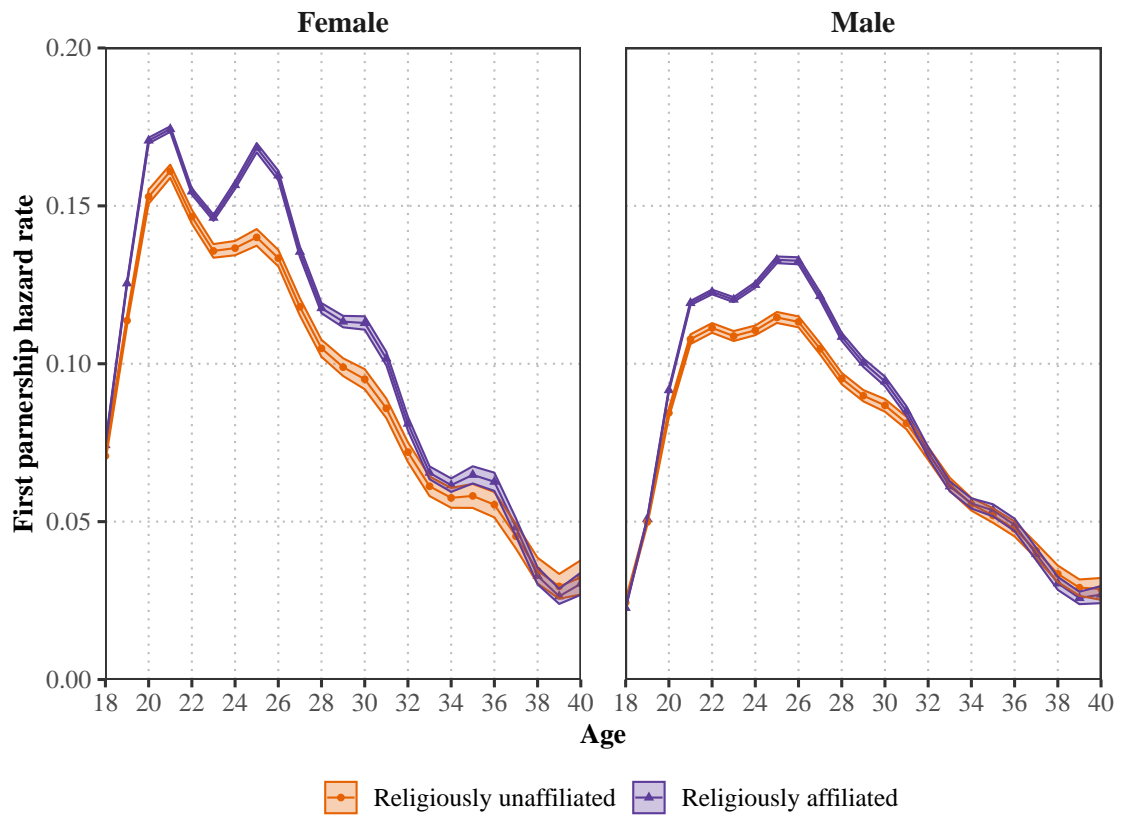


Figure B.15: Predicted first partnership rate from poisson-regression with age splines for males and females separately. The shaded area illustrates the 95%-confidence intervals.

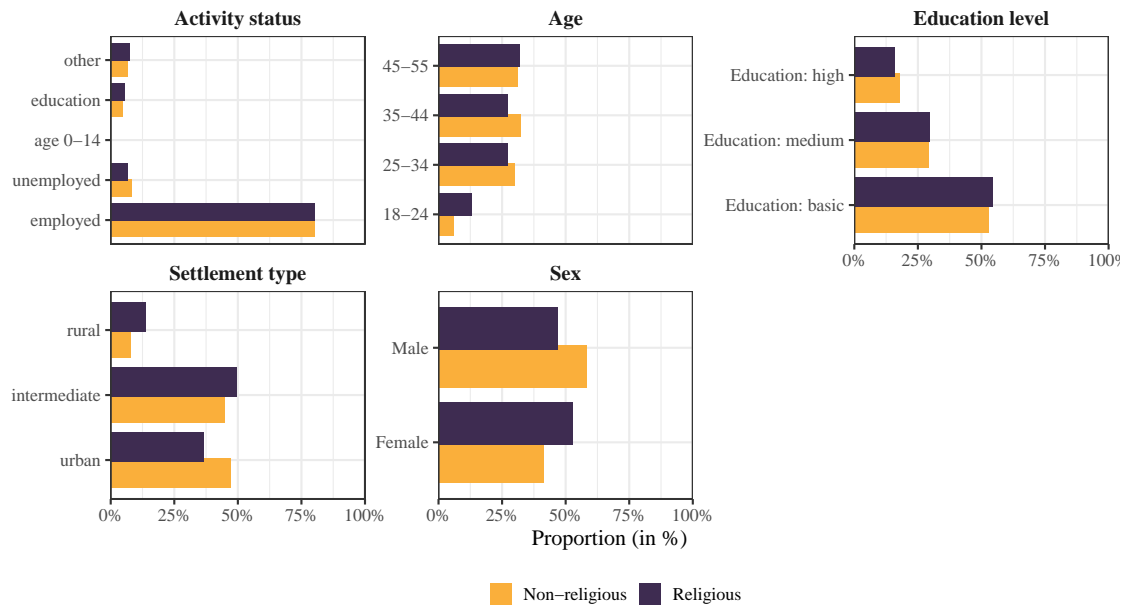


Figure B.16: The distribution of socio-economic characteristics in the religious and non-religious population.

B.3 Additional Tables

Table B.4: Summary statistics of the nominal and ordinal variables in the couple panel data set used in the discrete-time survival model.

Variable	Expression	Count	% Share
Birth	Childbirth	578.455	5.284
Birth	Censored	10.368.059	94.716
Religious affiliation (female)	unaffiliated	1.368.230	12.499
Religious affiliation (female)	affiliated	9.578.284	87.501
Religious affiliation (male)	unaffiliated	2.067.243	18.855
Religious affiliation (female)	affiliated	8.879.271	81.885
Activity status (female)	employed	8.908.923	81.386
Activity status (female)	unemployed	899.050	8.213
Activity status (female)	education	611.614	5.587
Activity status (female)	other	526.927	4.814
Activity status (male)	employed	9.229.950	84.319
Activity status (male)	unemployed	820.423	7.495
Activity status (male)	education	389.892	3.562
Activity status (male)	other	506.249	4.265
Income quantile (female)	0-25%	1.492.243	13.623
Income quantile (female)	25-50%	2.104.846	19.228
Income quantile (female)	50-75%	4.236.582	38.703
Income quantile (female)	75-100%	3.112.843	28.437
Income quantile (male)	0-25%	1.003.922	9.171
Income quantile (male)	25-50%	1.342.447	12.264
Income quantile (male)	50-75%	2.999.389	27.401
Income quantile (male)	75-100%	5.600.656	51.164
Education (female)	basic	1.685.912	15.144
Education (female)	intermediate	5.001.980	44.924
Education (female)	high	4.445.361	39.932
Education (male)	basic	2.212.150	19.871
Education (male)	intermediate	5.305.261	47.656
Education (male)	high	3.614.960	32.473
Settlement structure	rural	1.714.478	15.662
Settlement structure	intermediate	5.561.172	50.803
Settlement structure	urban	3.670.846	33.353
Period	1995-2000	3.620.765	33.077
Period	2000-2005	2.931.603	26.781
Period	2005-2010	2.101.932	19.202
Period	2010-2015	1.443.848	13.19
Period	2015-2019	488.366	7.75

	Male religiously unaffiliated	Male religiously affiliated
Female religiously un-affiliated	21.56%	36.82%
Female religiously affiliated	31.41%	37.38%

Table B.5: Distribution of Unions ending in first birth by religious affiliation of both partners.

Model	AIC
$Y = \beta_1 \text{religious}_f + \beta_3 \mathbf{X} + \epsilon_{i,t}$	2546997
$Y = \beta_1 \text{religious}_m + \beta_4 \mathbf{X} + \epsilon_{i,t}$	2546944
$Y = \beta_1 \text{religious}_m + \beta_2 \text{religious}_f + \beta_3 \mathbf{X} + \epsilon_{i,t}$	2546056
$Y = \beta_1 \text{religious}_m + \beta_2 \text{religious}_f + \beta_3 \text{religious}_{\text{both}} + \beta_4 \mathbf{X} + \epsilon_{i,t}$	2546043

Table B.6: Summary of the different discrete-time survival model specifications and their Akaike's Information Criterion (AIC). Lower AIC indicates that the model contains more information. The left column shows the model specification. The vector of control variables consists of female education, female income, couple education homogeneity, couple income, age and age². The right column contains the model specific Akaike's Information Criterion as measure of model fit.

Table B.7: Average marginal effect of the discrete-time survival model on the transition to first birth. The numbers can be interpreted as population level effect. The number indicates the average increase in the probability of childbirth if the predictor value was to increase by one unit.

term	AME Model 1	AME Model 2	AME Model 3	AME Model 4
Religious affiliation female: dY/dX	0.015 (0.01, 0.02)		0.012 (0.007, 0.017)	0.016 (0.01, 0.022)
Religiously affiliated male: dY/dX		0.014 (0.009, 0.018)	0.012 (0.007, 0.016)	0.013 (0.009, 0.018)
Age at onset: dY/dX	-0.001 (-0.001, 0)	-0.001 (-0.001, 0)	-0.001 (-0.001, 0)	-0.001 (-0.001, 0)
Union duration: dY/dX	0.002 (0.001, 0.003)	0.002 (0.001, 0.003)	0.002 (0.001, 0.003)	0.002 (0.001, 0.003)
Activity: unempl. - empl.	-0.015 (-0.02, -0.009)	-0.015 (-0.021, -0.01)	-0.015 (-0.021, -0.009)	-0.015 (-0.021, -0.009)
Activity: edu. - empl.	-0.004 (-0.01, 0.002)	-0.004 (-0.01, 0.002)	-0.004 (-0.01, 0.002)	-0.004 (-0.01, 0.002)
Activity: other - empl.	0.087 (0.072, 0.102)	0.085 (0.07, 0.1)	0.086 (0.071, 0.101)	0.086 (0.071, 0.101)
Activity male: unempl. - empl.	-0.005 (-0.012, 0.001)	-0.006 (-0.013, 0.001)	-0.006 (-0.012, 0.001)	-0.005 (-0.012, 0.001)
Activity male: edu. - empl.	-0.012 (-0.019, -0.004)	-0.012 (-0.019, -0.005)	-0.012 (-0.019, -0.005)	-0.012 (-0.019, -0.005)
Activity: other - employed	-0.029 (-0.039, -0.02)	-0.03 (-0.039, -0.02)	-0.03 (-0.039, -0.02)	-0.029 (-0.039, -0.02)
Education : medium - basic	0.013 (0.009, 0.017)	0.013 (0.01, 0.017)	0.013 (0.009, 0.017)	0.013 (0.009, 0.017)
Education : high - basic	0.043 (0.037, 0.05)	0.045 (0.038, 0.051)	0.044 (0.038, 0.051)	0.044 (0.038, 0.051)
Education male: medium - basic	0.004 (0, 0.008)	0.004 (0, 0.007)	0.004 (0, 0.008)	0.004 (0, 0.008)
Education male: high - basic	0.02 (0.015, 0.026)	0.02 (0.014, 0.026)	0.02 (0.014, 0.026)	0.02 (0.015, 0.026)
Income quantile: 2 - 1	0.007 (0.001, 0.012)	0.006 (0, 0.012)	0.006 (0, 0.011)	0.005 (0, 0.011)
Income quantile: 3 - 1	-0.004 (-0.009, 0.002)	-0.005 (-0.01, 0.001)	-0.005 (-0.011, 0.001)	-0.005 (-0.011, 0.001)
Income quantile: 4 - 1	-0.023 (-0.029, -0.017)	-0.024 (-0.031, -0.018)	-0.024 (-0.031, -0.018)	-0.025 (-0.031, -0.018)
Income quantile male: 2 - 1	0.008 (0.002, 0.015)	0.008 (0.001, 0.014)	0.008 (0.002, 0.014)	0.008 (0.002, 0.014)
Income quantile male: 3 - 1	0.019 (0.013, 0.025)	0.019 (0.013, 0.025)	0.019 (0.013, 0.025)	0.019 (0.013, 0.025)
Income quantile male: 4 - 1	0.02 (0.014, 0.026)	0.02 (0.014, 0.027)	0.02 (0.014, 0.026)	0.02 (0.014, 0.026)
Settlement: intermediate - urban	0.018 (0.015, 0.021)	0.018 (0.015, 0.022)	0.018 (0.014, 0.021)	0.018 (0.014, 0.021)
Settlement: rural - urban	0.031 (0.024, 0.037)	0.031 (0.025, 0.038)	0.03 (0.024, 0.037)	0.03 (0.024, 0.036)
Period: 2000-2005 - 1995-2000	0.018 (0.013, 0.022)	0.018 (0.013, 0.022)	0.017 (0.013, 0.022)	0.018 (0.013, 0.022)
Period: 2005,2010 - 1995-2000	0.024 (0.019, 0.029)	0.024 (0.019, 0.028)	0.024 (0.019, 0.028)	0.024 (0.019, 0.029)
Period: 2010-2015 - 1995-2000	0.013 (0.008, 0.018)	0.013 (0.008, 0.018)	0.014 (0.009, 0.019)	0.014 (0.009, 0.019)
Period: 2015-2020 - 1995-2000	-0.005 (-0.01, 0)	-0.005 (-0.01, -0.001)	-0.004 (-0.009, 0)	-0.004 (-0.009, 0.001)

Table B.8: Results from discrete-time survival analysis using logit-binomial models on the probability of childbirth. Results are displayed as odds ratios. The couple composition with respect to religious affiliation is held constant. The age-splines (at couple formation), couple duration-splines and age-duration-splines were omitted for readability.

	First childbirth			
	(1)	(2)	(3)	(4)
Religiously affiliated	1.196***		1.156***	1.212***
Religiously affiliated male		1.167***	1.133***	1.2***
Both religiously affiliated				0.929***
Activity: unemployed	0.761***	0.76***	0.761***	0.761***
Activity: education	0.658***	0.657***	0.658***	0.658***
Activity: other	1.475***	1.474***	1.475***	1.476***
Activity male: unemployed	1.004	1.006	1.007	1.006
Activity male: education	0.809***	0.81***	0.809***	0.809***
Activity male: other	0.843***	0.844***	0.844***	0.844***
Education: medium	0.962***	0.964***	0.961***	0.962***
Education: high	1.6***	1.606***	1.597***	1.598***
Education male: medium	0.905***	0.904***	0.904***	0.904***
Education male: high	1.075***	1.071***	1.072***	1.072***
Income quantile: 2	0.917***	0.918***	0.915***	0.915***
Income quantile: 3	0.652***	0.654***	0.651***	0.65***
Income quantile: 4	0.503***	0.504***	0.501***	0.501***
Income quantile male: 2	1.284***	1.284***	1.281***	1.281***
Income quantile male: 3	1.587***	1.589***	1.583***	1.583***
Income quantile male: 4	1.747***	1.755***	1.746***	1.745***
Settlement: intermediate	1.494***	1.494***	1.486***	1.487***
Settlement: rural	1.564***	1.559***	1.547***	1.548***
Period: 2000-2004	1.164***	1.162***	1.163***	1.162***
Period: 2005-2009	1.285***	1.282***	1.286***	1.285***
Period: 2010-2014	1.217***	1.216***	1.225***	1.224***
Period: 2015-2019	1.017**	1.019**	1.03***	1.029***
Intercept	0.01***	0.01***	0.01***	0.009***
N	5047249	5047249	5047249	5047249
R ²	0.082	0.082	0.083	0.083
AIC	2547745	2547753	2547045	2547006

*p < .05; **p < .01; ***p < .001

Table B.9: Discrete-time survival of the transition to first birth. The models control for the regional church tax rate. This table is displaying logit coefficients, which represent the average response in the log-odds of first birth.

