Same but different?

Male-female fertility differences at the subnational level over time and across countries

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Abstract

This study investigates subnational variations in male-female fertility differences across Australia, Finland, France, Mexico, and the United States[1], utilizing longitudinal register data. Findings reveal substantial subnational heterogeneity in fertility differences. Historically, male fertility exceeded female fertility by nearly 50%, particularly in less developed regions. However, over time, these disparities have dwindled, particularly in regions experiencing higher levels of development. Capital regions, often more developed, exhibit reduced fertility gaps, with recent years even seeing higher female fertility. The study attributes the reduction in differences to advancements in human development and, to a lesser extent, gender equality, impacting population structures and age-specific fertility patterns. This research underscores the importance of considering regional and developmental nuances when analyzing gender-based fertility disparities.

[1]In future iterations of the study the list of countries may be extended. I am in touch with owners of register data from Spain, Germany and Norway.

1 Introduction

Fertility indicators are widely reported and discussed. They are used to assess the reproductive behaviour of a population and to plan for future population change. These fertility indicators are mostly reported for women, which ignores the male contribution, that can be very different (Dudel and Klüsener, 2021; Schoumaker, 2019). The data quality of male fertility information has been one explanation for the lack of studies on male fertility (Joyner et al., 2012). In recent years, however, there has been an increase in the number of studies on the fertility differences between men and women (Bratsberg et al., 2021; Dudel and Klüsener, 2016, 2019; Dudel et al., 2021; Schoumaker, 2019; Zhang, 2011). This may be the result of methodological innovations (Dudel and Klüsener, 2019; Schoumaker, 2017) that have addressed inconsistencies in male fertility data and also new data sources on male fertility (Dudel and Klüsener, 2021).

Existing studies on male and female fertility show strong differences in quantum and timing (Dudel and Klüsener, 2021; Dudel et al., 2023; Schoumaker, 2019). Schoumaker (2019) shows that the differences in the TFR can be explained by sex differences in mortality and fertility timing, which are long-term trends, while Dudel and Klüsener (2021) shows short-term fluctuations driven by cohort size. Sex differences in fertility timing are more stable than those for fertility quantum (Kolk, 2015), but are found to diminish with increasing gender equality (Dudel et al., 2020; Presser, 1975). However, the aforementioned studies look at national-level indicators, which, on the one hand, may mask substantial heterogeneity, and on the other hand, fail to capture the drivers behind these differences. For instance, there is evidence that subnational sex ratios at reproductive ages are further from equilibrium than national estimates (Gulczynski, 2023), which may lead to marked differences in fertility rates. The only study on subnational sex differences in fertility to our knowledge is by Dudel and Klüsener (2016), comparing male and female TFR in East and West Germany, who reported the lowest total fertility rate ever reported. For men in East Germany in 1994 the TFR was at 0.74 ($TFR_{men}(1994) = 0.74$ $[CI : 0.72 - 0.78]$).

This study assesses differences in male and female fertility measures at the subnational level over time and across countries, using high-quality register data from Australia, Finland, Germany, France and the United States. Both fertility timing (age-specific fertility rates and mean age at childbearing) and quantum (TFR) are examined in detail. A particular aim is to describe differences in the measures, quantify their magnitude and identify trends and patterns. Furthermore, the study goes beyond describing the differences by using decomposition techniques and regression models to explain the differences and how they have evolved over time.

There may be several reasons for differences in fertility indicators. One explanation pertains to population imbalances with regard to sex, resulting from the sex ratio at birth, sex-selective migration and sex differences in mortality. Furthermore, behavioural explanations can be found in different age-related fertility patterns. Moreover, the interaction of population structure and fertility timing may produce large differences in fertility rates to the extent that births to smaller cohorts may have a greater impact on summary measures of fertility. Finally, one potential source of sex differences not to be forgotten is measurement error.

For the discussion of fertility in general, it is crucial to examine male-female fertility differences at the subnational level. First, sex differences in fertility may be larger at the subnational level than at the national level. As a result of sex-selective subnational migration (Gulczynski, 2023) and subnational variation in sex differences in mortality (Sauerberg et al., 2023) and fertility behaviour (See for the United States Porter and Purser, 2008; Scherbov and Gietel-Basten, 2020), there is considerable heterogeneity in population sex ratios (Gulczynski, 2023). Moreover, within-country research designs are promising because they are robust to some common sources of error in cross-country research. Empirical studies at the country level can be biased by unobserved heterogeneity due to cultural and institutional differences. These are difficult to control for. Moreover, cultural differences tend to be less pronounced and institutional arrangements vary less within than between countries. Therefore, a subnational design may provide new insights. Finally, comparing subnational trends and levels in fertility across countries allows to assess the impact of geographic regions, human development and welfare states. The selection of countries in this study represents three continents (Australia, Europe, Northern America), middle and high income countries (for example Mexico and the United States), three welfare states (social-democratic, liberal and conservative). Thus, the cross-country subnational design may reveal the impact of the context on fertility.

2 Background

2.1 Sex-differences in fertility quantum

The average number of children born to women can differ considerably from that of men. There is evidence that the number of children for women can be higher than the number of children for men and vice versa. These differences can be explained by three main demographic factors : 1) differences in the size of the male and female population; 2) sex differences in the timing of fertility; 3) and the interaction of population and age differences (Dudel and Klüsener, 2021; Schoumaker, 2019).

First, differences in the size of the population affect male-female fertility differences through two pathways. On one side, the impact is direct in the sense that population imbalances affect the size of the exposures, which form the denominator of birth rates. Thus, an excess (lack) of men lead to higher (lower) exposures compared to women, while the number of births are exactly the same. This difference in exposures reduces (increases) the male fertility rate compared to the female counterpart. On the other hand, population structures may impact the sex differences in fertility quantum indirectly through partner market processes, as the abundant sex has emphasized competition which may lead to changing fertility timing and childlessness. Studies have demonstrated the impact of partner markets on other fertility outcomes, for example on childlessness (Kravdal, 2021; Schubert, 2023).

Sex differences in the size of the male and female population are the result of past demographic trends. Births, mortality and migration determine ultimately the structure of a population, and sex imbalances are the result of sex differences in these population processes (chapter 1 in Gulczynski, 2023; Preston et al., 2008). Sex differences in births are measured by the sex ratio at birth (SRB), which is affected by biological and behavioural factors. In the absence of intervention, the sex ratio is around 105 male births per 100 female births, with some variation. This indicates an excess of males. However, sex-selective abortions, often resulting from culturally embedded gender preferences, can lead to large deviations. The highest country-level SRB was 117 in China for the year 2004/2005, but such deviations from 105 were not reported for the countries studied (Hesketh, 2009). Mortality affects the population structure by reducing the population size. Across countries and subnational units, the excess mortality of men is a strong empirical pattern (Sauerberg et al., 2023). Much of the sex difference in mortality is attributed to behavioural factors (Rogers et al., 2010), although, a sex gap in mortality may remain after controlling for all behavioural predictors (Luy, 2003; Luy et al., 2015).

Second, sex differences in fertility timing have an impact on male-female fertility differences. From a stable population perspective, cohorts shrink due to mortality as they age. Therefore, if one sex is having children later in life, there remain fewer exposures, which increases the fertility rate. Hence, sex differences in fertility timing translate to sex differences in fertility quantum.

Third, the interplay between cohort size and fertility timing (Akers, 1967; Schoen, 1977, 1985, referred to marriage and birth squeezes), understood as the number of births in subsequent years, is another explanation for sex differences in fertility. In the presence of fixed or robust age preferences for partners, a mismatch between subsequent cohorts has a profound impact on fertility (Akers, 1967; Eckhard and Stauder, 2019; Kravdal, 2021; Schoen, 1985). For example, men tend to mate with younger women. Therefore, declining cohort sizes reduce the pool of suitable partners for men. In recent years, birth squeezes have been observed in the USA (Dudel and Klüsener, 2021), East Germany (Dudel and Klüsener, 2016; Klein, 2003) and Norway (Kravdal, 2021), where declining cohort sizes have led to lower male fertility.

There may be strong subnational variations in the factors mentioned above that influence gender differences in fertility. Gulczynski (2023) has shown that the size of the female and male population at reproductive age differs significantly. The study showed that the gender differences at the subnational level exceed those at the national level. Sex-selective subnational migration was found to be the main driver. Because subnational migration is not even considered in national-level research, a subnational perspective is important. Beyond migration, sex differences in mortality also vary considerably at the regional level, although recent years have seen a narrowing of the sex gap in mortality (Sauerberg et al., 2023).

