# Reversal of the Sex Inequality in Fertility

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**Abstract**

Population structures show a growing male surplus around the globe as a consequence of declining mortality, narrowing sex differences in mortality, and in some places sex selective abortions. Population structures are important determinants of marriage markets and childbearing. In this study, we estimate the past, current and future difference between the male and female total fertility rates around the world using an indirect demographic approach on data from the UN World Population Prospects. Our results indicate a crossover from historically higher male fertility to increasingly higher female fertility, which occurs globally in 2024. This shift is not toward parity, but rather reflects a growing disparity driven by the increasing male surplus in populations, which exerts downward pressure on male fertility rates relative to those of females. The difference is expected to grow to up to 20% in countries like China and India, where sex selective abortion has caused sex imbalances in population structures. Overall, we highlight the growing sex inequalities in reproduction and call for more research on sex differences in fertility.

***Keywords–*** Demography, sex-selective abortion, male Fertility, Marriage Markets, sex inequalities

## 1 Introduction

Fertility is a fundamental demographic process that shapes population structures and profoundly influences individual well-being. Total fertility rates (TFR) are conventionally measured as the average number of children born per woman, yet this metric implicitly centers on female reproductive behavior and overlooks the male contribution to childbearing. The female TFR can be misleading in populations with imbalanced population structures, because it does not truly reflect the reproductive behavior of the entire population. While previous studies have demonstrated a strong synchrony between male and female fertility trends globally (Dudel and Klüsener, 2021; Schubert and Dudel, 2025b), notable deviations emerge in high-fertility contexts (Schoumaker, 2019) or in populations with marked sex imbalances (Schoen, 1985; Schubert and Dudel, 2025a,b). Despite these observations, the historical evolution and future trajectories of sex disparities in fertility remain poorly understood at the global scale.

Sex differences in fertility outcomes arise from two interrelated factors: sex-specific population structures and differential fertility timing. Because fertility is defined as the number of births relative to the population exposed to childbearing, imbalances in the sex ratio of the reproductive population can lead to divergent fertility estimates between sexes. Moreover, men typically exhibit a broader reproductive window and tend to delay childbearing compared to women, which can result in higher observed fertility rates among men, particularly in young and growing populations (Paget and Timæus, 1994; Schoumaker, 2019). These patterns are further modulated by demographic shocks—such as abrupt fertility transitions or mortality crises—that alter the age and sex composition of the population, thereby influencing the observed sex gap in fertility (Brouard, 1977; Dudel and Klüsener, 2021; Schoen, 1985; Schubert and Dudel, 2025b).

A growing surplus of men in populations is relevant because of the social, health and economic implications (for a review, see Dyson, 2012). Sex differences in fertility may indicate imbalanced mating markets in which the more abundant sex 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 and Willführ, 2022; Muhsam, 1974). Another concern is the effect on fertility and childlessness, as cohorts exposed to sex differences in fertility face a structural constraint to childbearing, potentially leading to increased childlessness among men and women (Klein, 2003; Kravdal, 2021; Schubert and Dudel, 2025b). Furthermore, sex differences in partnering and fertility may have downstream implications for social and health outcomes, including increased violence, the spread of sexually transmitted diseases, particularly among unpartnered and childless individuals, who may suffer from loneliness and have fewer kin to care for them at older ages (J. Angrist, 2002; J. D. Angrist, 2000; Edlund, 2005; Gupta, 2010; Thérèse Hesketh, 2009; Therese Hesketh and Xing, 2006; J. D. Tucker et al., 2005). Furthermore, a surplus of men in a population is postulated to increase economic vulnerability as well as violence and conflict (J. Angrist, 2002; Barakat and Urdal, 2009; Juárez, Urdal, and Vadlamannati, 2022; Østby and Urdal, 2014; Urdal, 2006).

This study presents a global analysis of male and female total fertility rates (TFRs), building on the methodological framework of Keilman, Tymicki, and Skirbekk (2014) and leveraging data from the United Nations World Population Prospects 2024 (United Nations Department of Economic and Social Affairs, 2024). We examine historical trends and future projections of sex disparities in fertility across countries, revealing a striking temporal shift: while male TFRs historically exceeded female TFRs in most nations, a crossover has occurred in recent decades, with female TFRs now surpassing male TFRs in an increasing number of countries. This reversal reflects underlying changes in population structure driven by sex-specific mortality and sex ratios at birth. By disentangling these demographic forces, we demonstrate how shifts in the sex composition of reproductive-age populations—particularly through differential survival and sex-selective birth patterns—have fundamentally reshaped the sex-specific dynamics of fertility over time.