	Childless at age 45			
	(1)	(2)	(3)	(4)
Intercept	-4.419***	-4.393***	-4.473***	-4.459***
Religiously affiliated	0.214***		0.157***	0.135***
Religiously affiliated male		-0.273***	0.141***	0.11***
Activity: unemployed	-0.418***	-0.419***	-0.272***	-0.272***
Activity: education	0.388***	0.388***	-0.418***	-0.418***
Activity: other	0.006	0.008	0.388***	0.388***
Activity male: unemployed	-0.212***	-0.211***	0.009	0.009
Activity male: education	-0.169***	-0.169***	-0.212***	-0.212***
Activity male: other	-0.039***	-0.037***	-0.169***	-0.169***
Education: medium	0.468***	0.473***	-0.04***	-0.04***
Education: high	-0.1***	-0.101***	0.468***	0.467***
Education male: medium	0.073***	0.069***	-0.101***	-0.101***
Education male: high	-0.088***	-0.087***	0.07***	0.069***
Income quantile: 2	-0.429***	-0.427***	-0.09***	-0.09***
Income quantile: 3	-0.689***	-0.688***	-0.432***	-0.432***
Income quantile: 4	0.249***	0.249***	-0.692***	-0.692***
Income quantile male: 2	0.46***	0.462***	0.247***	0.247***
Income quantile male: 3	0.556***	0.564***	0.458***	0.458***
Income quantile male: 4	0.398***	0.398***	0.558***	0.558***
Settlement: intermediate	0.44***	0.437***	0.394***	0.393***
Settlement: rural	0.154***	0.152***	0.432***	0.432***
Period: 2000-2004	0.257***	0.256***	0.153***	0.153***
Period: 2005-2009	0.209***	0.211***	0.26***	0.26***
Period: 2010-2014	0.031***	0.036***	0.222***	0.222***
Period: 2015-2019	0.001	0	0.051***	0.051***
Church tax	-4.419***	-4.393***	-0.002	-0.002
Both religiously affiliated				0.042***
N	5047249	5047249	5047249	5047249
R ²	0.083	0.083	0.083	0.083
AIC	2546998.586	2546946.018	2546057.539	2546043.99

*p < .05; **p < .01; ***p < .001

B.3.1 Regional panel fixed effects regression

Table B.10: Regression model of the regional TFR on the percent-share religious in a specific region (*finnish* Seutukunta) in the period between 1996 and 2019. The first model is an OLS regression. The second model is a first-difference model, which equals a fixed effects model, which accounts for omitted time-constant regional factors. The third model is a twoway fixed effects model, which accounts for time and region idiosyncrasies.

	TFR ⁺		ΔTFR	
	(1)	(2)	(3)	
	Pooled OLS	Province fixed effects	Twoway fixed effects	
% religiously affiliated	0.024***			
Δ % religiously affiliated		0.028***		0.027***
Constant	-0.034			
N	1254	1188		1188
R ²	0.178	0.037		0.317
Adjusted R ²	0.176	0.035		0.278

*p < .05; **p < .01; ***p < .001

+ Standard errors are clustered at the province level.

Table B.11: Regression model of the regional TFR of the religiously affiliated on the percent-share religiously affiliated in a specific region (*finnish* Seutukunta) in the period between 1996 and 2019. The first model is an OLS regression. The second model is a first-difference model, which equals a fixed effects model, which accounts for omitted time-constant regional factors. The third model is a twoway fixed effects model, which accounts for time and region idiosyncrasies.

	TFR ⁺		Δ TFR	
	(1)	(2)	(3)	
	Pooled OLS	Province fixed effects	Twoway fixed effects	
% religiously affiliated	0.014***			
Δ % religiously affiliated		0.023***		0.003
Constant	0.785***			
N	1254	1188		1188
R ²	0.113	0.044		0.261
Adjusted R ²	0.111	0.042		0.219

*p < .05; **p < .01; ***p < .001

+ Standard errors are clustered at the province level.

B.3.2 Results from the Twin Models

Table B.12: Female twin FE comparison for the effect of religious affiliation on fertility.

Dependent Variable:	birth				
Model:	(1)	(2)	(3)	(4)	(5)
<i>Variables</i>					
Female religiously affiliated		0.0201 (0.0182)		0.0190 (0.0184)	-0.0294 (0.0327)
Male religiously affiliated			0.0168 (0.0240)	0.0143 (0.0242)	0.0019 (0.0306)
Both religiously affiliated					0.0426 (0.0343)
<i>Fixed-effects</i>					
twin_id	Yes	Yes	Yes	Yes	Yes
<i>Fit statistics</i>					
Observations	10,440	10,440	10,440	10,440	11,155
R ²	0.54481	0.54491	0.54485	0.54494	0.59266
Within R ²	0.08049	0.08069	0.08058	0.08076	0.12742

Clustered (twin_id) standard-errors in parentheses

*Signif. Codes: ***: 0.01, **: 0.05, *: 0.1*

Table B.13: Male twin FE comparison for the effect of religious affiliation on fertility.

Dependent Variable:	birth				
Model:	(1)	(2)	(3)	(4)	(5)
<i>Variables</i>					
Female religiously affiliated		0.0201 (0.0182)		0.0190 (0.0184)	0.0299 (0.0323)
Male religiously affiliated			0.0168 (0.0240)	0.0143 (0.0242)	0.0259 (0.0370)
Both religiously affiliated					-0.0157 (0.0392)
<i>Fixed-effects</i>					
twin_id	Yes	Yes	Yes	Yes	Yes
<i>Fit statistics</i>					
Observations	10,440	10,440	10,440	10,440	10,440
R ²	0.54481	0.54491	0.54485	0.54494	0.54495
Within R ²	0.08049	0.08069	0.08058	0.08076	0.08078

Clustered (twin_id) standard-errors in parentheses

*Signif. Codes: ***: 0.01, **: 0.05, *: 0.1*

C

Appendix to Chapter 5

C.1 Birth squeezes thresholds

The expert-based approach relies on thresholds established in the existing literature, assuming that the authors of previous studies had valid reasons for selecting these thresholds, even if they were not explicitly stated. For instance, Dudel and Klüsener (2021) adopted the lowest total fertility rate (TFR) ratio reported by Schoen (1985) as a lower threshold, which was 0.89 in England and Wales in 1973. Additionally, Schoen (1985) noted that the TFR ratio of 1.12 in the United States in 1970 was relatively high compared to that in other high-income countries. This suggests a range of thresholds between 0.89 and 1.12. Coleman (2000) reported sex ratios ranging from 0.91 (Denmark in 1988) to 1.1 (German birth cohorts from 1902 to 1928). Gulczynski (2023) studied sex ratios and found that deviations from 1 greater than ± 0.085 were rare, indicating gender-skewed populations. This led to slightly narrower thresholds of 0.915 and 1.085. For the purposes of this analysis, we will use 0.9 and 1.1 as thresholds, as they fall within the range of the three variants with minimal differences. Furthermore, these values are equivalent to rounding the TFR ratio thresholds from the literature.

C.1.1 Data-based approach

We estimate a Bayesian log-log linear regression model to assess the relationship between TFR_{women} and the TFR ratio. We opted for a Bayesian model and not for a frequentist model, because our objective is to express uncertainty in parameter estimates, which can be more consistently achieved within the Bayesian framework (Gelman et al., 2020). The model estimation follows,

$$Likelihood : R = Normal(\log(\mu_i), \sigma), \quad (C.1)$$

$$Linear\ model: \mu_i = \alpha + \beta \log(x_i), \quad (C.2)$$

$$Prior : \alpha = Normal(\mu = 0, \sigma = 2), \quad (C.3)$$

$$Prior : \beta = Gamma(\kappa = 1, \theta = 1), \quad (C.4)$$

$$Prior : \sigma = HalfNormal(\mu = 0, \sigma = 1), \quad (C.5)$$

where μ_i is the mean prediction, which depends on the transformation of x_i (TFR of women) using α_i and β_i , see equation 2. We also obtain an estimate of the standard deviation σ .

We selected a normal distribution as Likelihood-Function, but we take the log of the outcome to obtain positive predictions. Thus, our predictions fulfill that TFR ratios are a 1) continuous variable, and 2) range between 0 and ∞ .

The priors were selected based on both mathematical and substantial considerations. The prior for α is neutral, as it is centered on 0 and has a standard deviation of 2. The prior for β is set to a gamma distribution with a shape parameter $\kappa = 1$ and a rate parameter of $\theta = 1$, because the gamma distribution ranges only over positive values, so that it captures the observation that the TFR ratio increases with the TFR of women (Schoumaker, 2019). The prior for σ follows a half-normal distribution with a $\mu = 0$ and $\sigma = 1$, which yields only positive values.

In order to obtain confidence intervals (c_α), we draw on the normal distribution and the estimated μ_i and σ :

$$c_\alpha = \exp(\alpha + \beta \cdot \log(TFR_w)) + 1.96 \cdot \sigma \quad (C.6)$$

Table C.1: This table displays the results from the regression model of the country-level relationship between TFR_{women} and the male-female TFR ratio using data from Dudel et al. (2021), Schoumaker (2019) and Schoen (1985).

	variable	median	5%-Credible Interval	95%-Credible Interval
1	α	-0.161	-0.171	-0.15
2	β	0.304	0.29	0.319
3	σ	0.091	0.088	0.096

C.1.2 Stable population approach

Stable population theory describes the asymptotic behaviour of closed populations with constant fertility and mortality rates. A closed population assumes no migration. The stable population approximation of the male female TFR ratio by Schoumaker (2019) and Tucker and Van Hook (2013) looks as follows:

$$\frac{TFR_m}{TFR_f} \approx \frac{1}{SRB} \cdot \frac{p(MAC)}{p(MAF)} \cdot \exp(r \cdot (T^m - T^f)), \quad (C.7)$$

where SRB is the sex ratio at birth, $p(MAC)$ and $p(MAF)$ are the probability of surviving until the mean age at childbearing, r is the growth rate, and T is the generation length.

Data sources for the stable population approach

We can study the behavior of male-female TFR ratios through the lens of the stable population approximation using realistic input values. For that exercise, we derive input values using data from different sources. Female and male life tables (1-year) were obtained the Human Mortality Database (Wilmoth et al., 2017). Male and female age-specific fertility rates were obtained from the Human Fertility Collection and the Human Fertility Database. Estimates of the sex ratio at births are drawn from (Chao et al., 2019) and the World Population Prospects 2024 (United Nations Department of Economic and Social Affairs, 2024).

Estimation for the stable population approach

Some input values require further transformation steps, which we are going to explain below. We estimate the probability of surviving to the mean age of childbearing in a sequential way. First, we estimate the mean age of childbearing based on age-specific fertility rates: $\frac{\sum_{x=15}^{59} f_x \times x}{\sum_{x=15}^{59} f_x}$. Second, once we have the mean age of childbearing, we look up the survival probability until that age from the female life table, which is given by ℓ_x/ℓ_0 . The estimation of the survival probability until the mean age of fatherhood follows an analogous procedure, but uses data for men.

The growth rate in a stable population is the first *eigenvalue* of the Leslie matrix (\mathbf{A}) based on the life table and age-specific fertility rates. The Leslie matrix is a matrix expression of the stable population. The matrix contains only values in the first row (fertility) and subdiagonal (survival) and we follow the notation in Wachter (p. 107, 2003). We estimate the elements in the first row by $A_{1,j(x)} = \frac{nL_0}{2\ell_0} \left({}_nF_x + {}_nF_{x+n} \frac{nL_{x+n}}{nL_x} \right) f_{fab}$. The values on the subdiagonal follow $A_{j+1,j} = \frac{nL_{x+n}}{nL_x}$. The growth rate r is equal to the harmonic mean of the male and female *eigenvalues*: $r = \frac{2}{1/\lambda_1^{A_m} + 1/\lambda_1^{A_m}}$.

The estimation of the generation length follows Keyfitz and Caswell (p. 169, 2005) and looks as follows:

$$T^f = \frac{\sum_{x=0}^{59} x \cdot p_x \cdot f_x}{\sum_{x=0}^{59} p_x \cdot f_x} \quad (\text{C.8})$$

C.1.3 Parameter estimates for the stable population approximation

The estimated parameter values are shown in Table C.2 in the column input range. The sex ratio at birth is set to range between 1.04 and 1.06. The population survival ratio to the mean age at childbearing is set to 0.915 and 1.085. The difference in generation length ranges between 2 and 4. The population growth rate is set to -0.01 and 0.01.

Table C.2: This table summarizes the simulation experiment using the stable population approximation by Schoumaker (2019) and realistic input values for the components.

Component	Estimation of components	Input range	TFR ratio	U (Schoen, 1985)
Sex ratio at birth	$SRB = \frac{B_m}{B_f}$	min = 1.04 max = 1.06	0.85 to 1.09 0.83 to 1.07	-0.17 to 0.08 -0.19 to 0.06
Population ratio	$p(MAC) = \frac{\ell_{MAC}}{\ell_0}$	min = 0.915 max = 1.085	0.83 to 0.92 0.98 to 1.09	-0.19 to -0.09 -0.02 to 0.08
Generation length	$T = \frac{\sum_{x=15}^{55} p_x \cdot m_x \cdot x}{\sum_{x=15}^{55} p_x \cdot m_x}$	min = 2 max = 4	0.84 to 1.08 0.83 to 1.09	-0.18 to 0.07 -0.19 to 0.08
Growth rate	$r = \lambda_1^A$	min = -0.01 max = 0.01	0.83 to 1.01 0.89 to 1.09	-0.19 to 0.01 -0.12 to 0.08
Overall	$\frac{1}{SRB} \cdot \frac{p(MAC)}{p(MAF)} \cdot \exp(r \cdot (T^m - T^f))$	See above	0.83 to 1.09	-0.19 to 0.08

Note: The columns show from left to right the components how it is commonly estimated, shows the range of the input values, the range of resulting TFR ratios and U values. The rows are ordered following the appearance in the equation C.7.

Source: Authors' analysis of data from Dudel and Klüsener (2021), Chao et al. (2019), and the Human Mortality Database (Wilmoth et al., 2017).

C.1.4 Outcome-based approach

The outcome-based approach uses regression analysis on individual-level data from Finnish administrative registers to study the strength of the relationship between TFR ratios and childlessness. In this section, we describe the data processing, the model estimation, and the algebra to derive the cut-offs.

First, we link the region-year TFR ratio data with individual data by year and residence in a region. Thus, we obtain data on the TFR ratio at the place of residence in a specific year. Second, we obtain information on the transition to first birth for all individuals. If a person does not have a child, the person is considered childless. Third, we filter respondents at age 30. Moreover, we filter persons who complete age 40 before the last year of observation, e.g., 2020. We then have the following data structure.