Furthermore, age differences and differences in cohort size may also produce subnational variation in sex differences in fertility. Gender inequalities and differences in development often underlie differences in the age pattern of fertility between men and women (Presser, 1975; Schoumaker, 2019). Within countries there is considerable variation in human and economic development (Scherbov and Gietel-Basten, 2020). The timing of fertility between the sexes may therefore also differ, which may have profound implications for sex differences in fertility quantum.

2.2 Sex-differences in fertility timing

Fathers are on average older than mothers in humans. This shows remarkable empirical robustness across time and space (Dudel and Klüsener, 2021; Kenrick and Keefe, 1992; Kolk, 2015; Schoumaker, 2017). The average difference in age between mothers and fathers is found to be around 3 years. Both evolutionary and social explanations were put forward.

Evolutionary arguments refer to different reproductive roles and strategies (Buss and Schmitt, 1993; Fieder and Huber, 2007; Kenrick and Keefe, 1992; Sear, 2015), assuming that both men and women develop strategies to maximize reproduction and survival. Women are assumed to select a childbearing partner that is able to provide for children, which is related to career progression and maturity, that are functions of age. Thus, women are inclined to select an older mate for reproduction. In contrast, men maximize reproductive output by selecting a younger partner, because female fecundity declines with age.

Social explanations for gender differences in fertility timing relate to the cultural and institutional roles of men and women. They are therefore gender-related. Men start reproducing significantly later than women (Schoumaker, 2019). This is linked to the establishment of a career as an economic provider, which is important for reducing economic insecurity for the family and also for fulfilling the household breadwinner role. Furthermore, as women were historically excluded from upward mobility through education and employment (Presser, 1975), partnering became a means of securing social status. Living conditions were therefore improved by selecting an older and more established partner. Moreover, as argued by Oppenheimer (1988), a crucial difference between the sexes in mate choice is the decline in value due to ageing for women. This may force women into a conflict between maximising information about the mate and their own value. Thus, women have a stronger incentive to have a partner earlier in the life course.

The evolutionary and the gender framework of fertility timing lead to different expectations regarding sex differences in fertility timing at the subnational level. The evolutionary framework suggests that sex differences in fertility timing across regions should be limited, because the timing differentials are hard-wired by evolution. However, some variation may result from geographic variation in economic stability, welfare support and mortality reductions, which may relax evolutionary pressures. In contrast, the gender framework suggests that sex differences in fertiltiy timing are related to social roles in the society, which allows more heterogeneity. Thus, increasing career involvement of women and growing gender equality in institutional and personal spheres may reduce sex differences.

2.3 Trends in male-female differences

Male fertility follows female fertility usually very closely (Dudel and Klüsener, 2021). However, there are differences between the sexes. Differences between male and female fertility range from a ratio of 0.84 (reported for East Germany in 1997, see Dudel and Klüsener, 2016) to 2.1 (reported for Senegal in 2011, see Schoumaker, 2019). In general, higher values are reported for countries in sub-Saharan Africa, while lower values are reported for high-income countries in the West. This relationship is the result of the demographic transition and progress in human development: The gender gap in fertility timing is narrowing as a result of progress in gender equality, and the gender gap in mortality is narrowing as a result of improved access to health care and a decline in lifestyle-related deaths. However, the relationship is less clear and even fluctuating, once the demographic transition is completed and the country has reached a certain level of development (Dudel and Klüsener, 2021). Period fluctuations appear to account for the volatility of the fertility gap between men and women at high levels, as the pattern is linearly declining for cohort fertility rates (ebd.). Furthermore, the elimination of age differences in childbearing by the means of counterfactual simulations reduces the volatility, pointing to gender differences in timing as a driving factor behind the period fertility differences (ebd.).

Regarding differences in timing, men tend to have children later in life on average (Carmichael, 2013; Dudel and Klüsener, 2021; Schoumaker, 2019). The sex difference in fertility timing seems to narrow with increasing economic development (Schoumaker, 2019). However, at high levels of development, the age gap persists, the negative association between development and age gap disappears and age differences barely fluctuate over time (Dudel and Klüsener, 2021; Kolk, 2015). Overall, declining sex gaps in fertility timing are the result of different speeds of fertility postponement, which is emphasized for women, because of the rapid increase in women's educational and economic participation (Mills et al., 2011). Thus, the closing of the age gap is an indication of a stronger postponement of childbearing by women than by men following progress in gender equality. However, cross-country comparisons show that the age gap may not only be related to gender equality. Japan has the smallest age gap, while it is not particularly advanced in terms of gender equality among high-income countries (Dudel and Klüsener, 2021).

2.4 Research aims

The analysis has three main objectives. First, assess the size of male-female differences in fertility indicators at the subnational level. Sex differences in fertility can pertain to differences in quantum and tempo. Second, how does the size and the variation of subnational sex differences in fertility vary over time and across countries. Finally, does human development or gender equality affect the narrowing sex gap in fertility.

3 Data and methods

3.1 Data

Data quality has been a major obstacle to estimating male fertility, as discussed in the introduction. By relying on vital statistics data for births, we overcome the problem of data quality. There are several reasons why these data provide high quality information. First, the information is based on birth certificates, which are both mandatory and official documents. Due to legal enforcement, the combination of official and mandatory minimises case and item non-response. Second, birth certificates are issued shortly after birth, which reduces the risk of measurement error due to recall bias. It also minimises the risk of missing information on the father, as it is unlikely that the father has left the country. Therefore, official vital statistics ensure the completeness and accuracy of the information.

Table 1 summarizes the data sources used in the study. We obtain vital statistics for Australia, Finland, France, Mexico, and the United States. It should be noted that the time series length differs across countries. Moreover, the size of the spatial units vary across countries. For Finland, we can estimate fertiltiy indicators for small spatial units (*fin.* Seutukunta), while Australia and the United States provide only data at the state-level. The information for maternal age was complete in all countries, while missing age of father makes up 1-10 % of the cases. The missing information was imputed following Dudel and Klüsener (2019). Exposures for the estimation of rates are the two-year average of population counts for the age, sex, region group (Wachter, 2014).

Country	Period	Level	N	Source
Australia	1990-2020	States, Territories	10	`explore.data.abs.gov.au`
Finland	1990-2020	Seutukunta	107	`https://www.stat.fi/`
France	1989-2013	Departments	81	`insee.fr/fr/statistiques`
Mexico	1990-2020	Regions	22	`inegi.org.mx/programas/natalidad`
USA	1990-2004	States	51	`https://data.nber.org/natality/`

Table 1: 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.

4 Methods

This study analyses sex differences in fertility quantity and timing. The former is assessed through the estimation of subnational total fertility rates (TFRs). The total fertility rate (TFR) is a widely used demographic measure of the average number of children that a person would conceive under the fertility regime of a given year (period), if the person survives the reproductive period (Preston et al., 2008). The measure therefore takes account of the age structure. The total fertility rate is defined as the sum of age specific fertility rates: $TFR = \sum_{x=12}^{55} \frac{births(x)}{exposure(x)}$. Sex differences in the measure are quantified by the estimation of the **TFR ratio** between men and women ($TFR - ratio = \left(\frac{TFR_{male}}{TFR_{female}}\right)$).

Moreover, **decomposition** is used to investigate sex differences in the total fertility rate. The difference of the male and female total fertility rate can be decomposed into two components: *population structure* and *birth rates*. In order to be able to decompose the TFR differences, we rearrange the TFR equation:

$$TFR = \sum_{x=1}^{55} \sum_{i=1}^{p} \underbrace{f_i(x)}_{Birthrates} \times \underbrace{weight_i}_{Populationstructure} \tag{1}$$

The equation above can be used to decompose the difference in the TFR into the rate component stemming from a difference in $f_i(x)$ and a structural component $weight_i$. We apply the approach developed by Horiuchi et al. (2008).

Furthermore, the timing of fertility may be different for men and women, as discussed in section 2.2. We estimate the difference in mean age at childbearing between men and women $\Delta timing = mac_{male} - mac_{female}$, and mac indicates the mean age at childbearing. This is a summary indicator of overall timing, where higher values indicate later childbearing among men compared to women.