# 2 Materials and Methods

## 2.1 Data

We conduct a global analysis of male and female total fertility rates (TFRs) using data from the United Nations World Population Prospects 2024 (WPP2024) and harmonized estimates of male fertility from recent demographic studies (Schoen, 1985; Schoumaker, 2019; Schubert and Dudel, 2025a).[1] WPP2024 provides comprehensive, internally consistent time series of population counts by single age and sex, births, deaths, and international migration for all countries and areas from 1950 to 2100. The dataset is freely accessible at https://population.un.org/wpp/. It integrates diverse data sources—including civil registration systems, sample registration, censuses, surveys, and national estimates—while explicitly accounting for biases such as under-coverage, under-enumeration, and differential registration quality across age groups and regions (Johnson et al., 2022). The population estimates are derived using the cohort component method, which reconstructs population dynamics through the population balancing equation. This approach ensures temporal consistency and enables reliable projections to 2100. Fertility and mortality indicators—including TFR and adult mortality—are generated via Bayesian hierarchical modeling that synthesizes heterogeneous data sources, adjusts for known measurement errors, and propagates uncertainty appropriately (Chao, Gerland, et al., 2025; Chao, Kantorova, and Gonnella, 2023; P. D. United Nations Department of Economic and Social Affairs, 2024). This methodological framework enhances the reliability of estimates, particularly in data-sparse regions.

For male fertility, we use country- and time-specific TFR estimates derived from multiple sources: Dudel and Klüsener (2021), Schoen (1985), and Schubert and Dudel (2025a) applied classical demographic methods to vital statistics; whereas Schoumaker (2019) employed the own-child method using data from the Demographic and Health Surveys (DHS) (Schoumaker, 2017). These estimates are harmonized to ensure comparability across countries and time periods.

## 2.2 Estimating male fertility

We measure fertility using the total fertility rate for men ($TFR_m$) and for women ($TFR_w$). The total fertility rate is a period measure of fertility intensity, and provides the average number of children a women would have at the end of a reproductive period if she was subject to the age-specific fertility of a given year. The $TFR_w$ is obtained from the WPP2024, but the $TFR_m$ is not readily available or is subject to data deficiencies (Dudel and Klüsener, 2019; Joyner et al., 2012), and therefore needs to be estimated.

The estimation of the $TFR_m$ follows Keilman, Tymicki, and Skirbekk, 2014 and exploits a theoretical relationship of $TFR_m$ to adult sex ratios and $TFR_w$. The $TFR_m$ follows the $TFR_w$ usually closely (Dudel and Klüsener, 2021), but unbalanced population structures can affect the reproduction of the abundant sex (Schoumaker, 2019; Schubert

[1] All code and data required to replicate the main and supplementary results of the article can be found here: https://github.com/Henrik-Alexander/global_birth_squeezes.

and Dudel, 2025a). Therefore, the $TFR_m$ is logarithmically related to the overall fertility level ($TFR_w$) and the sex difference in the size of the population at reproductive age ($SR$). The estimation follows:

$$log(TFR_m) = \alpha + \beta_1 log(TFR_w) + \beta_2 log(SR) + \varepsilon \quad (1)$$

where $log(TFR_m)$ is the logarithm of the TFR for men, $log(TFR_w)$ is the logarithm of the TFR for women, and $log(SR)$ is the logarithm of the sex ratio at reproductive age.

We estimate three distinct models that differ in how they account for population sex ratios. The *baseline model* (model 1) uses the sex ratio in the ages 20 to 39, consistent with the approach previously employed by Keilman, Tymicki, and Skirbekk (2014). The *postponement model* (model 2) adjusts for the trend of fertility postponement by estimating the sex ratio within the age group 25 to 44, reflecting the shift in reproductive timing observed in recent decades (E. Beaujouan, 2020; É. Beaujouan and Sobotka, 2017). The *age-gap model* (model 3) further refines this approach by accounting for the observed pattern of later childbearing among men: it calculates the sex ratio using men aged 25–44 and women aged 20–39, thereby capturing the age gap between partners at the time of childbirth (Dudel, Cheng, and Klüsener, 2023; Schoumaker, 2019). While Models 1 and 2 compare sex ratios within the same age groups, Model 3 introduces a temporal shift in the male age group to better reflect the demographic realities of partner age differences in contemporary fertility.