Table C.3: Example for the data structure used in the impact approach. Note that the data is fictive.

ID	Year	Age	Region	TFR ratio	Childless
1	1990	30	Uusimaa	0.99	1
⋮	⋮	⋮	⋮	⋮	⋮
2	2005	30	Lapland	0.75	0

Source: Authors' analysis of population register data from Statistics Finland.

We then estimate a logistic regression to estimate the association between the TFR ratio at age 30 and being childless at age 40. We model childlessness using a logistic regression model, such that

$$\Pr(C|TFR_m/TFR_f) = \frac{\exp(\alpha + \beta \frac{TFR_m}{TFR_f})}{1 + \exp(\alpha + \beta \frac{TFR_m}{TFR_f})}, \quad (\text{C.9})$$

where C is childlessness, TFR_m/TFR_f is the TFR ratio, and α and β are the coefficients.

What we are interested in: how much deviation δ from a balanced ratio, $\frac{TFR_m}{TFR_f} = 1$, is needed to change $\Pr(C)$ by some value μ . That is, what is δ such that $\Pr(C|1 + \delta) - \Pr(C|1) = \mu$. We are solving this equation below.

Plugging in definitions

$$\mu = \frac{\exp(\alpha + \beta(1 + \delta))}{1 + \exp(\alpha + \beta(1 + \delta))} - \frac{\exp(\alpha + \beta)}{1 + \exp(\alpha + \beta)} \quad (\text{C.10})$$

For simplification we write $l_\delta = \exp(\alpha + \beta(1 + \delta))$ and $l = \exp(\alpha + \beta)$ such that we have

$$\mu = \frac{l_\delta}{1 + l_\delta} - \frac{l}{1 + l} \quad (\text{C.11})$$

After rearranging we obtain

$$\delta = \frac{\log\left(\frac{-l - \mu l - \mu}{\mu - 1 + \mu l}\right) - \alpha - \beta}{\beta} \quad (\text{C.12})$$

If the point of reference is not $TFR_m/TFR_f = 1$ but some ratio $TFR_m/TFR_f = r$, the last equation becomes

$$\delta = \frac{\log\left(\frac{-l_r - \mu l_r - \mu}{\mu - 1 + \mu l_r}\right) - \alpha - \beta r}{\beta} \quad (\text{C.13})$$

where $l_r = \exp(\alpha + \beta r)$.

C.2 Birth squeeze thresholds using Schoen's U

Table C.4: This table summarizes the different approaches and their respective lower and upper cut-offs for birth squeezes.

Approach	Reasoning	Lower	Upper
Expert-based (E)	TFR ratios in previous literature.	-0.105	0.095
Data-based (D)	TFR ratios conditional on fertility level.	$0.66 + \delta^a$	$0.85 + \delta^a$
Stable population (S)	Sources of abnormal TFR Ratios.	-0.247	0.140
Outcome-based (O)	Impact of TFR ratios on childlessness.	-0.151	0.122

$$\delta = 0.136 \cdot TFR_w.$$

C.3 Parity-specific analysis

This section presents the results on gender differences in age-specific transition risks at different parities. The results are based on Poisson regression models with p-splines. The risk ratio is the ratio of the predicted male age-specific transition hazard to the predicted female age-specific transition hazard for the same parity. The results in Figure C.1 indicate gender differences in the risk of first birth, which are particularly pronounced at young ages, and no systematic pattern for higher parities.

The top panels of Figure C.1 show values below 1, which indicates a higher risk of first birth for women across all ages, across all regions, and over time. However, the gender difference in the risk of first birth diminishes with age, as the lines approach 1. For instance, after 5 years of process time (age 20) men have a 50% lower risk of transitioning to a first birth. However, the figure approaches unity after 20 years of process time (age 35). Geographic heterogeneities in gender differences result from differences in settlement type, as rural areas have large gender differences. For instance, at age 35, there is almost no difference in the risk of first birth between the sexes in Uusimaa, which is the Helsinki region, while in more rural areas, the risk remains lower for men.

Regarding higher parities, we see erratic fluctuations around equilibrium, which relate to small case numbers. However, it seems that at higher values of process

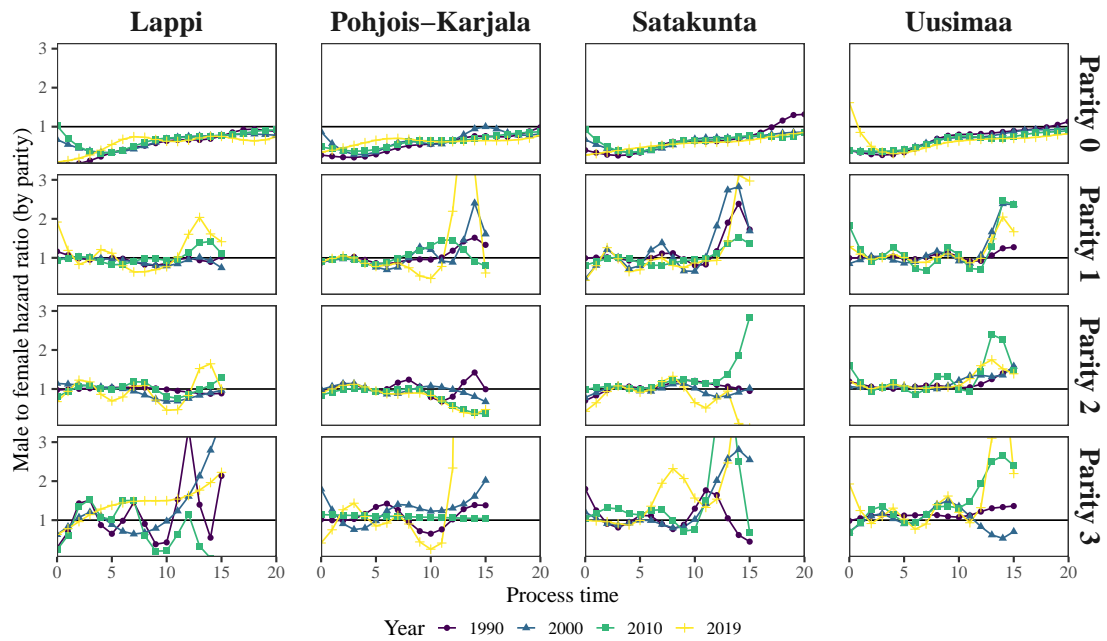


Figure C.1: Male-female hazard ratio of transitioning to the next birth. Values higher than 1 indicate a higher risk of men. For first births (Parity 0) the process time refers to time since age 15. For higher parity births, the process time is measuring the time since the last birth.

time, which occur at later ages, we observe higher transition risks for men relative to women. For instance, we find a relative risks of up to 3 for men for higher parities at the end of the process time.

C.4 Misreporting in war zones

Mexico’s war on drugs and Colombia’s internal armed conflict may affect the data quality, leading to a potential bias of our estimates on gender differences in fertility (Castro Torres & Urdinola, 2019). Our results would be biased, if the resulting undercoverage is different for men and for women. Gender-symmetric biases cancel out in our measure, given that we analyse TFR ratios. We use sensitivity analysis to account for the possibility of such a bias. We found increasing TFR ratios in war zones (see Section 5.4), which could be explained by two patterns. First, excess male mortality reduces male exposures stronger than female exposures during conflicts. Second, conflicts may lead to administrative delays and malfunctionings, which may contribute to undercounting men, which diminishes male exposures relative to female exposures. We want to make sure that the conclusions are robust to the latter.

We pursue two approaches to account for potential undercoverage. Both approaches draw on weights that account for the bias in the male exposures (w_m). We simply multiply the male population exposures by the weight that accounts for the undercoverage (${}^mL_i(x) = {}^mL_i(x) \cdot w_m$). The approaches differ in the way the weights are estimated and applied.

On one side, we assume that men are constantly undercount (constant bias across regions), so that we multiply all male exposures by a weight. We assume that the undercount is 10%, so that the weight w becomes 1.1 (see equation C.14).

$$L_i^m(x) = {}^mL_i^m(x) \cdot w^m; w^m = 1.1 \quad (\text{C.14})$$

This rather crude approach, however, does not distinguish between war zones and the rest, which may over-adjust in less affected areas.

Therefore, we use a more nuanced approach that derives the weight from a measure of conflict intensity, e.g. excess homicide rates (see equation C.15). Drawing on mortality statistics, we estimate the proportion of homicide deaths for all regions, which is the ratio of deaths caused by homicide to all deaths. The higher the

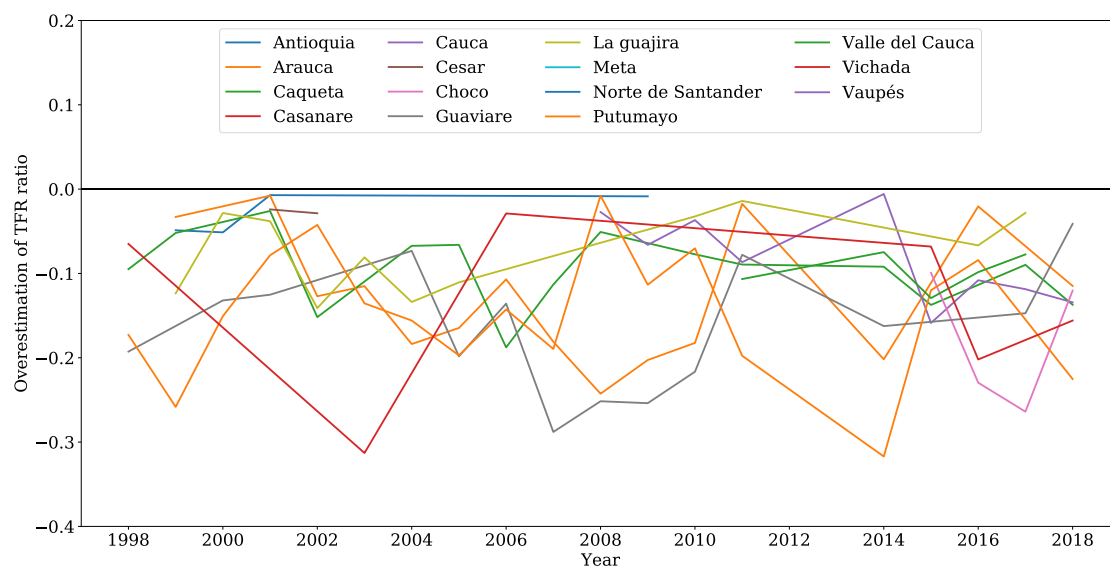


Figure C.2: This figure illustrates the potential impact of conflict-related undercoverage of men in the population. The estimate is the percentage-difference between the observed TFR ratio and the TFR ratio, that has re-weighted male exposures in conflict-affected areas. The weights are estimated following equation C.15.

number, the more people die from homicides. In the next step, we estimate an expected value of proportion of homicide deaths, which we say is the country mean increased by two standard deviation. This rather complicated measure is inspired by the fact that everything that is one standard deviation higher from the mean homicide rate is an extreme value, similar to box plots. Finally, we derive the weight w^m from the excess homicide rate, which is the percent difference between the expected and the observed homicide rate.

$$w_i(x) = \frac{(m_i^h(x) - E[m^h(x)])}{E[m^h(x)]}; E[m^h(x)] = \sum_{i=1}^n m_i^h(x) \cdot \frac{1}{n}, \quad (\text{C.15})$$

where m is the homicide rate, x indicates the year, the subscripts m and i indicate men and region respectively.

C.5 Additional figures

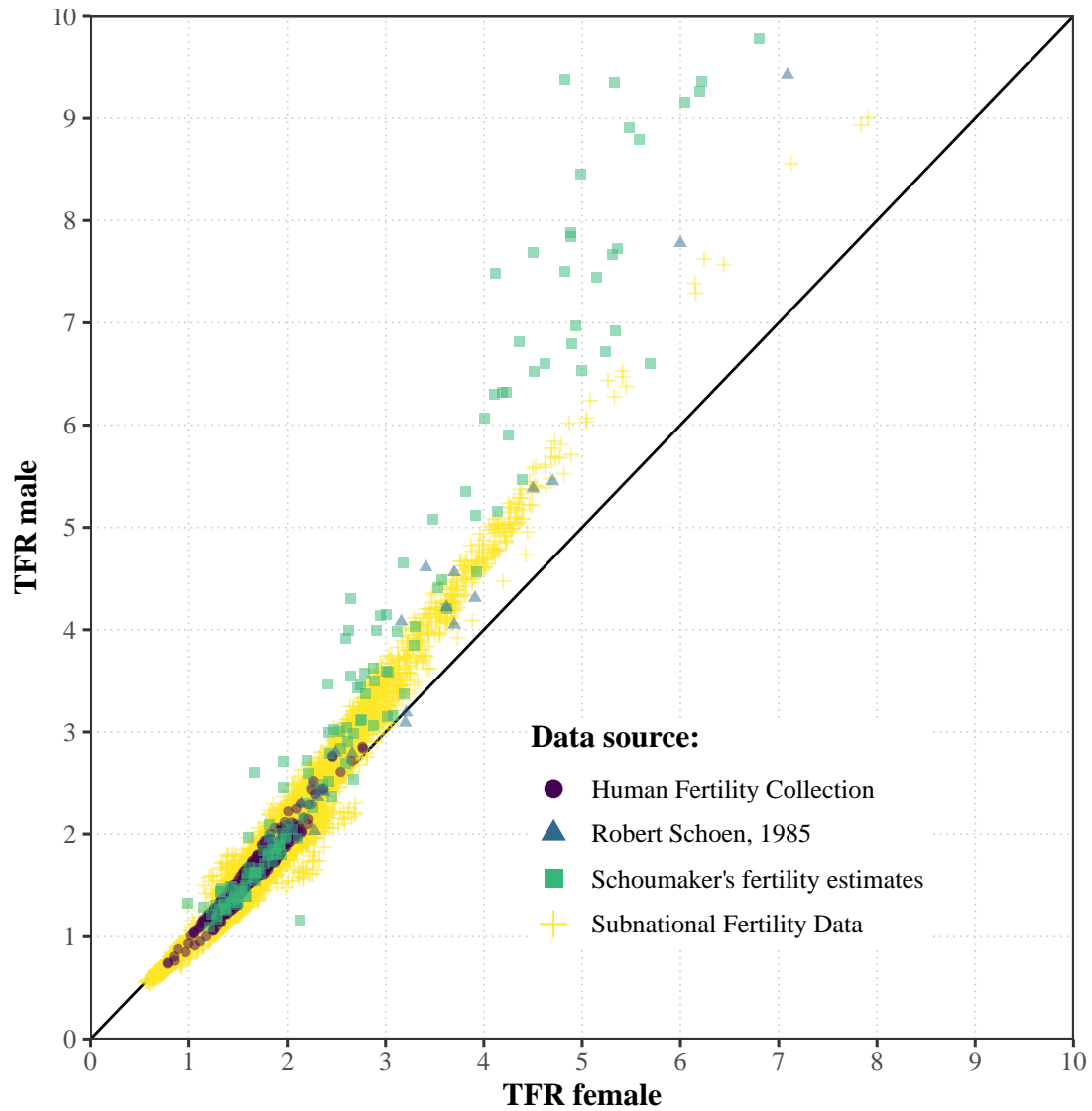


Figure C.3: This figure displays the distribution of region-year observations for the country and subnational data sources. *Source:* The data on male fertility in the human fertility collection was created by Dudel and Klüsener (2021). Schoumaker's fertility estimates are obtained from Schoumaker (2019). Data was also obtained from Schoen (1985). The subnational fertility data was created by the author's.