As outlined in section 2.3, with progresses in development and gender equality, sex differences in fertility are expected to diminish and to disappear. To test this hypothesis, we use simple ordinary least squares regression and fixed effects regression models to estimate the relationship between the fertility indicators and gender and development indicators. Human development is measured by the Human Development Index (HDI). The HDI is one of the main measures of development cited in the literature. The subnational HDI is calculated in the same way as the national HDI and it consists of three dimensions: living standards, knowledge and long and healthy lives. Standard of living is measured by gross domestic income (GDI) per capita, adjusted for inflation; knowledge is assessed by expected years of schooling and average years of schooling; and long and healthy life is measured by life expectancy. Gender inequality is quantified by the Gender Development Index (GDI) (Smits and Permanyer, 2019). The Gender Development Index captures the differences between men and women in the three dimensions of the Human Development Index.

5 Results

5.1 Descriptive results

When comparing the subnational TFR for men and women, we see substantial differences. The male TFR exceed the TFR for women in most regions, as the results in the left panel of Figure 1 indicate. Points that land above the diagonal line indicate higher male TFR compared to female TFR. Notwithstanding, there exist regions with higher female TFRs, as some points land below the diagonal line, which are usually economic centers or capital regions. For instance, the male-to-female TFR ratio in the District of Columbia in 2004 was 1.06, in Helsinki in 2018 was 0.89, and in the city of Mexico in 2020 was 0.98. Moreover, the sex differences in timing are smaller at lower fertility levels. This pattern is very similar to the finding reported by Schoumaker (2019).

There are robust sex differences in fertility timing, as the right panel in Figure 1 shows. All points fall underneath the diagonal line, which shows that the average paternal age is higher than the average maternal age in all regions. Moreover, the country differences in the sex gaps in the mean age of childbearing seem to be larger than the subnational variation, as the countries form isolated clusters. The United States show the smallest sex differences in fertiltiy timing, and Mexico shows the largest ones, while France and Australia lie somehow in between. Moreover, the sex differences remained relatively stable over the observation period, as the countries form lines that parallel the diagonal. Hence, we do not see a trend of conversion in fertility timing.

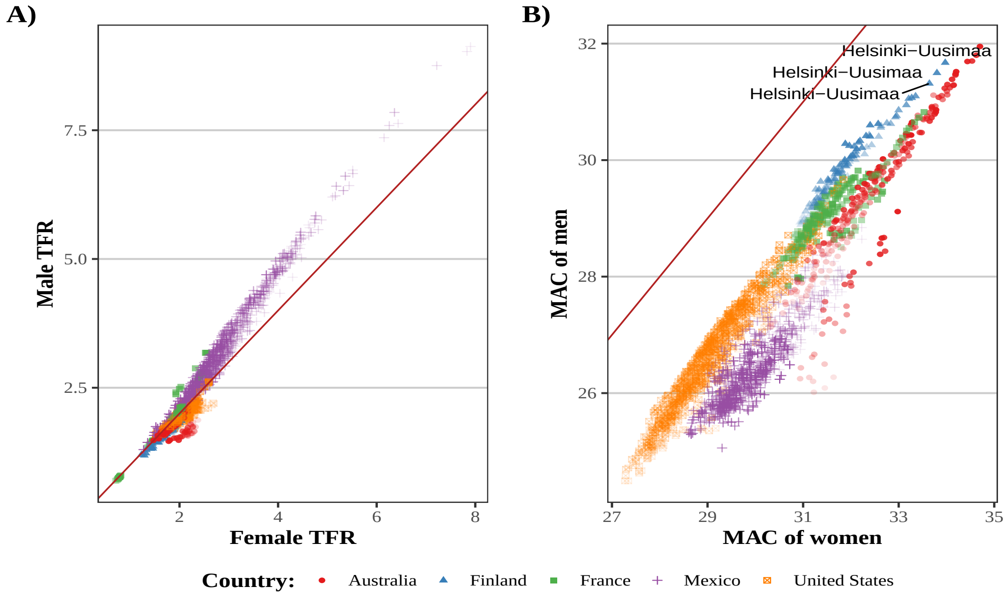

Figure 1: Sex differences in fertility quantum and timing. Panel A) shows the relationship between the female TFR displayed on the x-axis and the corresponding value for the male TFR in the same region in the same year. The lower the overall fertility level the smaller the sex difference. Panel B) shows the relationship between the mean age of childbearing for women displayed on the x-axis and the corresponding value for men in the same region in the same year. The sex difference in the mean age of childbearing does not show much variation across regions.

5.2 Trends in level and variation

The male-female TFR ratios have declined over time which indicates a vanishing of the sex differences, across most regions in almost all countries, as can be seen in Table 2. However, the trend for Australia and France is reversed, both the median as well as the minimal and maximal values have increased over time. Thus, in Australia seems to exhibit a reversed trend. Moreover, some states in Mexico showed increases in the male-female TFR ratios in the period between 2000 and 2010 as can be seen in Figure A.3. Two of these states have been strongly affected by the war on drugs in terms of mortality peaks (Aburto et al., 2016) This points at the relevance of the exposures for the TFR and sex differences in fertility timing.

Regarding the subnational variation, which we measured by the value range, we see a tendency towards less variation in sex differences. Thus, regions not just have diminishing male-female fertility differences, the process is accelerated for regions with larger differences. The closing gap becomes visible in the second last column in Table 2.

		Median male-female TFR ratio		Range male-female TFR ratio	
Country	Year	Value	Δ	Value	Δ
United States	1990	1.101	-0.254	min = 0.846, max = 1.18	min = 0.058, max = -0.12
United States	2004	0.973	-0.254	min = 0.903, max = 1.06	min = 0.058, max = -0.12
Mexico	1990	1.17	-0.12	min = 1.06, max = 1.25	min = -0.08, max = -0.11
Mexico	2021	1.05	-0.12	min = 0.98, max = 1.14	min = -0.08, max = -0.11
Australia	1990	0.950	0.016	min = 0.801, max = 0.984	min = 0.021, max = 0.17
Australia	2020	0.966	0.016	min = 0.822, max = 1.01	min = 0.021, max = 0.17
Finland	1987	0.995	-0.023	min = 0.935, max = 1.06	min = -0.039, max = -0.02
Finland	2018	0.972	-0.023	min = 0.839, max = 1.04	min = -0.039, max = -0.02
France	1989	0.981	0.015	min = 0.951, max = 1.04	min = 0.005, max = 0.215
France	2013	0.996	0.015	min = 0.956, max = 1.26	min = 0.005, max = 0.215

Table 2: This table compares summary measures (mean as well as the range) of the male TFR to female TFR ratio within and across countries. Change over time for Australia, the United States, Mexico and Finland. The first row for each country marks the oldest observation in the data. The second row marks the most recent observation. The median and range indicate the corresponding summary statistics for the male-female TFR ratio in that specific year for the country. The Δ columns indicate a corresponding change over time in the values. A negative value indicate a decline, thus that the male TFR declined relatively to the female TFR.

5.3 Decomposition

The decomposition results for two example regions with particular high and low sex differences in fertility quantum in the US are shown in Figure 2 pointing at a strong contribution from birth rate differences, shown in red, and a weaker effect from population imbalances, shown in blue. In addition, the impact is found to be age dependent, which is evident through the peak in the 20s, which shows that both men were more plentiful and women had children earlier, as the peak is made up of blue and red bars. However, somewhere between the ages of 25 and 35, the contribution of births and exposure turns negative, although not in the case of Alaska because of the military base. The same results hold for the decomposition of sex differences in fertility quantum in Helsinki in Figure A.4. The conclusion is that subnational sex differences are the result of contributions from population imbalances, sex differences in fertility timing and their interaction.