### 2.2.1 Model results

All three models reach a superior fit relative to the model in Keilman, Tymicki, and Skirbekk (2014) and the age-gap model performs best. The *baseline* and *postponement models* yield a robust fit, as the $R^2$ are at 0.969 and 0.97 respectively, while the $R^2$ in Keilman, Tymicki, and Skirbekk (ibid.) was only 0.83. The *age-gap model* performs best with a $R^2$ of 0.984. Furthermore, we perform out-of-sample validation using high-quality data from the Human Fertility Collection (Dudel, 2021) to evaluate the performance of the regression models and assess the problem of overfitting. Overall the fit is good reaching a root mean squared error ($RMSE$) of around 0.05. The best model fit is again found for model 3 accounting for the age gap, which has an $RMSE$=0.041. The 90%-prediction intervals are conservatively calibrated as they include 98% of the $TFR_m$ observations. [2]

The regression results are displayed in Table 1, indicating a positive correlation of the $TFR_w$ with the $TFR_m$ and a negative correlation of the adult sex ratio (SR) with the $TFR_m$ across models. The coefficients across the regression models in Table 1 are statistically significant, as opposed to results in Keilman, Tymicki, and Skirbekk (2014), because of a larger sample size ($n$) and/or the better model fit ($R^2$=0.983). Hence, we use the complete regression equation for the approximation of $TFR_m$. We now present the results for model 3, which is the best-performing model. If the population is balanced (sex ratio=1) and the $TFR_w$ is at replacement level ($TFR_w$=2.1 births per woman), $TFR_m$ is predicted to be slightly higher at 2.09 births per man. However, if there are twice as many women in the reproductive age ranges (sex ratio=0.5), $TFR_m$ is predicted to increase to 3.31. If there are half as many women than men (SR=2), $TFR_m$ drops to 1.32, holding the $TFR_w$ at replacement level. Holding the population balanced, the impact of the $TFR_w$ is negative, which implies that at a lower $TFR_w$ of 1.0, $TFR_m$ equals 0.92, and if the $TFR_w$ increases to 3 births per woman, the $TFR_m$ reaches 3.1 births per man.

## 2.3 Standardization

Beyond the regression-based approach, we employ demographic standardization to isolate the impact of sex-specific population structures on observed sex differences in total fertility rates (TFRs). Standardization is a widely used technique to disentangle the influence of population composition—such as age and sex structure—on aggregate demographic indicators (Preston, Heuveline, and Guillot, 2001). Here, we apply the distribution of births by maternal age to the male population structure, effectively estimating what male TFR would be if men experienced the same fertility schedule as women, but were exposed to the actual age distribution of the male population. The standardized TFR is computed as:

$$\text{TFR}_{std} = \sum_{x=15}^{55} \frac{B_x}{P_x^m}, \quad (2)$$

where $B_x$ denotes the number of births to mothers aged $x$, and $P_x^m$ is the male population aged $x$ in the reproductive age range (15–55 years). This approach implicitly assumes that the fertility schedule is identical across sexes — a simplification that does not hold in reality. Empirical evidence shows that male fertility schedules are typically shifted to older ages, exhibit a broader reproductive window, and decline more gradually after the peak compared to female schedules (Paget and Timæus, 1994; Schoumaker, 2019). Despite this limitation, the standardization reveals how much of the observed difference in TFR between men and women is attributable solely to disparities in the age structure of the reproductive-age population-—particularly the skew in sex ratios at reproductive ages.

[2] In the remainder of the paper, we will only present results for the age-gap model unless explicitly stated.

Table 1: Regression table presenting the results from regression in equation 1. The predictor variables are the total fertility rate for women (logarithm) and the sex ratio at age 20 to 39 (logarithm). The outcome variable is the total fertility rate for men (logarithm). The top panel presents the regression coefficients and the bottom panel the model metrics.

| | *Dependent variable:* | | |
|---|---|---|---|
| | log TFR men | | |
| | (1) Baseline | (2) Postponement | (3) Age gap |
| log TFR women | $1.182^{***}$ (1.175, 1.190) | $1.197^{***}$ (1.190, 1.205) | $1.101^{***}$ (1.095, 1.107) |
| log SR (20-39) | $-0.887^{***}$ ($-0.922$, $-0.852$) | | |
| log SR (25-44) | | $-0.849^{***}$ ($-0.884$, $-0.814$) | |
| $\log \frac{\text{men}_{25-44}}{\text{men}_{20-39}}$ | | | $-0.661^{***}$ ($-0.675$, $-0.646$) |
| Intercept | $-0.092^{***}$ ($-0.098$, $-0.086$) | $-0.114^{***}$ ($-0.119$, $-0.108$) | $-0.078^{***}$ ($-0.082$, $-0.074$) |
| Observations | 4,024 | 4,024 | 4,024 |
| $R^2$ | 0.968 | 0.968 | 0.983 |
| Adjusted $R^2$ | 0.968 | 0.968 | 0.983 |
| *Note:* | | | $^{*}$p<0.1; $^{**}$p<0.05; $^{***}$p<0.01 |