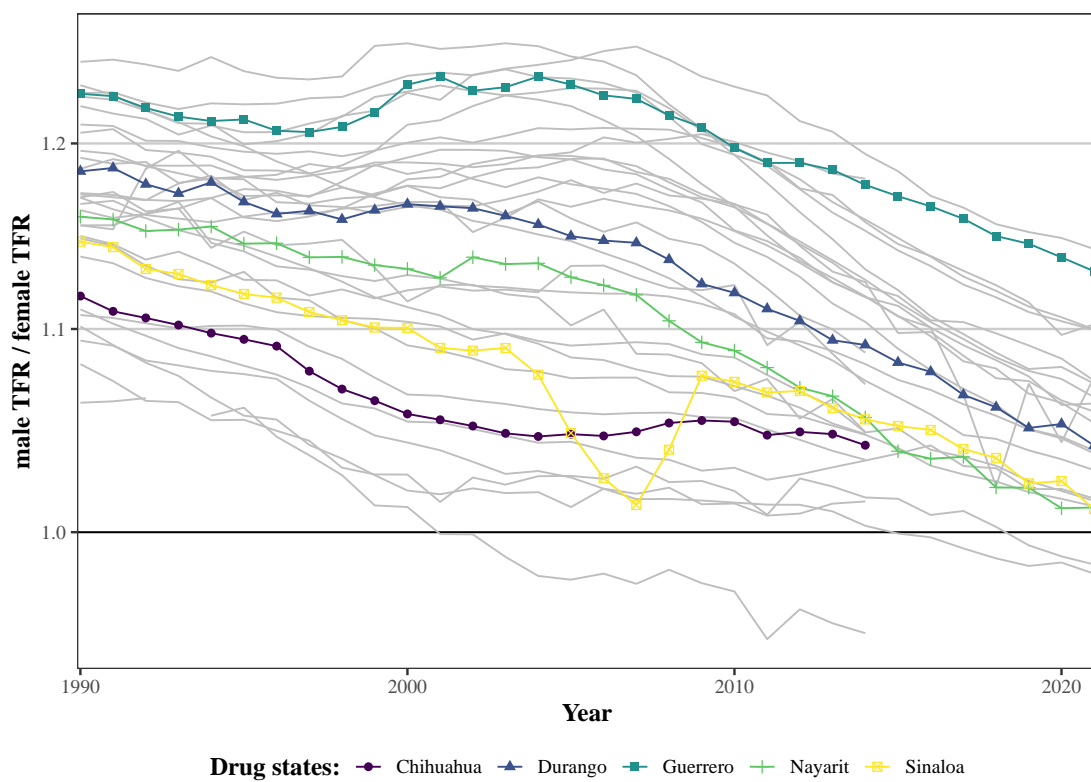


Figure C.4: This figure displays the time-trend in the male-female TFR ratios in the Mexican states. The coloured lines are the states most affected by the war on drugs according to Aburto et al. (2016), while the grey lines are the less and non-affected states.

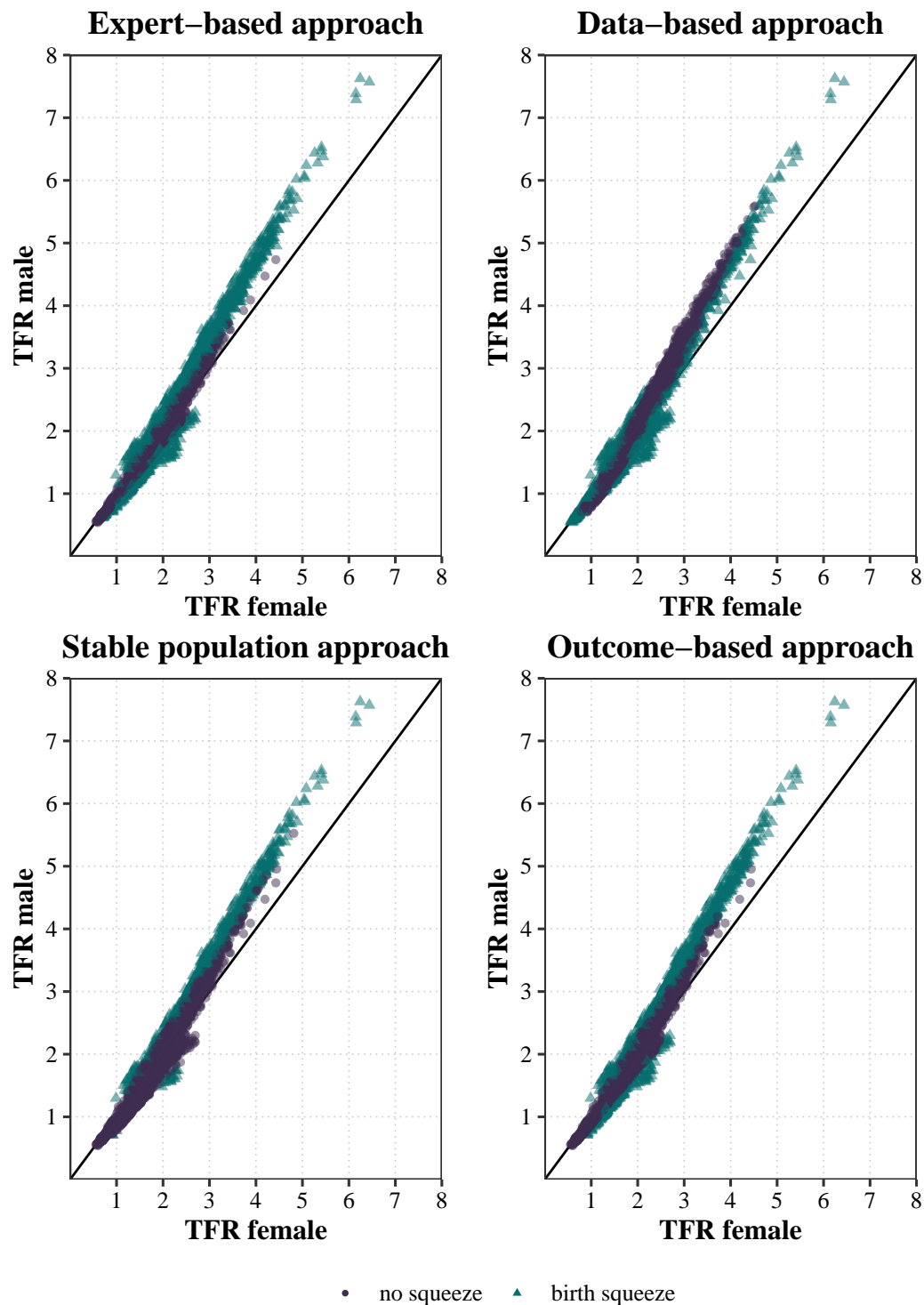


Figure C.5: The panels illustrate the occurrence of birth squeezes at the subnational level dependent on the measurement approach. Every point represents a region-year observation. The purple colour indicates male-female differences in the normal range, whereas yellow points indicate birth squeezes.

C.6 Additional tables

Table C.5: Quantiles of the male to female TFR ratio across different data sets.

	Source	N	10%	50%	90%
1	Human Fertility Collection	516	0.920	0.968	1.037
2	Robert Schoen, 1985	22	0.995	1.098	1.296
3	Schoumaker's fertility estimates	163	0.938	1.159	1.623
4	Subnational Fertility Data	5,278	0.882	0.994	1.146

Source: Dudel and Klüsener (2021), Schoen (1985), and Schoumaker (2019).

Table C.6: Regression model underlying the impact approach. Logit-binomial regression of TFR ratio at age 30 on the probability remaining childless at age 40. The results are displayed as logit-coefficients.

	Males	Females
α	-1.136*** (0.048)	-5.167*** (0.056)
β	0.347*** (0.0005)	4.089*** (0.059)
Observations	782,021	747,063

*p<0.1; **p<0.05; ***p<0.01

Source: Authors' analysis of population register data from Statistics Finland.

D

Appendix to Chapter 6

D.1 Summary of the partner market indicators

Table D.1: Comparison of partner market measures.

Measure	Estimation	Preferences	Availability	Competition
Sex Ratio	$\frac{F(y)}{M(x)}$	Same age	Same age	Same age
Preference Ratio	$\frac{\sum_{y=16}^{55} Prob(y x) \cdot F_{we}(y)}{M_{we}(x)}$	All ages	All ages	Same age
Availability Ratio	$\frac{\sum_y \sum_b w_{x,e}(y,b) F(y,b)}{\sum_y \sum_b w_{x,e}(y,b) \cdot \sum_x \sum_e w_{y,d}(x,e) M(x,e)}$	Age × Education	All	All

The first column gives the names of the measures, ordered by increasing data requirement and complexity. The second column shows the estimation. The third column indicates which preferences are incorporated. The fourth column shows how is competing with the group of interest for the available women. The last column indicates the dimensions that are fully reflected in the measure.

D.2 Estimation of weights for the availability ratio

The conditional age distribution by age of the father (x):

$$w_x(y) = \frac{B_x(y)}{B_x} \quad (\text{D.1})$$

For the availability ratio the conditional age distribution of mothers dependent on the age of the father was calculated at the national level $\left(\frac{B(x,y)}{B(x)}\right)$, whereas $B(x, y)$ refers to the number of births of men at age x with women at age y and $B(x)$ denotes to total number of births to men in the same age group.

D.3 Figures illustrating gender differences in the society

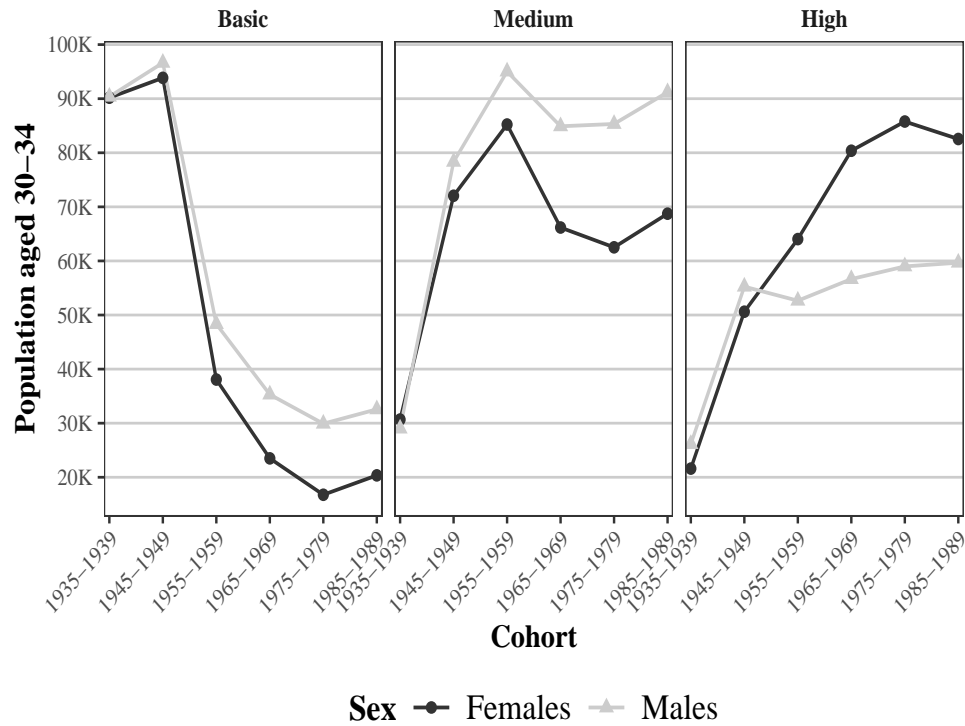


Figure D.1: The educational distribution of women and men at age 30 to 34 in the cohorts 1935-1989 in Finland. Source: Statistics Finland (2020).

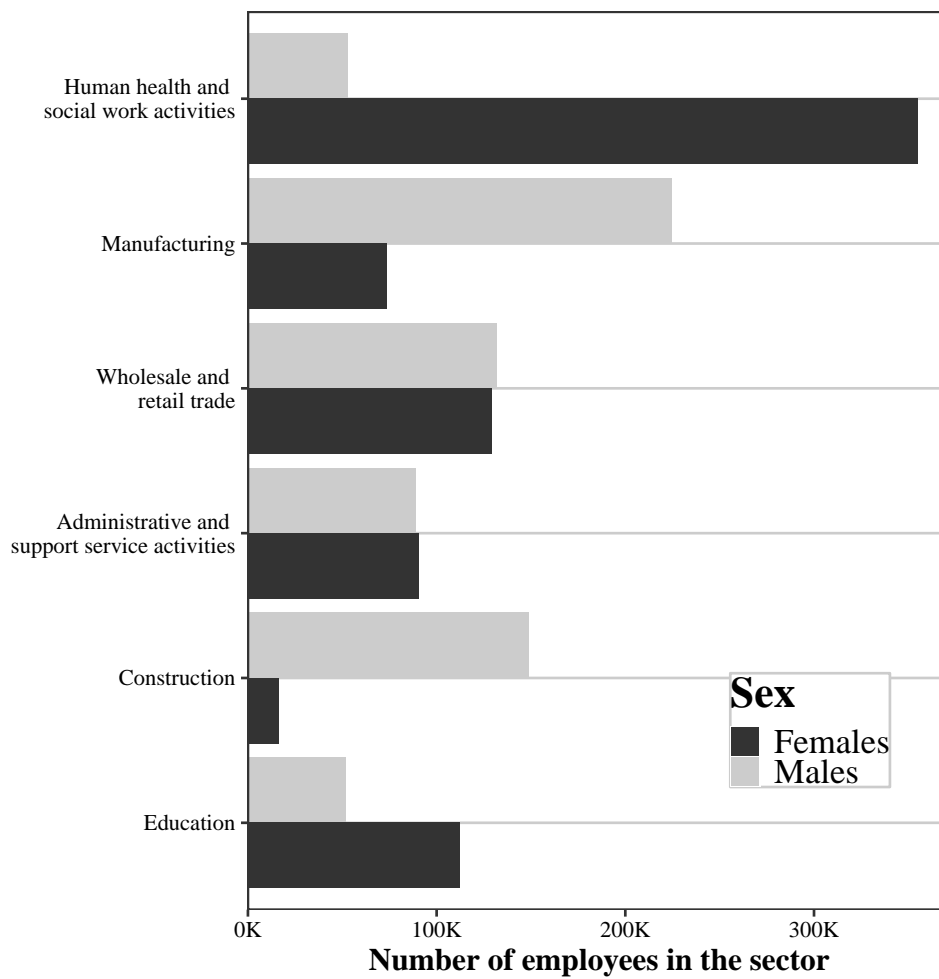


Figure D.2: The distribution of women and men across the 5 largest sectors in Finland in 2019. Source: Statistics Finland (2019).