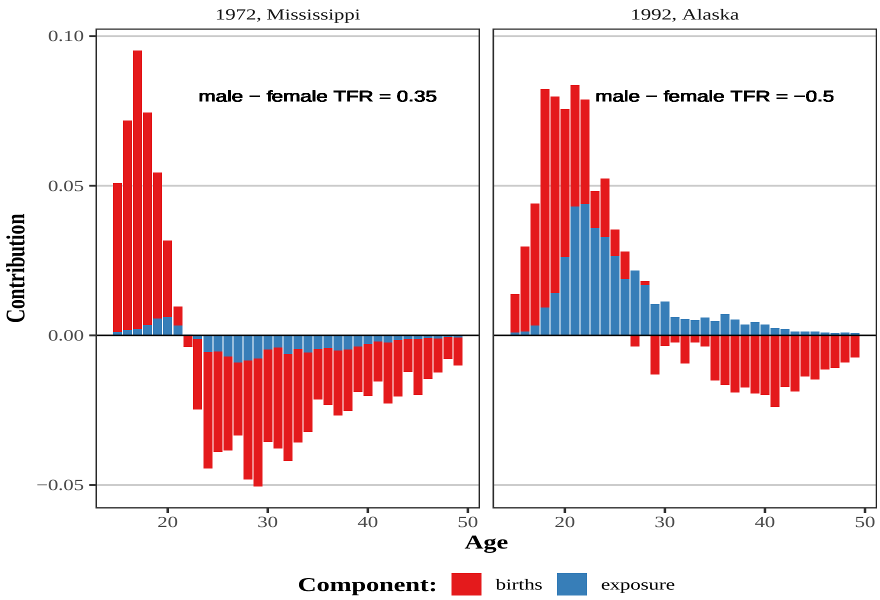

Figure 2: This graph presents the results from the Horiushi decomposition (Horiuchi et al., 2008) of the sex difference in TFR in two US states that showed smallest and largest sex gap. Mississippi in 1972 had a TFR for men that was 0.38 points higher than the corresponding value for women. In Alaska in 1992 was the male TFR by 0.5 smaller than the female TFR. The figure shows the contribution to the difference by age-group (x-axis), birth count (red bars) and exposure (blue bars).

5.4 Regression results

The TFR for men declines stronger than the TFR for women with increasing development, as Panel A) of Figure 3 shows the strong relationship between the Human Development Index and the male-to-female TFR-ratio. This shows that development is associated with the sex differences in fertilit quantum. Measured by the ratio of male to female TFR, the higher the level of development, the lower the sex difference in fertility quantum. The strength of the relationship can be inferred from the results of the ordinary regression model. These are shown in table 3 in the left column. The human development index, indicated by R^2, explains about 81 % of the variation in the male-female TFR ratio. Although macro-level relationships are generally stronger, this is a high value in sociological research. The coefficient gives an indication of the slope of the relationship. Given the assumption of a linear relationship, a 0.1 point increase in the Human Development Index is associated with a 0.098 decrease in the TFR ratio between men and women. This is a strong negative association, given that the observed values range between 0.9 and 1.3.

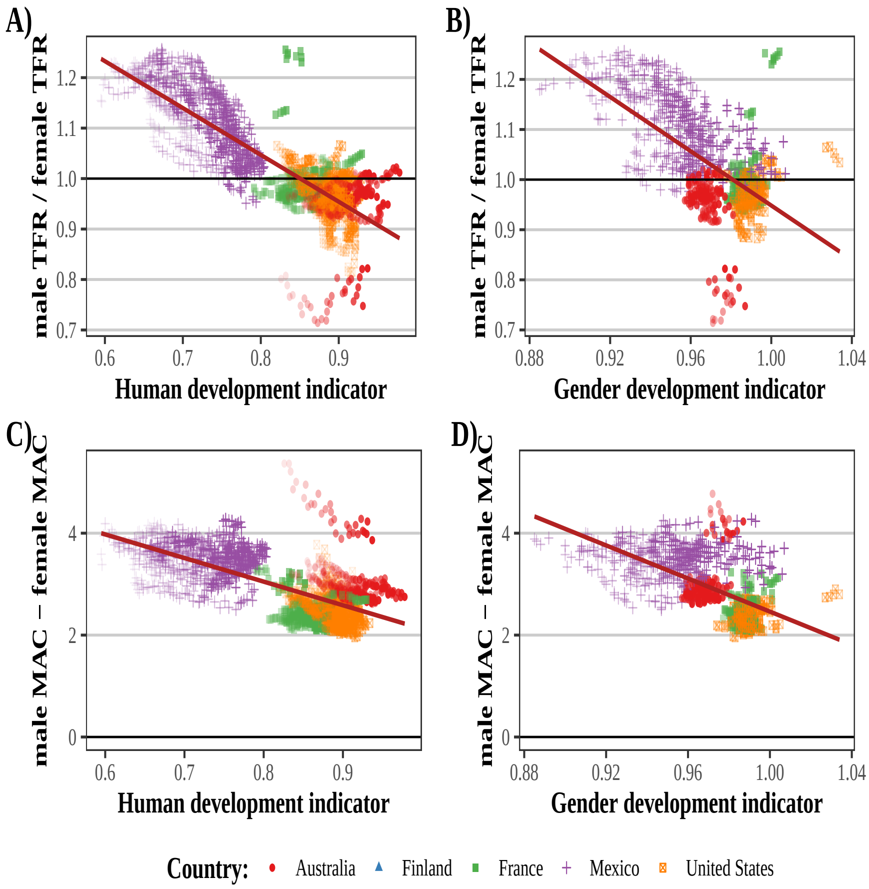

Figure 3: Relationship between human and gender development to sex differences in fertility timing and quantum.

In contrast, the association between the Human Development Index and the sex difference in fertility timing is much weaker. While the negative relationship is evident, the strength of the relationship we estimated using an ordinary regression model is much weaker (Table 3 right column). Only about 47 % of the variation in the sex difference between in the mean age at childbearing is explained by the Human Development Index. This is indicated by the R^2. Assuming a linear relationship, a 0.1 point increase in the Human Development Index reduces the male-female difference in the mean age at which children are born by about 0.463 years. Thus, the sex difference in the timing of childbearing are smaller in more developed regions.

Table 3: Ordinary least squares regression model of fertility quantum and timing on human development index.

	Dependent variable:	
	Δ Quantum	Δ Timing
	(1)	(2)
HDI	−0.928***	−4.635***
	(−0.955, −0.902)	(−4.854, −4.415)
Intercept	1.790***	6.757***
	(1.767, 1.812)	(6.575, 6.939)
Observations	1,919	1,919
R^2	0.707	0.472
Adjusted R^2	0.707	0.471
Note:		*p<0.1; **p<0.05; ***p<0.01

The relationship between male-female fertility differences and gender inequality seems to be weaker than the relationship with development, which becomes apparent from the left-to-right panel comparison in Figure 3. The results from the regression reinforce the interpretation, as can be seen by the R^2 of 0.38 in Table B.1.

Moreover, we have estimated country Fixed Effects models (FE) to remove country idiosyncracieis. We included HDI and GDI at the same time as predictor variables, because they may confound each other. The results are displayed in Table 4. Interestingly, the effects on fertility quantum remain of the same size and remain significant when accounting for the other development variable (model 1) and including country Fixed Effects (model 2), supporting our interpretation of a decline in sex differences. The inclusion of HDI does not change the impact of gender development on the sex differences in fertility timing (model 3). However, the effect of HDI and GDI on sex differences in timing changes the direction in the country FE model. The coefficient of GDI is positive when controlling for country idiosyncrasies and level of development in the region. This points at country idiosyncrasies that may drive the relationship between sex differences in fertility timing and gender equality.

6 Discussion and conclusion

In this paper, we examined sex differences in fertility quantum and tempo at the subnational level over time and across countries. The results of this paper uncovered substantial differences between male and female fertility. The differences in fertility quantum at the

Table 4: Ordinary least squares regression and country fixed effects model of the ratio of the male to female TFR and the difference in mean age of childbreaing on the Human Development Index (HDI) and Gender development Index (GDI).

	Dependent variable:			
	Δ Quantum		Δ Timing	
	(1)	(2)	(3)	(4)
hdi	−0.833***	−0.614***	−3.373***	−2.135***
	(−0.889, −0.777)	(−0.722, −0.507)	(−3.818, −2.927)	(−2.751, −1.519)
gdi	−0.637***	−1.054***	−9.302***	4.176***
	(−0.834, −0.440)	(−1.300, −0.809)	(−10.868, −7.736)	(2.770, 5.582)
Constant	2.336***		14.733***	
	(2.175, 2.497)		(13.453, 16.013)	
Country FE	No	Yes	No	Yes
Observations	1,144	1,144	1,144	1,144
R^2	0.678	0.226	0.525	0.048
Adjusted R^2	0.678	0.224	0.524	0.046
Note:				*p<0.1; **p<0.05; ***p<0.01

subnational level exceed the national-level result, while subnational sex differences in fertility timing are clustered within countries, which may point at other contextual factors. The decomposition results showed that the sex gap in the TFR is mostly explained by the contribution of rates, and less so by sex differences in the population structure. Regression results showed a particular strong relationship between the Human Development Index (HDI) and a weaker relationship with the Gender Development Index (GDI). Regardless, both development and gender equality relate to sex differences in fertility.