### 2.4 Untangling the demographic drivers of sex imbalances

To disentangle the contributions of sex ratios at birth and sex-specific mortality to changing population structures, we leverage sex-specific life tables and sex ratios at birth from the WPP2024. We construct age-specific sex ratios by applying a synthetic-cohort approach: starting from the sex ratio at birth (e.g., the number of male births per 100 female births), we project the survival of males and females through each age group using the corresponding sex-specific life tables. Specifically, we set the radix for males to the observed sex ratio at birth (e.g. 105 males per 100 females), while setting the radix for females to 100. This allows us to compute the age-specific sex ratio – the number of men per 100 women – at each age, reflecting the cumulative impact of imbalanced sex ratios at birth and sex-specific mortality across the life course. By using this approach, we effectively isolate the demographic forces shaping the sex composition of the reproductive-age population, neutralizing the influence of international migration, which is not directly modeled in this decomposition.

## 3 Declining male fertility

Countries overall transition from higher $TFR_m$ in the past to higher $TFR_w$ in the future, see Figure 1, showing a reversal of the sex inequality in reproduction. In 1950, $TFR_m$ used to exceed the $TFR_w$ around the world, see top panel in Figure 1. In 1950, 96.2% of the countries showed higher TFR for men than for women. However, male fertility declines more compared to female fertility, so that there are both countries with higher male and higher female TFR in 2025. In 2025, 47.5% of the countries showed higher TFR among men. In 2100, it is projected that male fertility will be higher only in 9.75% of the countries.

The difference between the $TFR_m$ and the $TFR_w$ can be substantial and range between -61.6% (Qatar, 2009) and +131.01% (Turks and Caicos Islands, 1975). Extreme cases are often found in smaller countries, where a modest change in mortality or migration affecting only one sex can greatly alter the relative size of the male and female populations. Yet, even in countries with large populations—such as China, India, and the Republic of Korea—marked differences between male and female TFRs have also been observed. Figure 2 shows the relative difference between the male and female TFR and reveals a cross-over in China in 1990, in India in 2010 and in the Republic of Korea already in 1982. Moreover, these countries will reach the minimum of the relative difference in the 2020s and 2030s, respectively, indicating that sex disparities in fertility are likely to become more pronounced in the near future.

The time point when $TFR_w$ first exceeds $TFR_m$ for the world occurs in the year 2024, but the timing of these fertility cross-overs varies across geographic regions, see Figure 3. For the majority of European and Northern American countries, this cross-over happened in the past, especially in the 1960s and 1970s. In Australia, New Zealand and the Latin American countries, those cross-overs happened mainly in the recent past. Northern Africa, Eastern Asia, Oceania and Central Asian Countries are expected to experience the majority of crossovers in the near future. Sub-Saharan Africa is expected to have crossovers in the long-term future, and many of those countries will not have a crossover before 2100.

In a robustness check, we accounted for fundamental uncertainty in the regression model and used 90% prediction intervals, which blurred the picture a bit. The TFR differences for Caribbean, Central America and the Less developed regions became indistinguishable from zero due to prediction uncertainty, but cases in high-income countries, Sub-Saharan Africa and Eastern Asia remained robust.

### 3.1 Standardization results

The results from the standardization corroborate the regression-based results, showing that male TFR declines relative to the female TFR over time. However, two noticeable differences emerge between the regression-based and the standardization approaches. First, fewer crossovers occur in the standardization results than in the regression-based results. Second, the sex difference in fertility in the past is weaker and more muted. Both observations may be related to the fact that population structures are more masculine at an earlier stage of the fertility transition than indicated by the regression-based approach, but that larger age differences between men and women and high population growth rates offset the impact of male skewed population at reproductive age (Schoumaker, 2019), because male births occur at later ages when the exposures a smaller.

### 3.2 Untangling the demographic drivers

Figure 4 illustrates how the sex ratio at birth and sex differences in mortality shape the population sex ratio in Cambodia, China, India, Guatemala, the Republic of Korea and Rwanda. It shows that both the rising sex ratio at birth and changing mortality patterns contributed to the observed crossover in fertility and pose a secular trend towards more masculine populations. In 1950, women began to outnumber men around age 50 in all contexts, except in Guatemala and the Republic of Korea, where male survival was lower due to the excess male mortality caused by