D.4 Maps of the partner market indicators

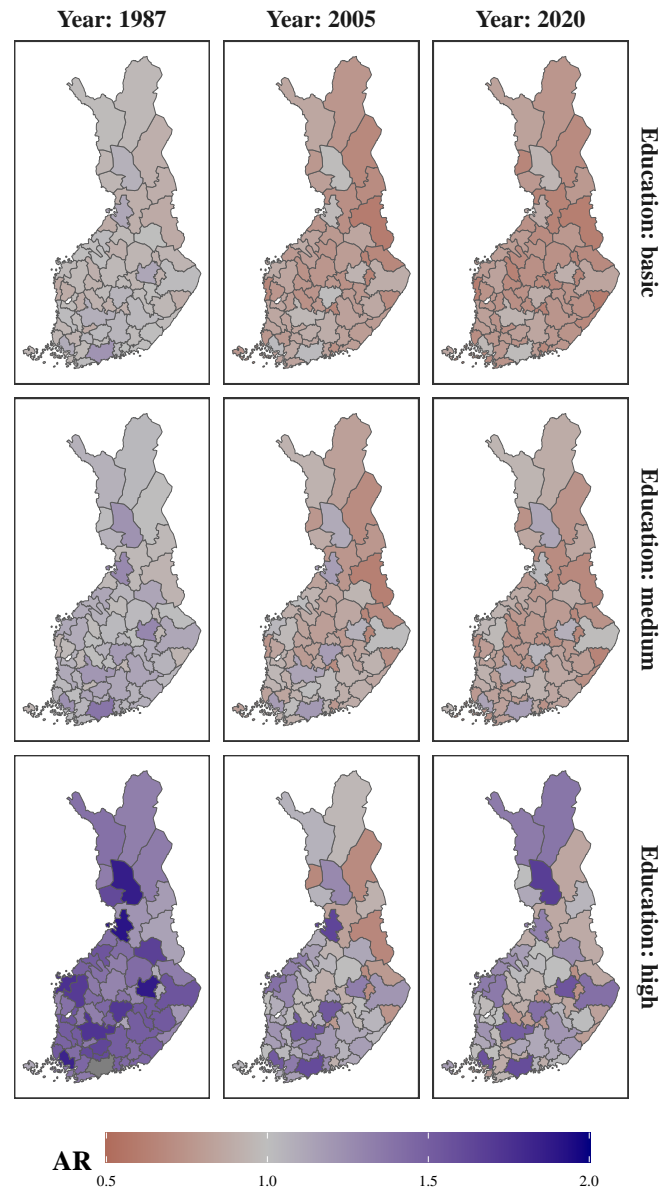


Figure D.3: Cross-sectional data on partner availability for men measured with the availability ratio for men at age 30 for different educational levels (vertical panels) and in different years (horizontal panels) using administrative boundaries. **Interpretation:** Red colours indicate a weak partner market situation at age 30, while greyish entities have balanced partner markets, and blue regions have an excess of potential partners.

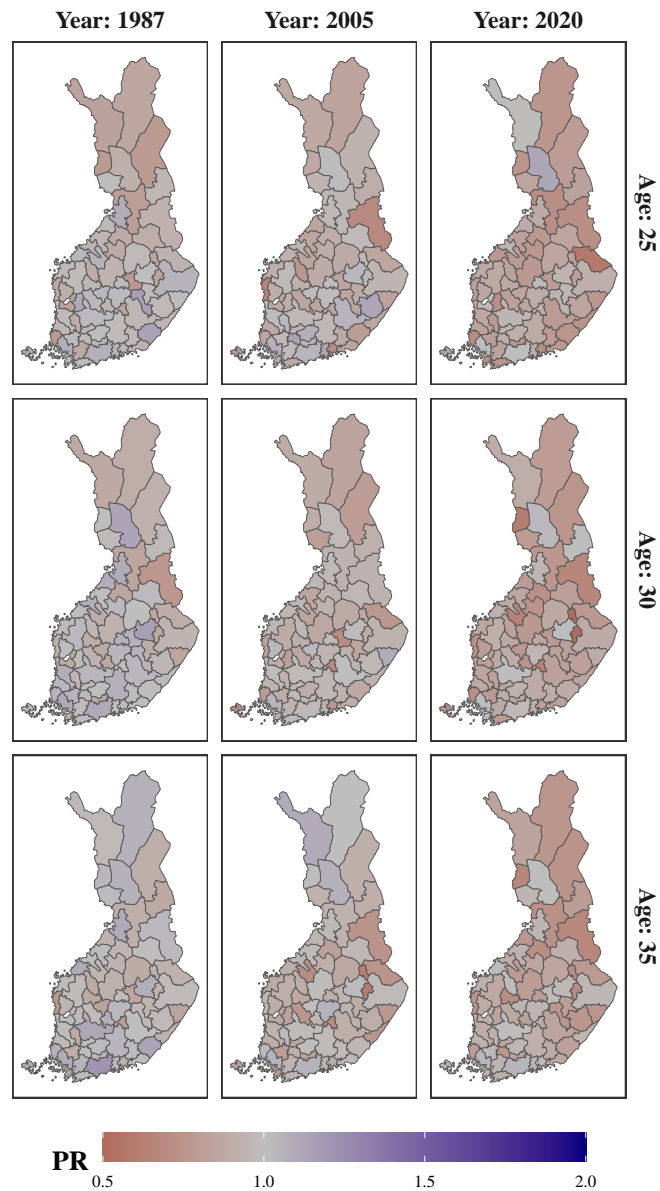


Figure D.4: Cross-sectional data on partner availability for men measured with the preference ratio at age 25, 30 and 35 (vertical panels) over different years (horizontal panels) using administrative boundaries. **Interpretation:** Red colours indicate a weak partner market situation, while greyish entities have balanced partner markets, and blue regions have an excess of potential partners.

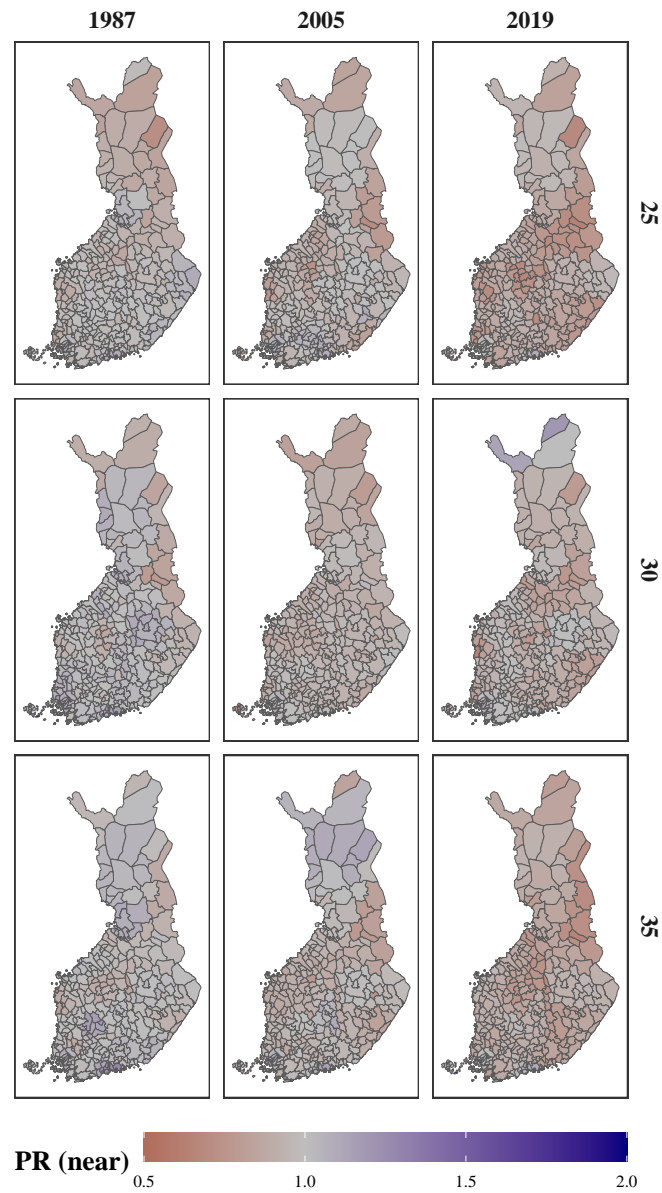


Figure D.5: Cross-sectional data on partner availability for men measured with the preference ratio at age 25, 30 and 35 (vertical panels) over different years (horizontal panels) using the proximate approach. **Interpretation:** Red colours indicate a weak partner market situation, while greyish entities have balanced partner markets, and blue regions have an excess of potential partners.

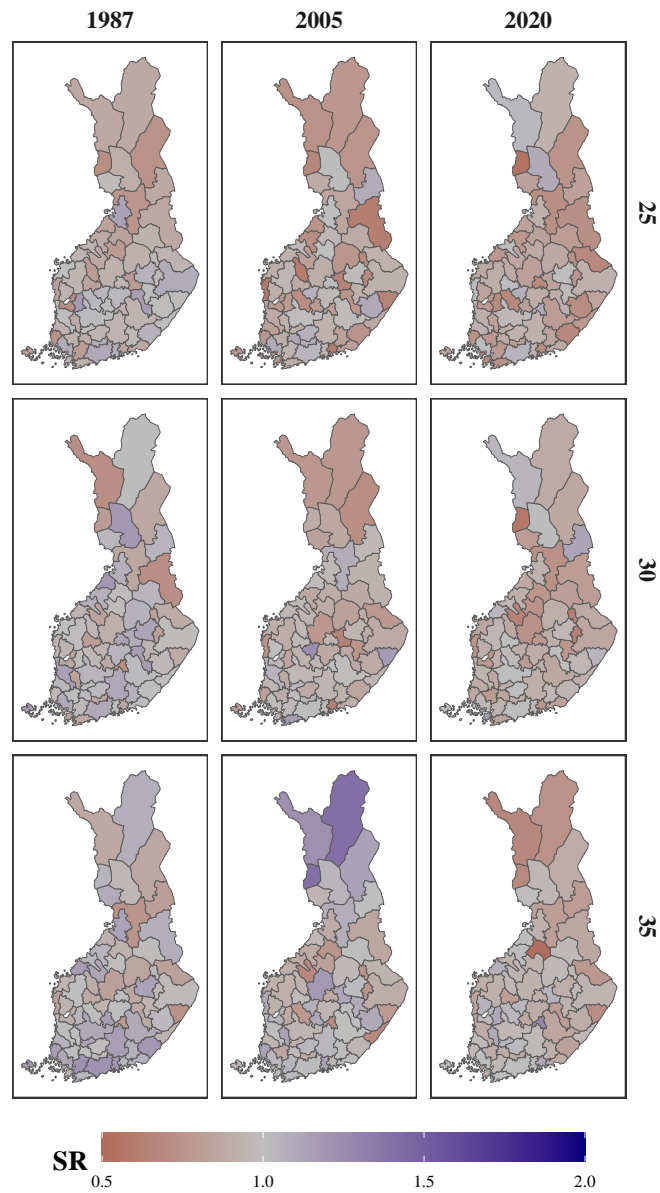


Figure D.6: Cross-sectional data on partner availability measured by the age-specific sex ratio for men at age 25, 30, 25 (vertical panels) in different years (horizontal panels) using administrative borders. **Interpretation:** Red colours indicate a weak partner market situation, while greyish entities have balanced partner markets, and blue regions have an excess of potential partners.

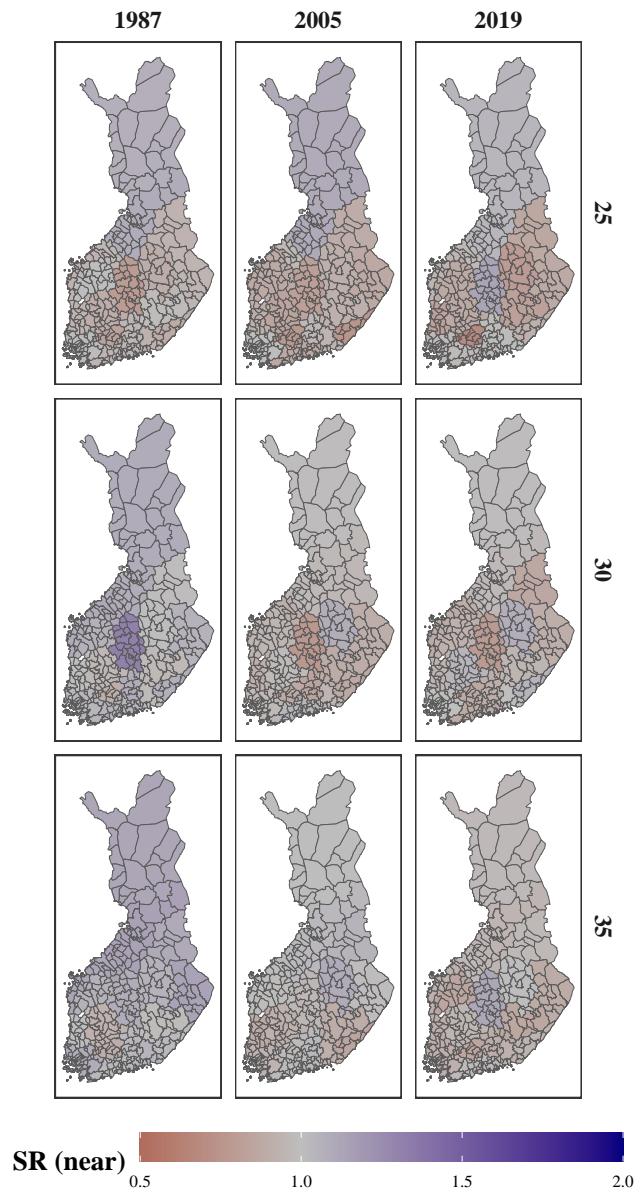


Figure D.7: Cross-sectional data on partner availability measured by the age-specific sex ratio for men at age 25, 30, 35 (vertical panels) in different years (horizontal panels) using the proximate approach. **Interpretation:** Red colours indicate a weak partner market situation, while greyish entities have balanced partner markets, and blue regions have an excess of potential partners.

D.5 Supplementary results and figures

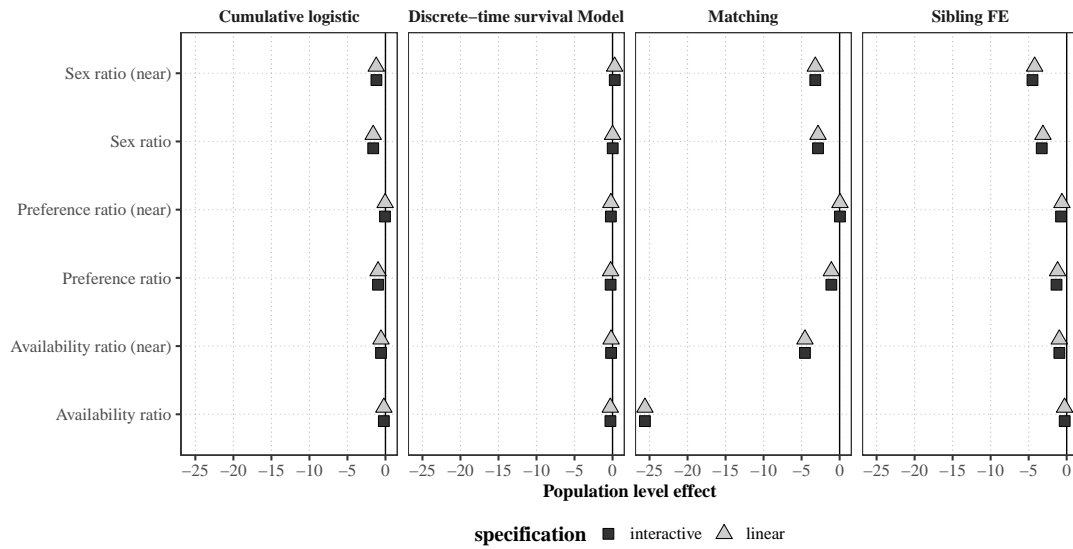


Figure D.8: This figure summarises the results across all models, control variable selections and availability indicators. The different panels distinguish the model type; the different shape of the points highlight the variable specification (**linear** effect of partner market or **interactive** effect with income quantile) and the different symbols and rows display the results for the different availability indicators.