Our subnational results are in line with those from cross-country comparisons of Schoumaker (2019) and Dudel and Klüsener (2021) on the fertility differences between men and women. We find the same time trend towards narrowing fertility differentials or reversals in all countries except for Australia and France. The decline is more pronounced in more developed regions. Our regression results lend support to the interpretation by Schoumaker (2019) that sex differences disappear as development progresses. Dudel and Klüsener (2021) postulated a relationship between gender equality and gender differences, but this proved to be much weaker. Moreover, the sign of the coefficient of gender development changes in the country Fixed Effects model, which may suggest that the association is driven by country idiosyncrasies. This aligns with the country clusters of male-female differences in fertility timing uncovered in Figure 1. Yet, development and gender equality are co-linear, so that any conclusion should be cautious. In addition, population structure seems to have significant impact on sex differences in fertility quantum at high levels of development, supporting the findings of Dudel and Klüsener (2021). New insights are the previously unknown heterogeneity that was uncovered by the subnational and longitudinal design of the present study. In line with Dudel (2014), we find that the sex differences at the subnational level are larger than those observed at the national level.

The large sex differences in fertility indicators, especially the TFR, raise concerns about one-sex fertility indicators. There is not one number summarizing the fertility behaviour in a country, but different numbers at the same time. Moreover, the change in the sex difference in the TFR does reflect rather mortality and subnational-migration than differences in fertility behaviour. This is apparent in the decomposition of the sex difference in the TFR, where the contribution of exposures is stronger than the contribution of the age pattern of fertility. Moreover, it can be seen for regions in Mexico that were affected by the war on drugs have larger sex differences and even reversals of the narrowing of the sex difference in fertility. Therefore, one sex fertility indicators are also reflecting population structures with respect to sex. This adds to other critiques on the usage of the total fertility rates as indicator for fertility. A promising avenue of future research may be the development of two-sex fertility indicators (Keilman et al., 2014; Schoen, 1985).

In our analysis, the size of the spatial units in terms of population and area differs, which inhibits robust cross-country comparisons. However, the consistency of the results is quite astonishing. The result from the very small socio-economic units in Finland are comparable to the large units in the United States, despite the difference in size and surface is immense. Therefore, subnational analysis are meaningful on one side, and the other side, able to uncover heterogeneity regardless of the spatial granularity.

6.1 Methodological considerations

The study is not without limitations. The methods are descriptive and do not lend support for causal claims. Moreover, the decomposition used in this study is based on the assumption that the components of male and female fertility act independently and linearly. It should be noted that this is certainly not the case. For example, the age pattern of male fertility would change if women started to have children at a younger age. Another weakness of the study is that the subnational units vary strongly in terms of population size and surface area, which inhibits robust cross-country comparisons. Nonetheless, the variation in spatial units also allows to inspect how the level of analysis may impact the results.

Despite the weaknesses, our study has also strengths and improved upon previous research. The high quality register data overcomes weaknesses in surveys that have been raised by Joyner et al. (2012). Moreover, the subnational and longitudinal structure allows to account for country heterogeneity and untangles trends in the differences over time and across countries.

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References

J. M. Aburto, H. Beltrán-Sánchez, V. M. García-Guerrero, and V. Canudas-Romo. Homicides In Mexico Reversed Life Expectancy Gains For Men And Slowed Them For Women, 2000–10. *Health Affairs*, 35(1):88–95, Jan. 2016. ISSN 0278-2715. doi: 10.1377/hlthaff.2015.0068. URL https://www.healthaffairs.org/doi/full/10.1377/hlthaff.2015.0068. Publisher: Health Affairs.

D. S. Akers. On Measuring the Marriage Squeeze. *Demography*, 4(2):907–924, 1967. doi: 10.2307/2060328.

B. Bratsberg, A. Kotsadam, and S. Walther. Male Fertility:facts, Distribution and Drivers of Inequality, 2021.

D. M. Buss and D. P. Schmitt. Sexual Strategies Theory: An Evolutionary Perspective on Human Mating. *Psychological Review*, 100(2):204–232, 1993.

G. A. Carmichael. Estimating Paternity in Australia, 1976-2010. *Fathering: A Journal of Theory, Research, and Practice about Men as Fathers*, 11(3):256–279, Sept. 2013. ISSN 1537-6680, 1933-026X. doi: 10.3149/fth.1103.256. URL http://www.mensstudies.info/OJS/index.php/FATHERING/issue/view/103.

C. Dudel. *Vorausberechnung von Verwandtschaft: wie sich die gemeinsame Lebenszeit von Kindern, Eltern und Großeltern zuku?nftig entwickelt*. PhD Thesis, B. Budrich, Opladen, 2014.

C. Dudel and S. Klüsener. Estimating male fertility in eastern and western Germany since 1991: A new lowest low? *Demographic Research*, 35:1549–1560, Dec. 2016. ISSN 1435-9871. doi: 10.4054/DemRes.2016.35.53. URL http://www.demographic-research.org/volumes/vol35/53/.

C. Dudel and S. Klüsener. Estimating men's fertility from vital registration data with missing values. *Population Studies*, 73(3):439–449, Sept. 2019. ISSN 0032-4728, 1477-4747. doi: 10.1080/00324728.2018.1481992. URL https://www.tandfonline.com/doi/full/10.1080/00324728.2018.1481992.

C. Dudel and S. Klüsener. Male–Female Fertility Differentials Across 17 High-Income Countries: Insights From A New Data Resource. *European Journal of Population*, 37(2):417–441, Apr. 2021. ISSN 0168-6577, 1572-9885. doi: 10.1007/s10680-020-09575-9. URL https://link.springer.com/10.1007/s10680-020-09575-9.

C. Dudel, Y.-h. A. Cheng, and S. Klüsener. The unexplored parental age gap in an era of fertility postponement. Technical Report WP-2020-018, Max Planck Institute for Demographic Research, Rostock, Apr. 2020. URL https://www.demogr.mpg.de/en/publications_databases_6118/publications_1904/mpidr_working_papers/the_unexplored_parental_age_gap_in_an_era_of_fertility_postponement_6710.

C. Dudel, S. Klüsener, E. Loichinger, M. Myrskylä, and H. Sulak. The extension of late working life in Germany: trends, inequalities, and the East-West divide. Technical Report WP-2021-018, Max Planck Institute for Demographic Research, Rostock, Oct. 2021. URL https://www.demogr.mpg.de/en/publications_databases_6118/publications_1904/mpidr_working_papers/the_extension_of_late_ working_life_in_germany_trends_inequalities_and_the_east_west_divide_7099. Edition: 0.

C. Dudel, Y.-h. A. Cheng, and S. Klüsener. Shifting Parental Age Differences in High-Income Countries: Insights and implications. *Population and Development Review*, 2023.

J. Eckhard and J. Stauder. Partner market opportunities and union formation over the life course— \textlessspan style="font-variant:small-caps;"\textgreaterA\textless/span\textgreater comparison of different measures. *Population, Space and Place*, 25(4):e2178, May 2019. ISSN 1544-8444, 1544-8452. doi: 10.1002/psp.2178. URL https://onlinelibrary.wiley.com/doi/10.1002/psp.2178.

M. Fieder and S. Huber. The effects of sex and childlessness on the association between status and reproductive output in modern society. *Evolution and Human Behavior*, 28 (6):392–398, Nov. 2007. ISSN 10905138. doi: 10.1016/j.evolhumbehav.2007.05.004. URL https://linkinghub.elsevier.com/retrieve/pii/S1090513807000487.

M. J. Gulczynski. Migration and Skewed Subnational Sex Ratios among Young Adults. *Population and Development Review*, 2023.

T. Hesketh. Too many males in China: the causes and the consequences. *Significance*, 6(1):9–13, 2009. ISSN 1740-9713. doi: 10.1111/j.1740-9713.2009.00335.x. URL https://onlinelibrary.wiley.com/doi/abs/10.1111/j.1740-9713.2009.00335.x. _eprint: https://onlinelibrary.wiley.com/doi/pdf/10.1111/j.1740-9713.2009.00335.x.