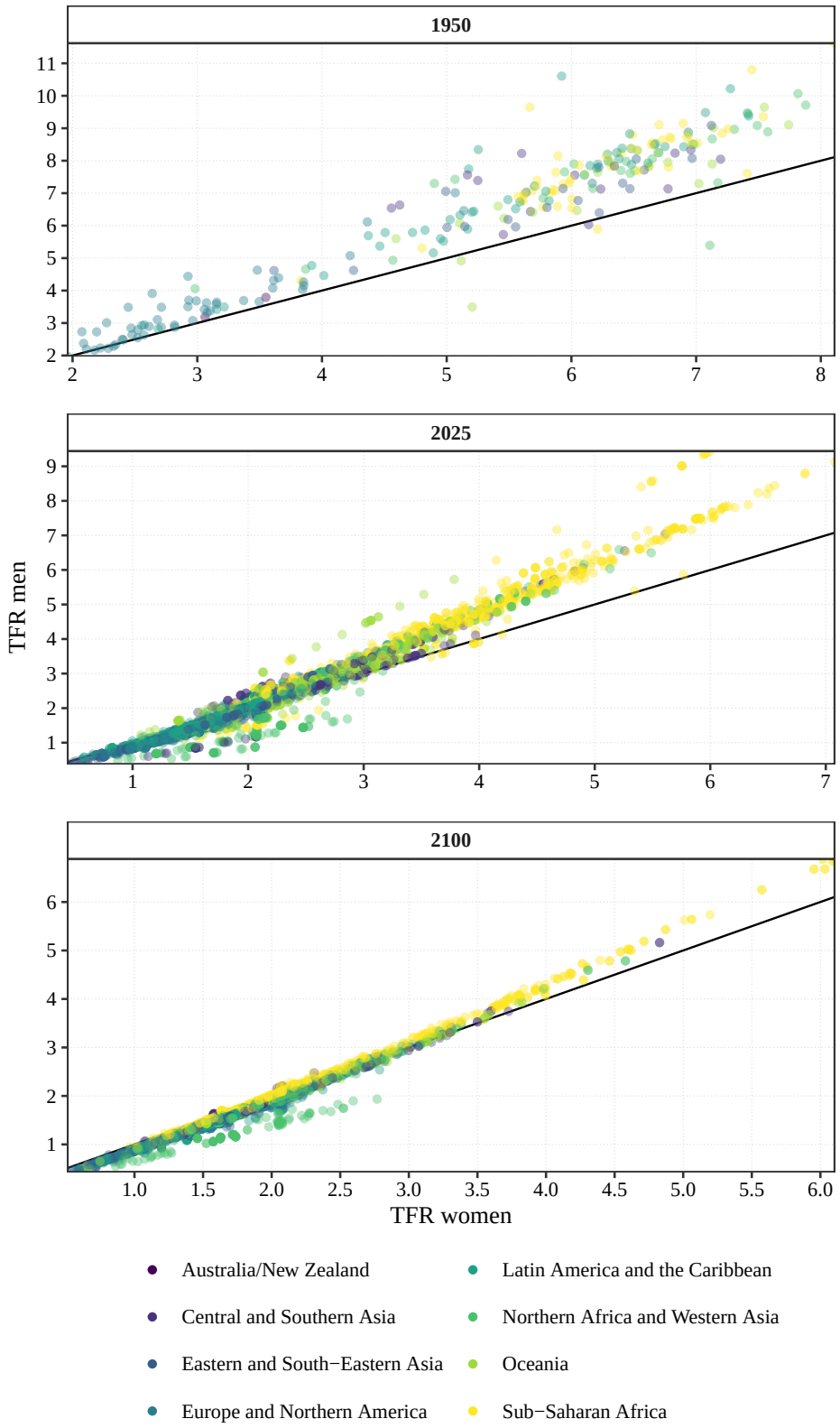


Figure 1: TFR for women (x-axis) realtive to TFR for men (y-axis) in three different years 1950 (top panel), 2025 (middle panel) and 2100 (bottom panel). The diagonal line represents identity between male and female TFR, while values above the diagonal indicate higher TFRs among men and values below the diagonal indicate higher TFRs among women.