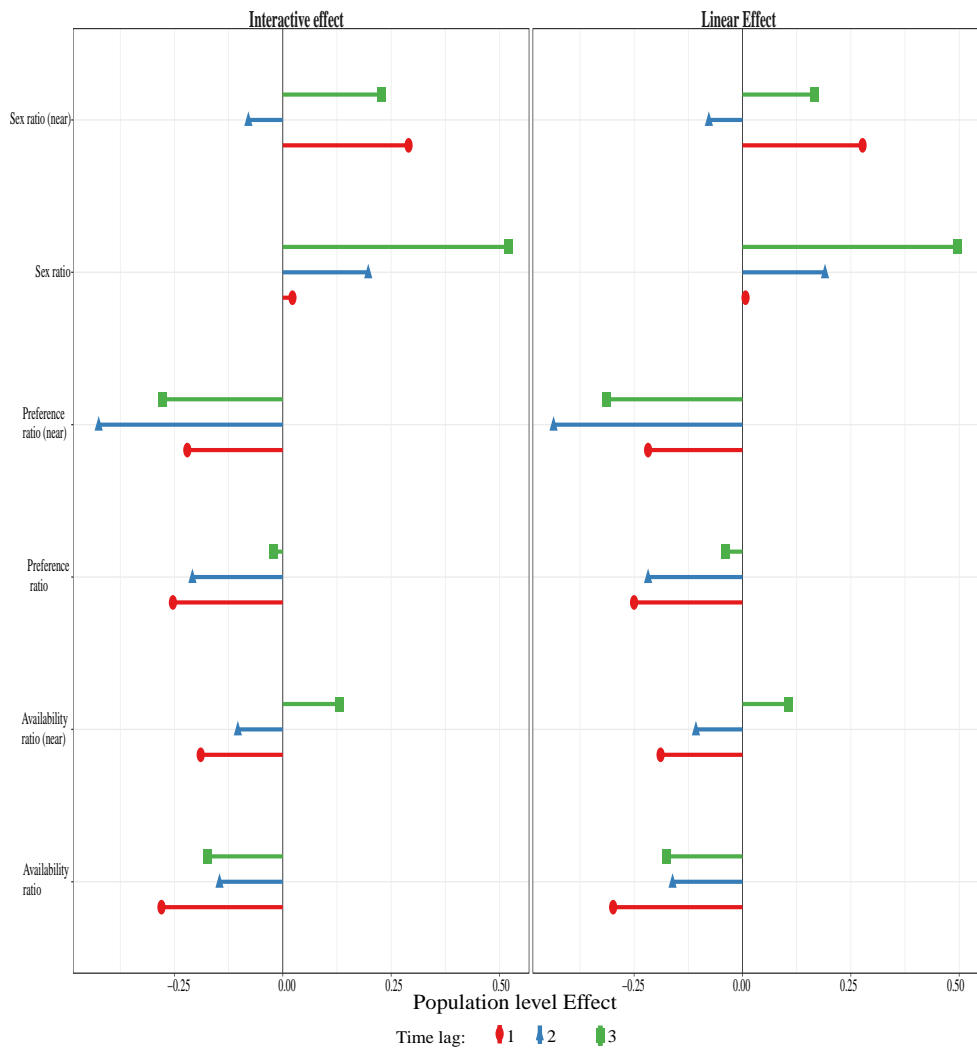


Figure D.9: Population level effects in the discrete-time survival model on the transition to first-birth. A negative value indicates that the absence of partner market imbalances would decrease population level childlessness.

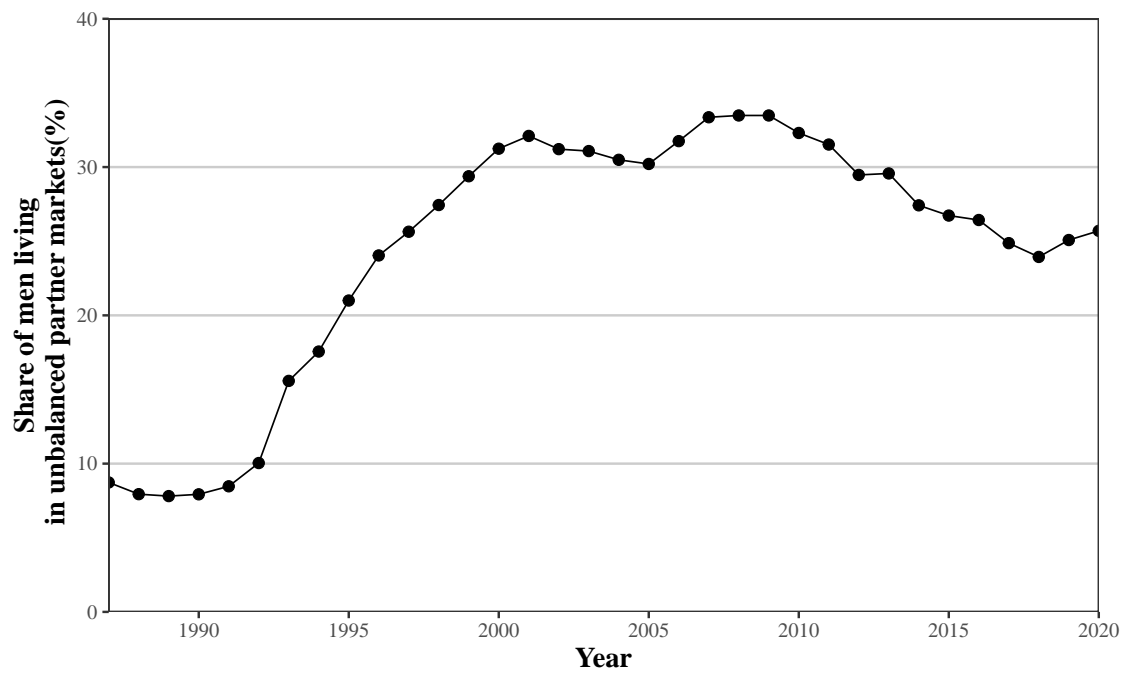


Figure D.10: This figure illustrates the share of men exposed to unbalanced partner markets (availability ratio < 1) in the period between 1987 and 2020 using repeated cross-sections.

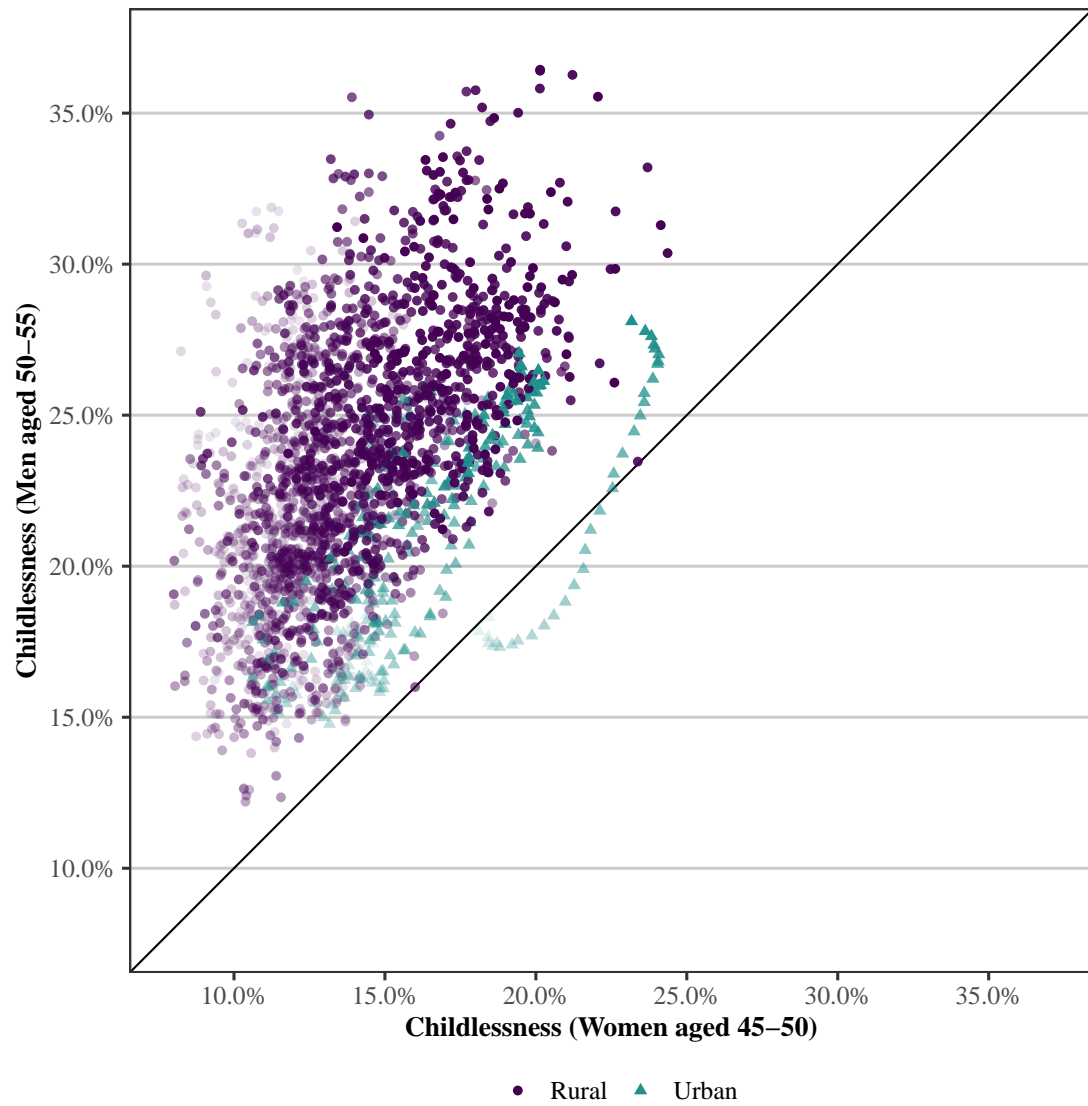


Figure D.11: This figure illustrates the relationship of male and female childlessness across regions in the period between 1987 and 2020.

D.6 Additional regression tables

Table D.2: Logistic random effects regression of childlessness at age 45 on the cumulative partner market exposure using the availability ratio (near) as the predictor variable.

	<i>Dependent variable: childless at age 45</i>			
	(1)	(2)	(3)	(4)
Availability ratio	-3.818*** (-3.903,-3.734)	-5.079*** (-5.183,-4.975)	-6.496*** (-6.636,-6.356)	-6.762*** (-6.986,-6.537)
Cohort: 1972-1975		-0.428*** (-0.450,-0.406)	0.060*** (0.032,0.088)	0.058*** (0.030,0.086)
Income Q2		-0.505*** (-0.539,-0.471)	-0.667*** (-0.709,-0.626)	-0.639*** (-0.701,-0.577)
Income Q3		-0.687*** (-0.720,-0.654)	-0.828*** (-0.869,-0.787)	-0.870*** (-0.931,-0.809)
Income Q4		-0.731*** (-0.766,-0.696)	-0.970*** (-1.013,-0.928)	-1.124*** (-1.187,-1.061)
Duration unemployed		0.192*** (0.187,0.196)	0.142*** (0.138,0.147)	0.142*** (0.137,0.146)
Education: high		-0.587*** (-0.627,-0.548)	-0.831*** (-0.877,-0.784)	-0.836*** (-0.883,-0.790)
Education: medium		-0.156*** (-0.189,-0.123)	-0.242*** (-0.284,-0.201)	-0.250*** (-0.291,-0.208)
Proportion tertiary: high			1.464*** (1.415,1.512)	1.469*** (1.420,1.518)
Proportion unemployment: high			-0.943*** (-0.957,-0.930)	-0.942*** (-0.956,-0.929)
Urban settlement			-0.298*** (-0.348,-0.248)	-0.300*** (-0.350,-0.250)
Poverty: high			1.688*** (1.636,1.740)	1.688*** (1.636,1.740)
Availability ratio:Income Q2				-0.214* (-0.469,0.041)
Availability ratio:Income Q3				0.206* (-0.032,0.444)
Availability ratio:Income Q4				0.771*** (0.533,1.009)
Constant	-0.768*** (-0.883,-0.653)	-0.178*** (-0.302,-0.055)	9.016*** (8.760,9.272)	9.059*** (8.801,9.317)
<i>Region random-effects</i>	<i>Yes</i>	<i>Yes</i>	<i>Yes</i>	<i>Yes</i>
Observations	194,080	194,080	194,080	194,080
Log Likelihood	-114,800	-101,162	-76,532	-76,488
Akaike Inf. Crit.	229,606	202,345	153,093	153,011

*p<0.1; **p<0.05; ***p<0.01

Note: The availability ratio is the average log availability ratio over the period between age 18 and conception or age 45. This table displays logit coefficients, which represent the average response in the log-odds of childlessness to a value change of one. Confidence intervals are estimated based on standard errors clustered at the regional partner market. Model (1) contains no controls; Model (2) adds individual control variables; Model (3) adds contextual control variables; and Model (4) adds interactions between income quartile and the availability ratio.

Source: Authors' analysis of population register data from Statistics Finland.

Table D.3: Logistic regressions of the effect of cumulative partner-market exposure on childlessness at age 45 for men in Finland, using the logarithm of the availability ratio (near) as the predictor variable.