S. Horiuchi, J. R. Wilmoth, and S. D. Pletcher. A decomposition method based on a model of continuous change. *Demography*, 45(4):785–801, Nov. 2008. ISSN 0070-3370, 1533-7790. doi: 10.1353/dem.0.0033. URL https://read.dukeupress.edu/demography/article/45/4/785/169873/A-decomposition-method-based-on-a-model-of.

K. Joyner, H. E. Peters, K. Hynes, A. Sikora, J. R. Taber, and M. S. Rendall. The Quality of Male Fertility Data in Major U.S. Surveys. *Demography*, 49(1):101–124, Feb. 2012. ISSN 0070-3370, 1533-7790. doi: 10.1007/s13524-011-0073-9. URL https://read.dukeupress.edu/demography/article/49/1/101/169689/The-Quality-of-Male-Fertility-Data-in-Major-U-S.

N. Keilman, K. Tymicki, and V. Skirbekk. Measures for Human Reproduction Should Be Linked to Both Men and Women. *International Journal of Population Research*, 2014:1–10, June 2014. ISSN 2090-4029, 2090-4037. doi: 10.1155/2014/908385. URL https://www.hindawi.com/journals/ijpr/2014/908385/.

D. T. Kenrick and R. C. Keefe. Age preferences in mates reflect sex differences in human reproductive strategies. *Behavioral and Brain Sciences*, 15(1):75–91, Mar. 1992. ISSN 0140-525X, 1469-1825. doi: 10.1017/S0140525X00067595. URL https://www.cambridge.org/core/product/identifier/S0140525X00067595/type/journal_article.

T. Klein. Die Geburt von Kindern in paarbezogener Perspektive / Fertility in Male-Female Partnerships. *Zeitschrift für Soziologie*, 32(6):506–527, Dec. 2003. ISSN 2366-0325. doi:

10.1515/zfsoz-2003-0607. URL https://www.degruyter.com/document/doi/10.1515/zfsoz-2003-0607/html. Publisher: De Gruyter Oldenbourg.

M. Kolk. Age Differences in Unions: Continuity and Divergence Among Swedish Couples Between 1932 and 2007. *European Journal of Population*, 31(4):365–382, Oct. 2015. ISSN 0168-6577, 1572-9885. doi: 10.1007/s10680-015-9339-z. URL http://link.springer.com/10.1007/s10680-015-9339-z.

Kravdal. Sex Differences in Childlessness in Norway: Identification of Underlying Demographic Drivers. *European Journal of Population*, 37(4-5):1023–1041, Nov. 2021. ISSN 0168-6577, 1572-9885. doi: 10.1007/s10680-021-09590-4. URL https://link.springer.com/10.1007/s10680-021-09590-4.

M. Luy. Causes of Male Excess Mortality: Insights from Cloistered Populations. *Population and Development Review*, 29(4):647–676, 2003. ISSN 1728-4457. doi: 10.1111/j.1728-4457.2003.00647.x. URL https://onlinelibrary.wiley.com/doi/abs/10.1111/j.1728-4457.2003.00647.x. _eprint: https://onlinelibrary.wiley.com/doi/pdf/10.1111/j.1728-4457.2003.00647.x.

M. Luy, C. Wegner-Siegmundt, A. Wiedemann, and J. Spijker. Life Expectancy by Education, Income and Occupation in Germany: Estimations Using the Longitudinal Survival Method. *Comparative Population Studies*, 40(4), Dec. 2015. ISSN 1869-8999. doi: 10.12765/CPoS-2015-16. URL https://www.comparativepopulationstudies.de/index.php/CPoS/article/view/203. Number: 4.

M. Mills, R. R. Rindfuss, P. McDonald, E. te Velde, and on behalf of the ESHRE Reproduction and Society Task Force. Why do people postpone parenthood? Reasons and social policy incentives. *Human Reproduction Update*, 17(6):848–860, Nov. 2011. ISSN 1460-2369, 1355-4786. doi: 10.1093/humupd/dmr026. URL https://academic.oup.com/humupd/article/17/6/848/871500.

V. K. Oppenheimer. A Theory of Marriage Timing. *American Journal of Sociology*, 94(3):563–591, Nov. 1988. ISSN 0002-9602, 1537-5390. doi: 10.1086/229030. URL https://www.journals.uchicago.edu/doi/10.1086/229030.

J. R. Porter and C. W. Purser. Measuring relative sub-national human development: An application of the United Nation's Human Development Index using geographic information systems. *Journal of Economic and Social Measurement*, 33(4):253–269, Dec. 2008. ISSN 18758932, 07479662. doi: 10.3233/JEM-2008-0307. URL https://www.medra.org/servlet/aliasResolver?alias=iospress&doi=10.3233/JEM-2008-0307.

H. B. Presser. Age Differences Between Spouses: Trends, Patterns, and Social Implications. *American Behavioral Scientist*, 19(2):190–205, Nov. 1975. ISSN 0002-7642. doi: 10.1177/000276427501900205. URL https://doi.org/10.1177/000276427501900205. Publisher: SAGE Publications Inc.

S. H. Preston, P. Heuveline, and M. Guillot. *Demography: measuring and modeling population processes*. Blackwell, Oxford, 9. [pr.] edition, 2008. ISBN 978-1-55786-214-3.

R. G. Rogers, B. G. Everett, J. M. S. Onge, and P. M. Krueger. Social, behavioral, and biological factors, and sex differences in mortality. *Demography*, 47(3):555–578, Aug. 2010. ISSN 0070-3370, 1533-7790. doi: 10.1353/dem.0.0119.

URL https://read.dukeupress.edu/demography/article/47/3/555/169824/Social-behavioral-and-biological-factors-and-sex.

M. Sauerberg, S. Klüsener, M. Mühlichen, and P. Grigoriev. Sex differences in cause-specific mortality: regional trends in seven European countries, 1996–2019. *European Journal of Public Health*, page ckad111, July 2023. ISSN 1101-1262, 1464-360X. doi: 10.1093/eurpub/ckad111. URL https://academic.oup.com/eurpub/advance-article/doi/10.1093/eurpub/ckad111/7233459.

S. Scherbov and S. Gietel-Basten. Measuring inequalities of development at the sub-national level: From the human development index to the human life indicator. *PLOS ONE*, 15(4):e0232014, Apr. 2020. ISSN 1932-6203. doi: 10.1371/journal.pone.0232014. URL https://dx.plos.org/10.1371/journal.pone.0232014.

C. Schmertmann. D-splines: Estimating rate schedules using high-dimensional splines with empirical demographic penalties. *Demographic Research*, 44:1085–1114, June 2021. ISSN 1435-9871. doi: 10.4054/DemRes.2021.44.45. URL https://www.demographic-research.org/volumes/vol44/45/.

R. Schoen. A two-sex nuptiality-mortality life table. *Demography*, 14(3):333–350, Aug. 1977. ISSN 0070-3370, 1533-7790. doi: 10.2307/2060790. URL https://read.dukeupress.edu/demography/article/14/3/333/171826/A-two-sex-nuptiality-mortality-life-table.

R. Schoen. Population growth and the birth squeeze. *Social Science Research*, 14(3):251–265, Sept. 1985. ISSN 0049089X. doi: 10.1016/0049-089X(85)90004-3. URL https://linkinghub.elsevier.com/retrieve/pii/0049089X85900043.

B. Schoumaker. Measuring male fertility rates in developing countries with Demographic and Health Surveys: An assessment of three methods. *Demographic Research*, 36:803–850, Mar. 2017. ISSN 1435-9871. doi: 10.4054/DemRes.2017.36.28. URL http://www.demographic-research.org/volumes/vol36/28/.

B. Schoumaker. Male Fertility Around the World and Over Time: How Different is it from Female Fertility? *Population and Development Review*, 45(3):459–487, Sept. 2019. ISSN 0098-7921, 1728-4457. doi: 10.1111/padr.12273. URL https://onlinelibrary.wiley.com/doi/10.1111/padr.12273.

H.-A. Schubert. Too many men? Subnational Population Imbalances and Male Childlessness in Finland, 2023.

R. Sear. Evolutionary contributions to the study of human fertility. *Population Studies*, 69(sup1):S39–S55, Apr. 2015. ISSN 0032-4728, 1477-4747. doi: 10.1080/00324728.2014.982905. URL http://www.tandfonline.com/doi/full/10.1080/00324728.2014.982905.