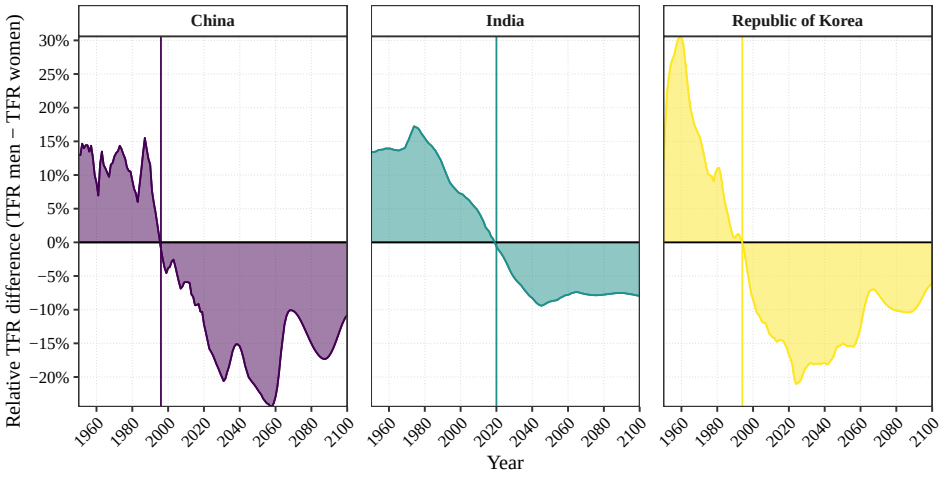


Figure 2: Percentage difference in male to female TFR (y-axis) in the period between 1950 to 2100 (x-axis) using the regression-based approach. Positive values indicate a higher TFR among men and negative values indicate a lower TFR among men. The vertical lines indicate the crossover from higher male TFR to higher female TFR.

war. The upward shift in the age at which women outnumber men is driven by higher sex ratios at birth (reflected in the increased intercept on the y-axis), overall declines in mortality, and narrowing sex differences in mortality (both indicated by the flattening of the curves). By 2020, this crossover occurred at around age 65 in China, India and the Republic of Korea. India is a special case showing sustained excess men related to the continuously high sex ratio at birth and narrow gender gap in mortality (due to comparatively high female mortality).

Notably, the cases of Cambodia (1964-53; 1967-1998), Guatemala (1965-1979), the Republic of Korea (1951-1953), and Rwanda (1990-1999) highlight the acute and lasting impact of conflict-related mortality. In these country-years, the sex ratio curves exhibit sharp, transient dips—reflecting elevated male mortality during periods of war and violence. For example, in 1950 the Republic of Korea, a cohort exposed to wartime mortality would have exhibited a sex ratio of 30 men per 100 women at age 30, had mortality rates remained constant. These temporary shocks leave enduring imprints on population structure, skewing the age-sex composition for decades and affecting subsequent fertility, marriage, and labor market dynamics.

Furthermore, we exploited the different demographic scenarios estimated by the WPP2024 to understand the impact of assumptions on fertility, mortality, and migration on sex differences in fertility. If fertility would drop to zero below age 18 across the world, there would be lower TFR ratios mainly in high fertility contexts like Sub-Saharan Africa, Oceania and Latin America, where teenage fertility is still frequent. If fertility would be at replacement level instantly, TFR ratios in lower fertility countries would increase, and TFR ratios in higher fertility countries would drop, highlighting the impact of the TFR on TFR ratios.

# 4 Discussion

This paper examined the inequality in average reproduction between women and men in the past, the present and the future around the world. While men used to have higher fertility than women in the past in Europe and Northern America, male-skewed population structures deflate reproduction numbers for men in the future, particularly in Eastern Asia. A universal force leading to these sex imbalances in reproduction is declining mortality, which sustains the male-skewed sex ratio at birth longer throughout life (Spoorenberg, 2016). A narrowing sex difference in mortality may also contribute to a masculinization of populations at the reproductive ages. In some East Asian countries, this effect is reinforced by sex selective abortion (Sen, 1998).

Male fertility historically exceeded female fertility, which is in line with previous findings (Schoumaker, 2019; Schubert and Dudel, 2025b). With the onset of the fertility decline and as fertility reaches lower levels, the male and female TFRs cross, and female fertility begins exceeding male fertility. The timing of the crossover depends on the progress of the fertility transition. Crossovers occur first in Europe (1960s) and later in other contexts. In some sub-Saharan Africa, some countries are not expected to have a fertility crossover before 2100.

Male and female fertility can differ substantially, as the relative difference ranges between -60% and +130%. Extreme cases of very high male TFRs relative to female TFRs (+100% or above) are mainly observed in the 1950s and 1960s in small populations like Lesotho, Tokelau, and Turks and Caicos Islands. Extreme cases of very low male TFRs to female TFRs are observed mainly in the 2020s and 2030s in countries like Qatar, the United Arab Emirates, the Maldives and Oman.