	<i>Dependent variable: Childlessness at age 45</i>			
	(1)	(2)	(3)	(4)
Availability ratio	-2.413*** (-2.836,-1.991)	-2.191*** (-2.817,-1.566)	-5.058*** (-5.857,-4.260)	-5.716*** (-6.491,-4.940)
Cohort: 1972-1975		-0.295*** (-0.365,-0.225)	-0.164** (-0.308,-0.019)	-0.163** (-0.307,-0.018)
Income Q2		-0.466*** (-0.511,-0.420)	-0.618*** (-0.675,-0.561)	-0.654*** (-0.733,-0.574)
Income Q3		-0.695*** (-0.752,-0.638)	-0.783*** (-0.853,-0.712)	-0.892*** (-0.979,-0.805)
Income Q4		-0.624*** (-0.694,-0.554)	-0.870*** (-0.941,-0.799)	-1.172*** (-1.299,-1.045)
Duration unemployed (years)		0.194*** (0.185,0.204)	0.175*** (0.167,0.183)	0.174*** (0.166,0.181)
Education: high		-0.089* (-0.191,0.014)	-0.667*** (-0.813,-0.521)	-0.674*** (-0.819,-0.529)
Education: medium		-0.044** (-0.086,-0.003)	-0.193*** (-0.252,-0.134)	-0.205*** (-0.263,-0.146)
Proportion tertiary: high			1.242*** (1.049,1.435)	1.253*** (1.059,1.447)
Proportion unemployment: high			-0.531*** (-0.625,-0.437)	-0.532*** (-0.626,-0.438)
Urban settlement			0.106 (-0.105,0.318)	0.109 (-0.103,0.321)
Proportion poverty: high			1.542*** (1.342,1.742)	1.550*** (1.350,1.751)
Availability ratio:Income Q2				0.111 (-0.205,0.428)
Availability ratio:Income Q3				0.547*** (0.206,0.888)
Availability ratio:Income Q4				1.509*** (1.056,1.962)
Constant	-0.260*** (-0.330,-0.190)	-0.113** (-0.223,-0.002)	4.845*** (3.807,5.883)	4.986*** (3.932,6.039)
Observed (% childless)	32.6	32.6	32.6	32.6
Counterfactual (% childless)	32.1	32.2	32.0	32.0
Population level effect	-0.467	-0.441	-0.587	-0.585
Observations	194,080	194,080	194,080	194,080
Log Likelihood	-119,316	-106,999	-85,200	-85,072
Akaike Inf. Crit.	238,637	214,016	170,426	170,177

*p<0.1; **p<0.05; ***p<0.01

Note: The availability ratio is the average log availability ratio over the period between age 18 and conception or age 45. This table displays logit coefficients, which represent the average response in the log-odds of childlessness to a value change of one. Confidence intervals are estimated based on standard errors clustered at the regional partner market. Model (1) contains no controls; Model (2) adds individual control variables; Model (3) adds contextual control variables; and Model (4) adds interactions between income quartile and the availability ratio.

Source: Authors' analysis of population register data from Statistics Finland.

D.7 Robustness checks of the preference measure

This section describes the robustness checks of the preferences that are estimated based on the conditional distribution of births. The estimation of preferences based on behavioural data, in this case for births, is subject to endogeneity. This is because population imbalances may distort the preference measure, given that the measure captures a combination of partnering opportunities and partner preferences. In other words, the observed sorting of men to women is the result of both partner availability and preferences, while the measure only captures preferences. Thus, the preference measure may be distorted by partner availability to some degree. To evaluate the extent of the distortion and to assess the robustness of the estimates, we compare the observed preferences based on the full sample of births (taking into consideration both partner availability and preferences) against a reduced sample of births that occurred in regions with excess women (considering only preferences without partner availability). This approach serves to neutralise the impact of partner availability. Subsequently, we compare the preference estimate derived from the entire sample and the preference estimate derived from the undisturbed sample. A significant degree of overlap may indicate that the preference measure is functioning as intended, and is thus capturing preferences rather than partner availability.

In order to quantify the difference between the distributions we estimate the cumulative absolute difference of the two discrete distributions. The estimation is as follows:

$$\Delta(f_1, f_2) = \sum_{x=18}^{55} \frac{|f_1(x) - f_2(x)|}{2} \quad (\text{D.2})$$

The result can be interpreted as the percentage points that would need to be redistributed in order to obtain identical distributions. Hence, the lower the value is, the more similar the two distributions are.

Table D.4: This table displays the cumulative difference between the overall preference distribution and the estimated preferences based on data for regions in which a sustained excess of females exist. The preferences are based on the conditional age distribution of the mother based on the age of the father.

Age	Difference
20	0.0610
30	0.139
40	0.0327
50	0.132

Interpretation: Overall, there is a small difference between the two distributions. However, the result for highly educated males at age 20 points to larger differences. These differences may be attributable to the low case numbers of highly educated males in that age, which may lead to large random fluctuations in the conditional distribution of births.

Table D.5: This table displays the cumulative difference between the overall preference distribution and the estimated preferences based on data for regions in which a sustained excess of females exist. The preferences are based on the conditional age-education distribution of the mother based on the age and education of the father.

Age	Education	Difference
20	basic	0.0744
20	medium	0.0681
20	high	0.515
30	basic	0.0827
30	medium	0.0751
30	high	0.0580
40	basic	0.0772
40	medium	0.0803
40	high	0.0390

Interpretation: Overall, there is a small difference between the two distributions. However, the result for highly educated males at age 20 points to larger differences. These differences may be attributable to the low case numbers of highly educated males in that age, which may lead to large random fluctuations in the conditional distribution of births.

D.8 Additional regression tables (continued)

Table D.6: Logit-binomial regression of being childless at age 45 on life-time partner market exposure, measured by the availability ratio for a subset of male sibling groups. Model 1 presents the between-effects, while model 2 presents the sibling fixed-effect result that harnesses only variation within sibling groups. This table is displaying logit coefficients, which represent the average response in the log-odds of childlessness to a value change of 1.

	Childless at age 45	
	(1)	(2)
Availability ratio	-6.666***	-17.128***
Education: high	-0.757***	-2.58***
Education: medium	-0.176***	-1.108***
Income quantile: 2	-0.601***	-1.419***
Income quantile: 3	-0.785***	-1.786***
Income quantile: 4	-0.885***	-2.241***
Activity: Unemployed	0.189***	0.311***
Oldest son	0.16***	-0.009
% tertiary in region	1.177***	2.391***
Unemployment rate	-0.392***	-1.771***
Sibling FE	No	Yes
N	52469	52469
Sibling groups	31730	7692
Null deviance	65782.3065346864	22116.07
Deviance	47475.3056798914	9763.43

*p < .05; **p < .01; ***p < .001

Table D.7: Discrete-time survival regression model on giving birth using time lag of 1.

	<i>Dependent variable:</i>			
	First birth			
	(1)	(2)	(3)	(4)
log ar(near)	0.161*	0.041	0.119	0.071
	(0.009,0.313)	(-0.130,0.212)	(-0.098,0.335)	(-0.305,0.448)
Age	0.227***	0.215***	0.257***	0.256***
	(0.129,0.326)	(0.111,0.319)	(0.134,0.379)	(0.134,0.379)
Age ²	-0.002**	-0.002*	-0.003**	-0.003**
	(-0.004,-0.001)	(-0.004,-0.0003)	(-0.005,-0.001)	(-0.005,-0.001)
Cohort: 1972-1976		0.028	0.049	0.049
		(-0.059,0.114)	(-0.054,0.152)	(-0.054,0.152)
Income Q2		-0.011	-0.019	-0.021
		(-0.131,0.108)	(-0.139,0.101)	(-0.150,0.109)
Income Q3		0.167**	0.160**	0.147*
		(0.041,0.293)	(0.034,0.287)	(0.013,0.282)
Income Q4		0.160*	0.151*	0.147*
		(0.024,0.296)	(0.013,0.289)	(0.003,0.291)
Activity: others		-0.110	-0.118	-0.118
		(-0.295,0.074)	(-0.303,0.067)	(-0.302,0.067)
Activity: student		-0.217**	-0.229**	-0.229**
		(-0.383,-0.052)	(-0.395,-0.063)	(-0.395,-0.063)
Activity: unemployed		0.177***	0.161**	0.160**
		(0.066,0.287)	(0.049,0.273)	(0.049,0.272)
Education: high		-0.385***	-0.360***	-0.359***
		(-0.520,-0.251)	(-0.501,-0.219)	(-0.499,-0.218)
Education: medium		-0.330***	-0.327***	-0.327***
		(-0.422,-0.238)	(-0.420,-0.235)	(-0.419,-0.234)
Urban		-0.009	-0.014	-0.013
		(-0.094,0.075)	(-0.105,0.077)	(-0.104,0.078)
% tertiary			0.005	0.005
			(-0.008,0.017)	(-0.008,0.017)
Unemployment rate			0.019	0.019
			(-0.001,0.038)	(-0.001,0.038)
% in poverty			0.005	0.004
			(-0.019,0.028)	(-0.019,0.027)
log ar(near):Income Q2				0.016
				(-0.434,0.466)
log ar(near):Income Q3				0.135
				(-0.301,0.570)
log ar(near):Income Q4				0.020
				(-0.412,0.452)
Constant	-6.072***	-5.816***	-6.924***	-6.908***
	(-7.499,-4.644)	(-7.366,-4.266)	(-8.819,-5.028)	(-8.808,-5.009)
Observed (% childless)	64.4	64.2	46.1	46.1
Counterfactual (% childless)	64.1	64.1	46.0	46.0
Population level effect	-0.255	-0.066	-0.189	-0.189
Observations	2,372,190	2,372,190	2,372,190	2,372,190
Akaike Inf. Crit.	12,109.940	12,053.250	12,055.780	12,061.410

Note:

*p<0.1; **p<0.05; ***p<0.01

Table D.8: Discrete-time survival regression model on giving birth using time lag of 1.

	<i>Dependent variable:</i>			
	First birth			
	(1)	(2)	(3)	(4)
Sex ratio	-0.114*** (-0.176,-0.051)	-0.429*** (-0.494,-0.363)	-0.405*** (-0.480,-0.330)	0.025 (-0.151,0.201)
Age	0.819*** (0.810,0.829)	0.694*** (0.684,0.704)	0.700*** (0.687,0.713)	0.700*** (0.687,0.713)
Age ²	-0.013*** (-0.014,-0.013)	-0.012*** (-0.012,-0.011)	-0.012*** (-0.012,-0.011)	-0.012*** (-0.012,-0.011)
Cohort: 1972-1976		0.067*** (0.057,0.077)	0.063*** (0.051,0.074)	0.063*** (0.052,0.074)
Income Q2		0.315*** (0.297,0.333)	0.316*** (0.298,0.334)	0.292*** (0.272,0.311)
Income Q3		0.559*** (0.541,0.577)	0.560*** (0.542,0.579)	0.537*** (0.517,0.557)
Income Q4		0.790*** (0.771,0.808)	0.792*** (0.773,0.810)	0.779*** (0.759,0.798)
Activity: other		-0.985*** (-1.021,-0.950)	-0.986*** (-1.021,-0.950)	-0.986*** (-1.021,-0.950)
Activity: student		-0.415*** (-0.438,-0.392)	-0.418*** (-0.441,-0.395)	-0.418*** (-0.441,-0.395)
Activity: unemployed		-0.272*** (-0.291,-0.253)	-0.277*** (-0.296,-0.257)	-0.276*** (-0.295,-0.256)
Education: medium		-0.076*** (-0.091,-0.061)	-0.077*** (-0.092,-0.062)	-0.077*** (-0.092,-0.063)
Education: high		0.160*** (0.144,0.176)	0.157*** (0.141,0.173)	0.156*** (0.140,0.172)
Urban		-0.068*** (-0.078,-0.057)	-0.082*** (-0.094,-0.070)	-0.081*** (-0.093,-0.069)
% tertiary educated			0.006*** (0.005,0.008)	0.006*** (0.005,0.008)
Unemployment rate			0.007*** (0.005,0.010)	0.007*** (0.005,0.010)
Poverty			0.007*** (0.004,0.009)	0.007*** (0.004,0.009)
Sex ratio:Income Q2				-0.633*** (-0.849,-0.416)
Sex ratio:Income Q3				-0.643*** (-0.850,-0.436)
Sex ratio:Income Q4				-0.287** (-0.490,-0.085)
Constant	-14.898*** (-15.049,-14.747)	-13.274*** (-13.437,-13.110)	-13.695*** (-13.909,-13.482)	-13.680*** (-13.894,-13.467)
Observations	2,372,190	2,372,190	2,372,190	2,372,190
Akaike Inf. Crit.	971,503.200	948,408.200	948,343.700	948,312.300

Note:

*p<0.1; **p<0.05; ***p<0.01

Table D.9: Linear regression on matched data for childlessness

	<i>Dependent variable:</i>			
	Childless at age 45			
	(1)	(2)	(3)	(4)
High availability	-0.160*** (-0.244,-0.076)	-0.222*** (-0.314,-0.130)	-0.565*** (-0.679,-0.451)	-1.104*** (-1.331,-0.878)
Cohort: 1972-1976		-0.272*** (-0.359,-0.185)	-0.276*** (-0.375,-0.177)	-0.264*** (-0.364,-0.165)
Income Q2	-0.590*** (-0.715,-0.464)	-0.580*** (-0.706,-0.454)	-0.678*** (-0.820,-0.537)	-0.919*** (-1.120,-0.719)
Income Q3	-0.970*** (-1.097,-0.843)	-0.970*** (-1.097,-0.843)	-1.056*** (-1.198,-0.914)	-1.318*** (-1.517,-1.120)
Income Q4	-0.976*** (-1.110,-0.841)	-0.994*** (-1.129,-0.859)	-1.147*** (-1.297,-0.996)	-1.665*** (-1.875,-1.454)
Education: high	-1.226*** (-1.383,-1.068)	-1.239*** (-1.399,-1.080)	-1.509*** (-1.691,-1.328)	-1.529*** (-1.712,-1.346)
Education: medium	-0.611*** (-0.767,-0.456)	-0.587*** (-0.743,-0.431)	-0.632*** (-0.809,-0.454)	-0.645*** (-0.824,-0.467)
% tertiary: high			1.232*** (1.103,1.361)	1.215*** (1.085,1.344)
Poverty: high			2.165*** (2.023,2.307)	2.177*** (2.035,2.319)
Unemployment rate			-0.361*** (-0.386,-0.336)	-0.367*** (-0.392,-0.342)
Urban		0.036 (-0.076,0.147)	-0.201*** (-0.334,-0.068)	-0.193*** (-0.327,-0.059)
High availability:Income Q2				0.473*** (0.191,0.754)
High availability:Income Q3				0.516*** (0.239,0.794)
High availability:Income Q4				1.031*** (0.748,1.315)
Constant	0.995*** (0.839,1.152)	1.147*** (0.980,1.313)	3.793*** (3.456,4.130)	4.135*** (3.774,4.497)
Observed (% childless)	34.1	34.1	34.1	34.1
Counterfactual (% childless)	32.5	31.9	29.5	29.5
Population level effect	-1.64	-2.25	-4.56	-4.56
Observations	10,632	10,632	10,632	10,632
Akaike Inf. Crit.	12,724.070	12,690.550	10,737.690	10,691.030

Note:

*p<0.1; **p<0.05; ***p<0.01

Table D.10: Logit-binomial regression of childlessness at age 45 on life-time partner market exposure measured by the availability ratio (near). The availability ratio is the average log availability ratio over the period between age 18 and conception or age 45. This table is displaying logit coefficients, which represent the average response in the log-odds of childlessness to a value change of 1. Note that men residing in Helsinki in this period were dropped from the analysis.