J. Smits and I. Permanyer. The Subnational Human Development Database. *Scientific Data*, 6(1):190038, Mar. 2019. ISSN 2052-4463. doi: 10.1038/sdata.2019.38. URL http://www.nature.com/articles/sdata201938.

K. W. Wachter. *Essential Demographic Methods*. Harvard University Press, Cambridge, Massachusetts, 2014.

L. Zhang. *Male Fertility Patterns and Determinants*. The Springer Series on Demographic Methods and Population Analysis. Springer, Berlin, Heidelberg, 2011.

A Figures

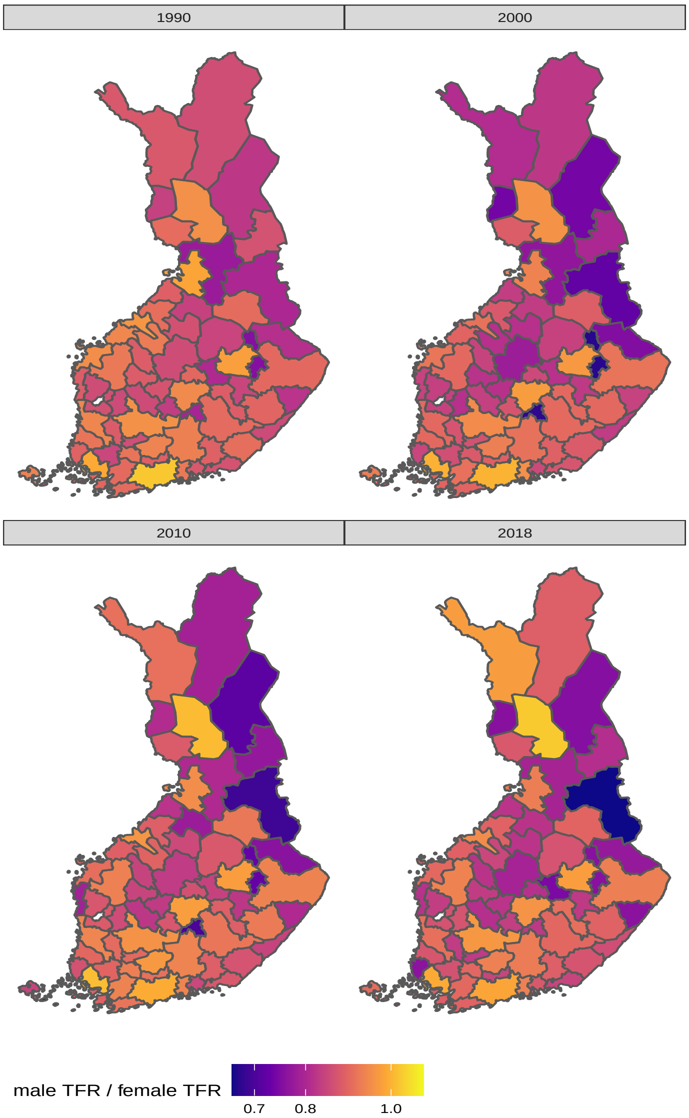

Figure A.1: Male-female TFR ratio in Mexico across regions between 1990 and 2018.

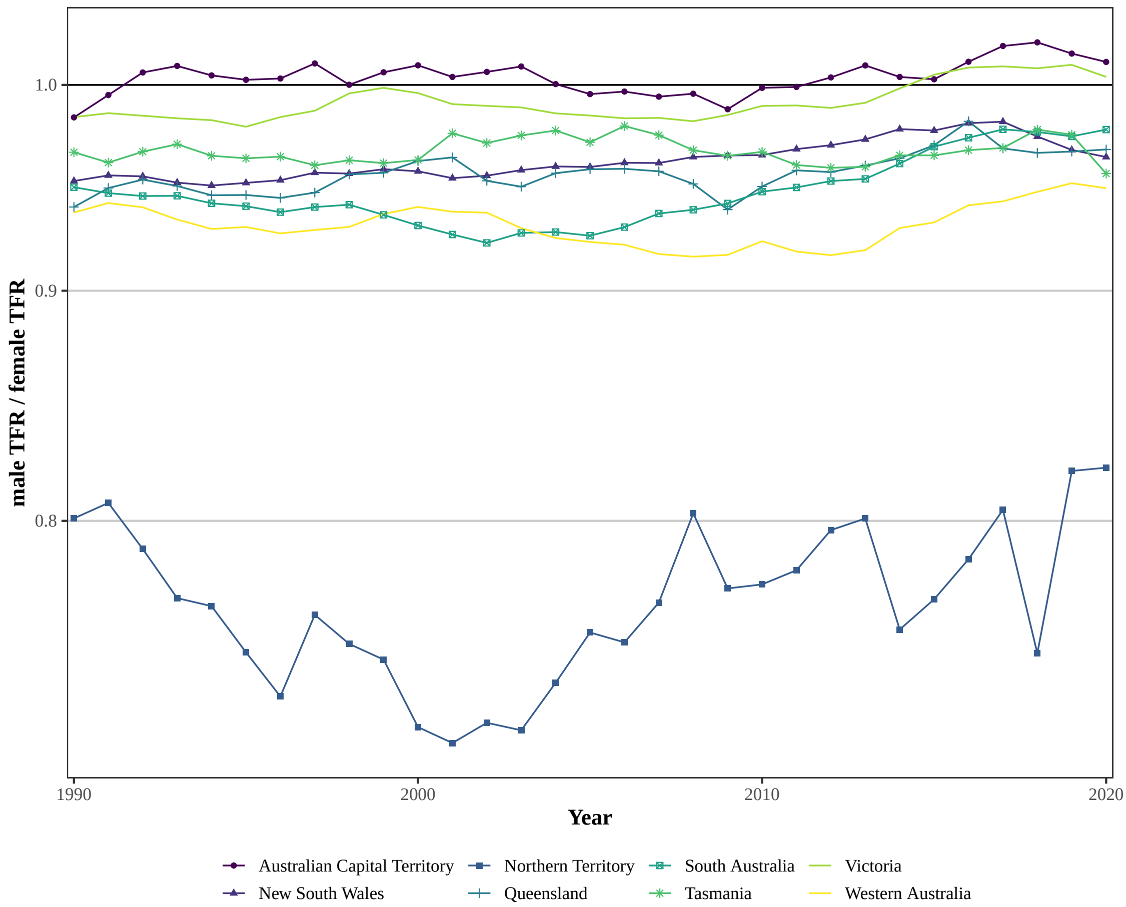

Figure A.2: Trend of the female-male TFR ratio over time in Australian states and territories.

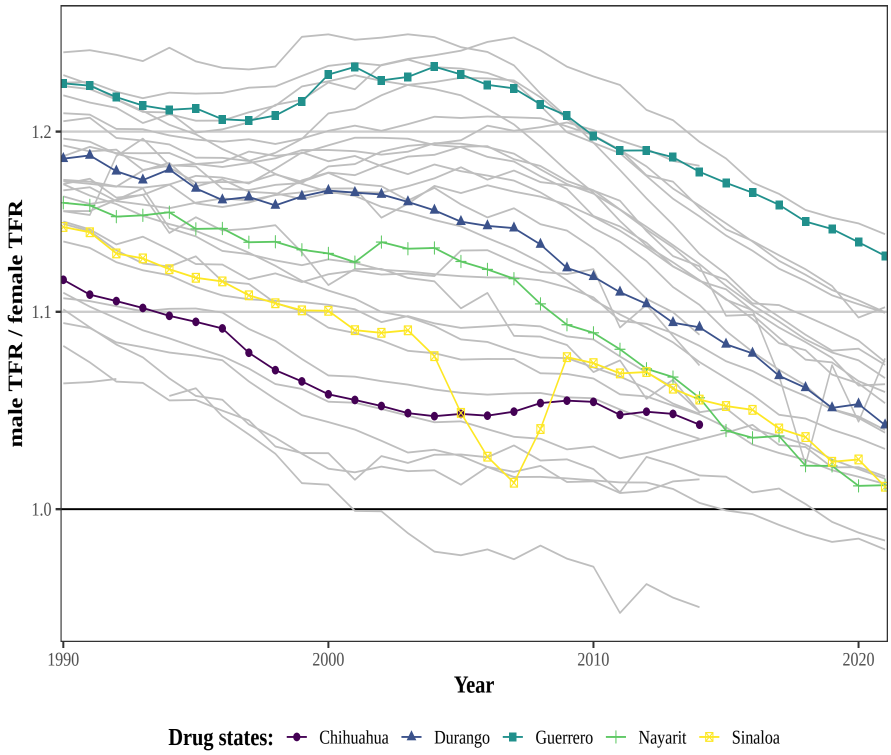

Figure A.3: This figures displays the time-trend in the male-female TFR ratios in the Mexican states. The coloured lines are the states most affected by the war on drugs according to Aburto et al. (2016), while the grey lines are the less and non-affected states.