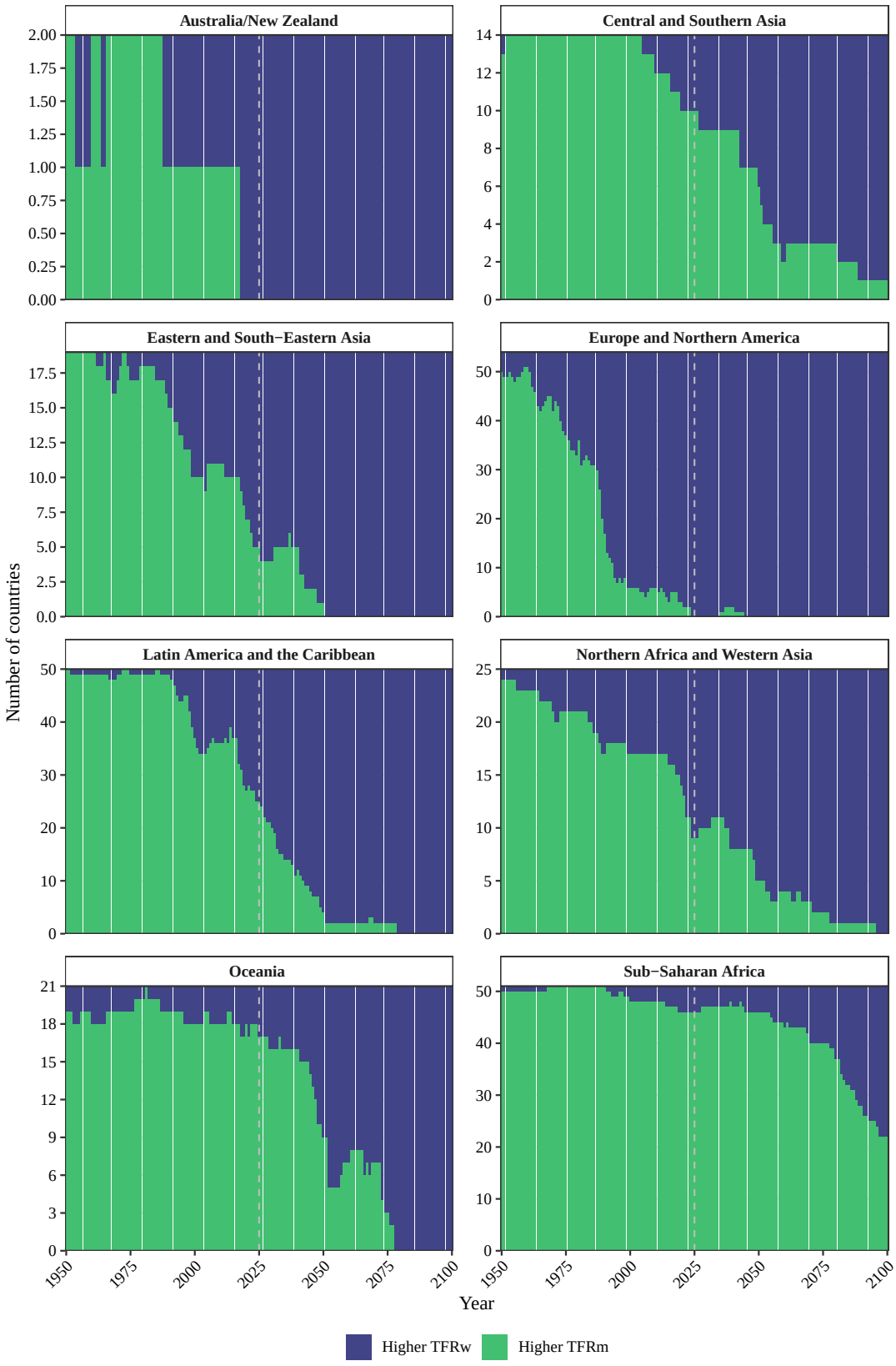


Figure 3: The number of countries with a higher $TFR_m$ in green and the number of countries with a higher $TFR_w$ in blue in a specific year by SDG-region.