	<i>Dependent variable:</i>			
	Childless at age 45			
	(1)	(2)	(3)	(4)
Availability ratio	-2.991*** (-3.066,-2.915)	-3.213*** (-3.300,-3.125)	-5.137*** (-5.257,-5.017)	-5.633*** (-5.870,-5.396)
Cohort: 1972-1976		-0.389*** (-0.414,-0.364)	-0.291*** (-0.321,-0.261)	-0.289*** (-0.319,-0.259)
Income Q2		-0.481*** (-0.518,-0.444)	-0.642*** (-0.685,-0.599)	-0.639*** (-0.698,-0.579)
Income Q3		-0.695*** (-0.732,-0.659)	-0.791*** (-0.833,-0.748)	-0.851*** (-0.909,-0.792)
Income Q4		-0.661*** (-0.701,-0.622)	-0.879*** (-0.925,-0.833)	-1.085*** (-1.148,-1.023)
Activity: unemployed		0.190*** (0.186,0.194)	0.168*** (0.164,0.173)	0.168*** (0.163,0.173)
Education: medium		-0.086*** (-0.122,-0.051)	-0.251*** (-0.293,-0.209)	-0.261*** (-0.303,-0.219)
Education: high		-0.306*** (-0.348,-0.265)	-0.834*** (-0.883,-0.784)	-0.836*** (-0.886,-0.787)
% tertiary educated			1.259*** (1.224,1.294)	1.262*** (1.227,1.297)
Unemployment rate			-0.463*** (-0.472,-0.455)	-0.465*** (-0.473,-0.456)
Urban settlement			0.024 (-0.013,0.060)	0.027 (-0.009,0.064)
Inequality: high			1.667*** (1.628,1.705)	1.673*** (1.634,1.711)
Availability ratio:Income Q2				-0.096 (-0.396,0.204)
Availability ratio:Income Q3				0.399*** (0.118,0.681)
Availability ratio:Income Q4				1.450*** (1.160,1.740)
Constant	-0.294*** (-0.310,-0.279)	0.037 (-0.012,0.085)	4.154*** (4.050,4.258)	4.241*** (4.132,4.350)
Observations	146,658	146,658	146,658	146,658
Log Likelihood	-88,669.930	-78,288.460	-62,221.710	-62,142.920
Akaike Inf. Crit.	177,343.900	156,594.900	124,469.400	124,317.800

Note:

*p<0.1; **p<0.05; ***p<0.01

Table D.11: Cumulative logistic regression singlehood at age 45 on partner log ar (near) using.

	<i>Dependent variable:</i>			
	Single at age 45			
	(1)	(2)	(3)	(4)
log ar (near)	-0.633*** (-0.688,-0.577)	-0.543*** (-0.605,-0.481)	-0.946*** (-1.020,-0.873)	-1.445*** (-1.598,-1.293)
Cohort: 1972-1976		-0.103*** (-0.123,-0.083)	-0.059*** (-0.081,-0.038)	-0.056*** (-0.077,-0.035)
Income Q2		-0.667*** (-0.698,-0.637)	-0.672*** (-0.703,-0.641)	-0.769*** (-0.818,-0.721)
Income Q3		-0.915*** (-0.945,-0.885)	-0.904*** (-0.934,-0.874)	-1.088*** (-1.136,-1.040)
Income Q4		-1.123*** (-1.154,-1.091)	-1.152*** (-1.184,-1.120)	-1.215*** (-1.266,-1.165)
Duration unemployed		0.099*** (0.096,0.102)	0.095*** (0.092,0.099)	0.095*** (0.091,0.098)
Education: high		-0.609*** (-0.641,-0.576)	-0.678*** (-0.712,-0.644)	-0.673*** (-0.706,-0.639)
Education: medium		-0.334*** (-0.362,-0.305)	-0.349*** (-0.378,-0.321)	-0.344*** (-0.373,-0.316)
% tertiary: high			0.258*** (0.232,0.284)	0.263*** (0.238,0.289)
Unemployment rate			-0.070*** (-0.075,-0.066)	-0.071*** (-0.076,-0.066)
Urban			-0.357*** (-0.384,-0.329)	-0.355*** (-0.383,-0.327)
log ar (near):Income Q2				0.479*** (0.288,0.670)
log ar (near):Income Q3				0.880*** (0.702,1.057)
log ar (near):Income Q4				0.305*** (0.120,0.490)
Constant	-0.320*** (-0.334,-0.305)	0.599*** (0.558,0.640)	1.552*** (1.480,1.624)	1.652*** (1.575,1.729)
Natural course (% childless)	39.00	39.00	39.00	39.00
Counterfactual (% childless)	38.87	38.90	38.84	38.84
Population level effect	-0.12	-0.10	-0.15	-0.16
Observations	194,080	194,080	194,080	194,080
Akaike Inf. Crit.	259,075.900	237,861.200	235,554.900	235,450.300

Note:

*p<0.1; **p<0.05; ***p<0.01

Table D.12: Logit-binomial regression of childlessness at age 45 on life-time partner market exposure measured by the availability ratio (near). The availability ratio is the average log availability ratio over the period between age 25 and conception or age 45. This table is displaying logit coefficients, which represent the average response in the log-odds of childlessness to a value change of 1. Note that spells after the year 1995 were considered.

	<i>Dependent variable:</i>			
	Childless at age 45			
	(1)	(2)	(3)	(4)
Availability	0.585*** (0.539,0.630)	0.860*** (0.808,0.913)	-0.352*** (-0.433,-0.271)	-1.495*** (-1.643,-1.347)
Income Q2		-0.341*** (-0.374,-0.307)	-0.413*** (-0.449,-0.377)	-0.471*** (-0.510,-0.432)
Income Q3		-0.404*** (-0.438,-0.371)	-0.460*** (-0.496,-0.425)	-0.561*** (-0.600,-0.523)
Income Q4		-0.578*** (-0.612,-0.543)	-0.549*** (-0.586,-0.512)	-0.754*** (-0.794,-0.714)
Unemployed		0.358*** (0.352,0.364)	0.337*** (0.330,0.343)	0.332*** (0.326,0.339)
Education: high		0.076*** (0.041,0.112)	-0.326*** (-0.366,-0.286)	-0.333*** (-0.373,-0.293)
Education: medium		0.009 (-0.023,0.041)	-0.133*** (-0.168,-0.098)	-0.142*** (-0.177,-0.107)
Education: high			0.518*** (0.484,0.551)	0.528*** (0.494,0.561)
Unemployment rate			-0.339*** (-0.346,-0.333)	-0.342*** (-0.348,-0.335)
Urban settlement			-0.442*** (-0.474,-0.410)	-0.434*** (-0.466,-0.401)
Inequality: high			1.331*** (1.301,1.360)	1.333*** (1.303,1.363)
Availability ratio:Income Q2				0.594*** (0.415,0.774)
Availability ratio:Income Q3				1.111*** (0.940,1.283)
Availability ratio:Income Q4				2.084*** (1.914,2.254)
Constant	-0.703*** (-0.713,-0.693)	-0.834*** (-0.871,-0.797)	2.216*** (2.138,2.293)	2.341*** (2.262,2.421)
Observations	184,125	184,125	184,125	184,125
Log Likelihood	-117,731.500	-102,048.900	-90,937.930	-90,595.850
Akaike Inf. Crit.	235,467.100	204,113.800	181,899.900	181,221.700

Note:

*p<0.1; **p<0.05; ***p<0.01

Table D.13: Summary of population level effects across statistical models, variable specifications of the effect and measurements of the partner market

	Model	specification	AR	AR (near)	PR	PR (near)	SR	SR (near)
1	Discrete-time survival Model	linear	-0.298	-0.189	-0.250	-0.218	0.007	0.277
2	Discrete-time survival Model	interactive	-0.280	-0.189	-0.254	-0.220	0.022	0.290
3	Sibling FE	linear	-0.194	-0.914	-1.227	-0.679	-2.980	-3.953
4	Sibling FE	interactive	-0.185	-0.748	-1.323	-0.771	-2.984	-3.983
5	Cumulative logistic	linear	-0.212	-0.587	-0.973	-0.045	-1.617	-1.213
6	Cumulative logistic	interactive	-0.212	-0.585	-0.983	-0.062	-1.612	-1.189
7	Matching	linear	-25.604	-4.560	-1.087	0.045	-2.842	-3.200
8	Matching	interactive	-25.604	-4.560	-1.087	0.045	-2.842	-3.200

D.9 Partner market distances

We perform the spatial proximity approach using different distances in order to evaluate the impact of spatial boundaries on the results, see Table D.15. We selected a distance of zero kilometer, 9.2 kilometers (main model), and 20 kilometers in our estimations. The zero kilometer specification is equal to the neighbouring municipality approach.

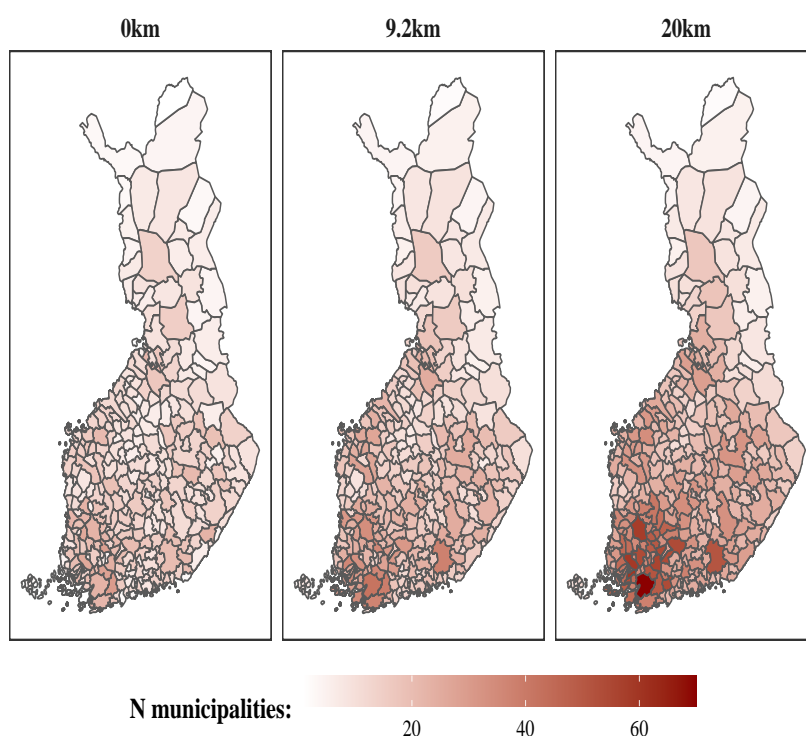


Figure D.12: The number of municipalities included based on the distance measure chosen. The larger the distance measure is, the more neighbouring municipalities are included. The changes mostly affect the smaller units in the South of the country

The impact of the different distances on the sizes of the units measured in number of municipalities is limited. Overall, the larger the chosen distance, the larger the partner markets are, Figure D.12. The choice of distance has a stronger effect in the south of Finland, where municipalities are smaller and closer, while the spatial distances between municipalities in the north are larger. Given that we include different municipalities based on the chosen distance, we can compare

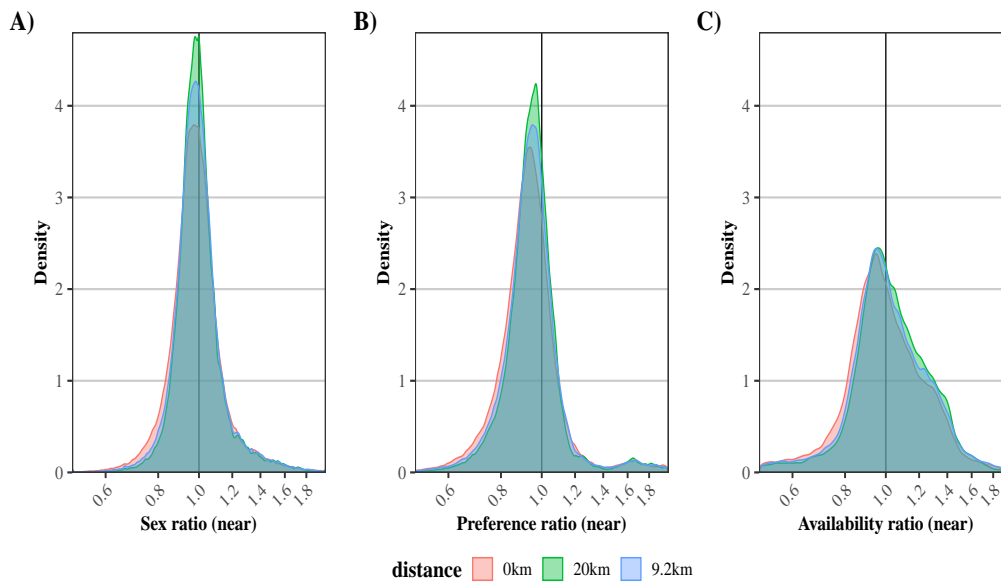


Figure D.13: The impact of the distance measure on the distribution of the availability indicators in the sample. The larger the distance, the more the measure concentrates around balance, which may indicate measurement error.

the results based on the number of included municipalities. The mean number of included municipalities is 12.4 in the zero km approach, it increases to 19.9 in the 9.2 kilometers approach (main approach), and it increases further to 29.1 in the 20 kilometres approach. However, the distribution of the availability indicators is only marginally affected by the distance, see Table D.13.

Table D.14: Summary of the impact of the chosen distance for the spatial proximity approach on the number of municipalities aggregated to one partner market

Distance	mean	min	max
0 km	12.4	1	30
9.2 km	19.9	1	42
20 km	29.1	2	70

Table D.15: Cumulative logistic regression on childlessness using different spatial distances for the estimation of the partner market indicator variable.

	<i>Dependent variable:</i>		
	Childless at age 45		
	(1)	(2)	(3)
log ar (0km)	-2.354*** (-2.439,-2.270)		
log ar (9.2km)		-5.058*** (-5.162,-4.955)	
log ar (20km)			-5.835*** (-5.950,-5.720)
Cohort: 1972-1976	-0.074*** (-0.099,-0.049)	-0.164*** (-0.189,-0.138)	-0.192*** (-0.217,-0.166)
Income Q2	-0.563*** (-0.600,-0.526)	-0.618*** (-0.656,-0.580)	-0.625*** (-0.663,-0.587)
Income Q3	-0.745*** (-0.781,-0.708)	-0.783*** (-0.820,-0.745)	-0.776*** (-0.813,-0.739)
Income Q4	-0.820*** (-0.858,-0.782)	-0.870*** (-0.909,-0.832)	-0.866*** (-0.905,-0.827)
Duration unemployed	0.189*** (0.185,0.193)	0.175*** (0.171,0.179)	0.175*** (0.171,0.179)
Education: high	-0.392*** (-0.432,-0.351)	-0.667*** (-0.709,-0.625)	-0.778*** (-0.821,-0.736)
Education: medium	-0.115*** (-0.151,-0.080)	-0.193*** (-0.230,-0.156)	-0.222*** (-0.260,-0.184)
% tertiary	0.871*** (0.841,0.901)	1.242*** (1.210,1.275)	1.260*** (1.228,1.293)
Unemployment rate	-0.530*** (-0.538,-0.522)	-0.531*** (-0.539,-0.523)	-0.545*** (-0.553,-0.536)
Urban	-0.264*** (-0.297,-0.230)	0.106*** (0.072,0.141)	-0.017 (-0.052,0.017)
Poverty: high	1.710*** (1.677,1.744)	1.542*** (1.508,1.576)	1.428*** (1.394,1.462)
Constant	4.249*** (4.153,4.346)	4.845*** (4.747,4.943)	5.290*** (5.188,5.392)
Natural course (% childless)	32.60	32.60	32.60
Counterfactual (% childless)	31.75	32.02	32.01
Population level effect	-0.85	-0.58	-0.59
Observations	194,080	194,080	194,080
Log Likelihood	-88,679.510	-85,200.000	-84,742.480
Akaike Inf. Crit.	177,385.000	170,426.000	169,511.000

Note:

*p<0.1; **p<0.05; ***p<0.01

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