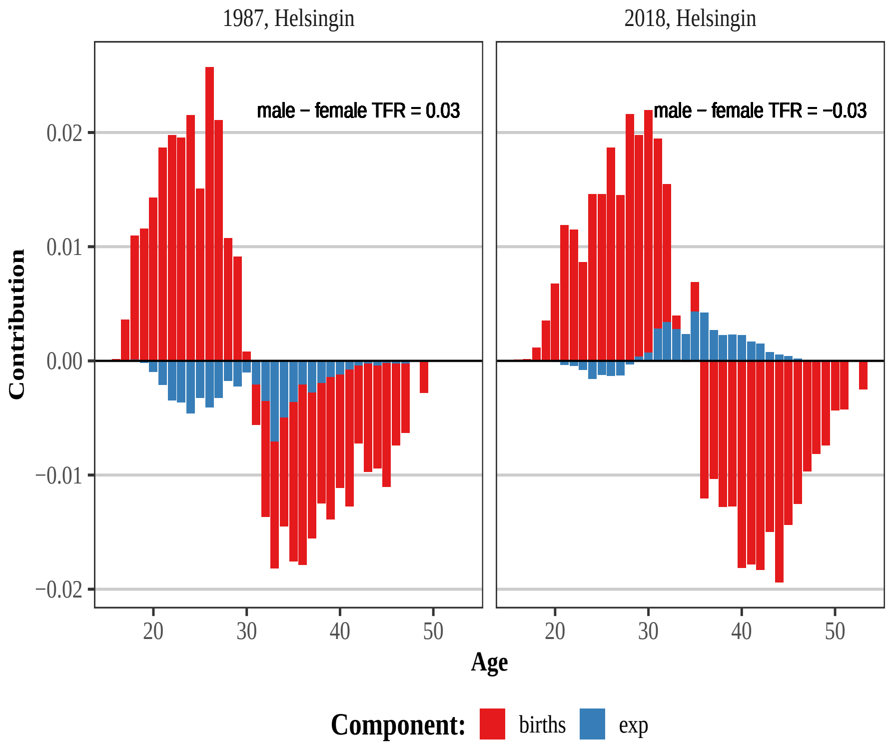

Figure A.4: This graph presents the results from the Horiushi decomposition (Horiuchi et al., 2008) of the sex difference in TFR in Helsinki for the year 1987 and 2018. Helsinki in 1987 had a TFR for men that was 0.03 points higher than the corresponding value for women. In 2018, the male TFR by 0.3 smaller than the female TFR. The figure shows the contribution to the difference by age-group (x-axis), birth count (red bars) and exposure (blue bars).

B Tables

Table B.1: Ordinary least squares regression model of fertility quantum and timing on gender development index.

	Dependent variable:	
	Δ Quantum	Δ Timing
	(1)	(2)
GDI	−2.748***	−17.854***
	(−2.928, −2.568)	(−19.039, −16.670)
Intercept	3.694***	20.234***
	(3.519, 3.869)	(19.084, 21.384)
Observations	1,144	1,144
R^2	0.439	0.433
Adjusted R^2	0.439	0.433
Note:		*p<0.1; **p<0.05; ***p<0.01

Table B.2: Ordinary least squares regression model of the difference in mean age of children between men and women on the Gender Development Index (GDI).

	Dependent variable:
	Δ Timing
GDI	−17.854***
	(−19.039, −16.670)
Intercept	20.234***
	(19.084, 21.384)
Observations	1,144
R^2	0.433
Adjusted R^2	0.433
Note:	*p<0.1; **p<0.05; ***p<0.01

Table B.3: Ordinary least squares regression model of the difference in mean age of children between men and women on the Human Development Index (HDI).

	Dependent variable:
	Δ Timing
hdi	-4.635^{***}
	(-4.854, -4.415)
Constant	6.757^{***}
	(6.575, 6.939)
Observations	1,919
R^2	0.472
Adjusted R^2	0.471
Note:	*p<0.1; **p<0.05; ***p<0.01

C Data preparation

C.1 Spain

The subnational population Data for Spain was erratic, which is probably related to the size of the spatial unit and data quality, and only available in 5-year binned format. Therefore, in the data pre-processing, we smoothed the population counts using splines (Schmertmann, 2021). The result can be seen in Figure C.5. In the next step, we used penalized composite link models to estimate the underlying continuous distribution. The procedure performs well for dis-aggregating male fertility rates according to Dudel et al. (2021).

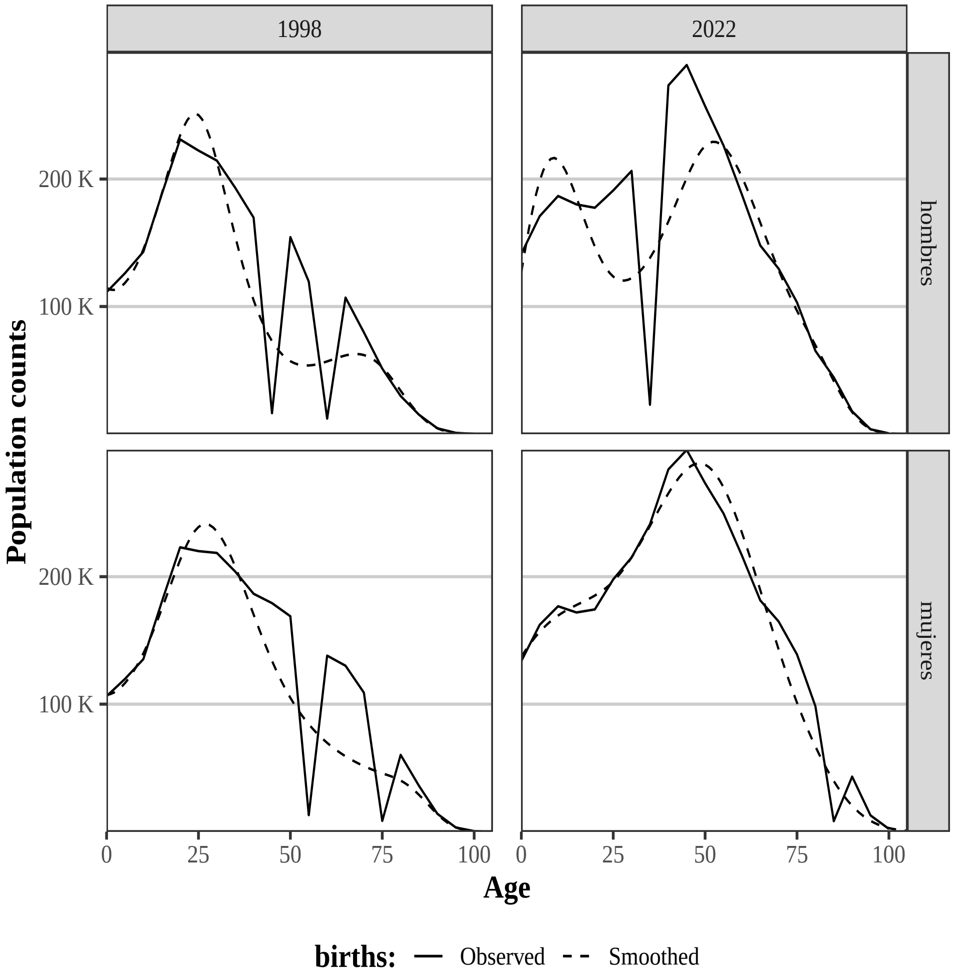

Figure C.5: This figure illustrates the adjustment of the population counts for the Spanish data. The population size in the observed data was very erratic with respect to age. We used splines to remove the fluctuations that stem from the small counts related to the subnational analysis and from data quality.