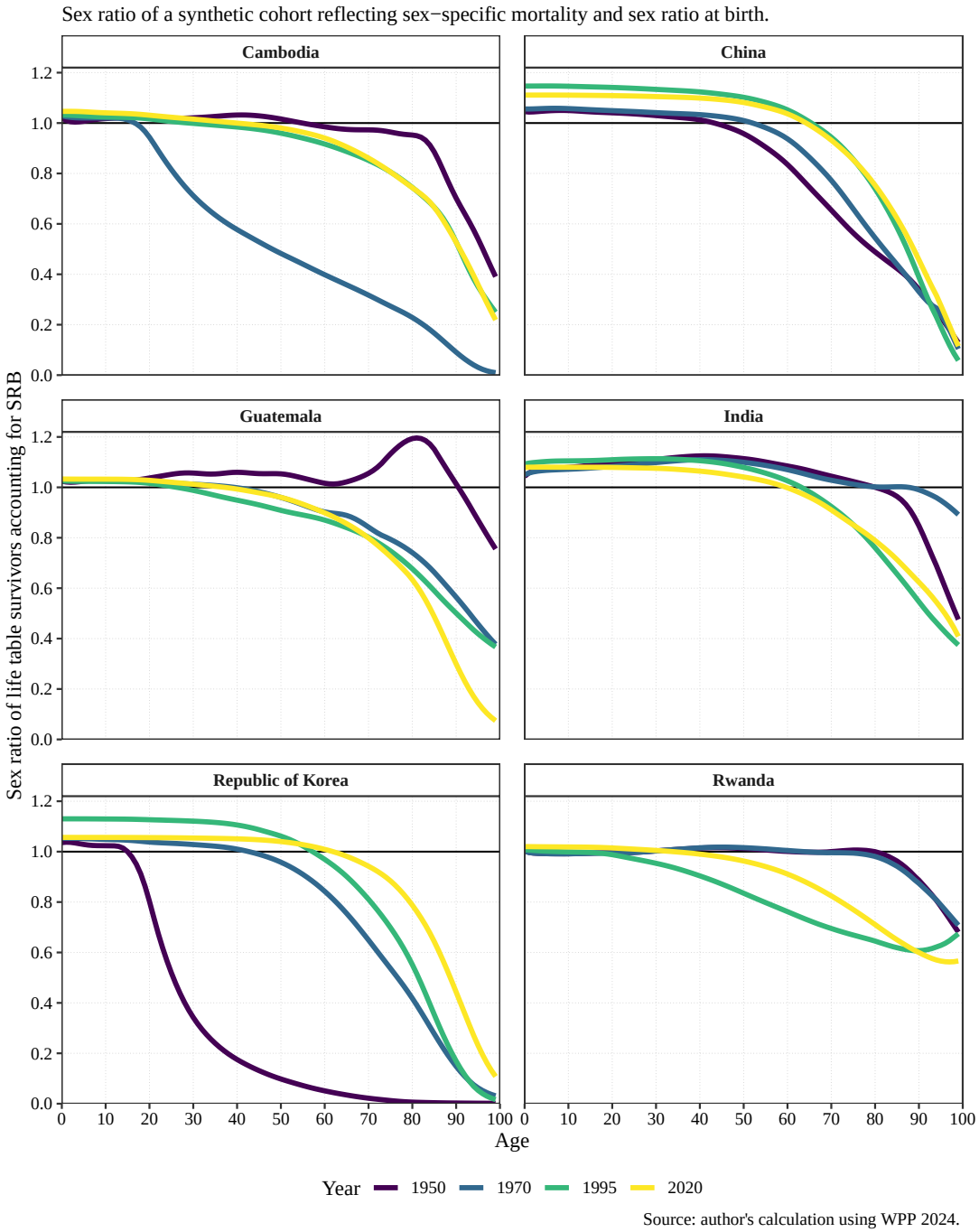


Figure 4: The sex ratio in a population (y-axis) reflecting period mortality rates and the sex ratio at birth at different ages (x-axis), e.g. excluding migration. Values above one indicate a male population and values below one indicate a female population.

The secular trend behind the crossover of male and female TFRs is the masculinization of populations related to declining mortality levels, narrowing sex gap in mortality, and in some East-Asian countries artificially imbalanced sex ratios at birth. The impact of mortality on the masculinization of populations has been observed for Western countries before (Schubert and Dudel, 2025b; Spoorenberg, 2016) and the missing women have been raised in Sen, 1998. We show that this has likely implications for reproduction, fertility and sex differences in fertility.

Beyond the secular trends driving masculinization of populations, conflicts pose a strong and lasting counterforce on the sex ratio in populations, leading to a female surplus. Dependent on the intensity and duration of conflicts, population structures can be altered with potential implications for childbearing for women. Using period mortality rates for the Republic of Korea and Cambodia, there would be 30 or 70 men per 100 women at age 30 respectively, if conflict mortality lasted for a cohort. The feminization of population structures may have positive effects on gender equality and participation of women, but also renders reproduction and partnering more difficult and selective for women.

The crossover marks the beginning of a new demographic reality, which will come with new opportunities and challenges. There is evidence suggesting that increasing levels of male childlessness and excess number of men have subsequent social and economic consequences. U.S. based research indicates implications for marriage rates and fertility (Akers, 1967; Dyson, 2010). Research on Finland shows that excess number of men increases the levels of male childlessness and steepens the socio-economic gradient of childlessness (Schubert and Dudel, 2025b). Moreover, in East Asian countries excessive male populations were linked to increased crime, sexually transmitted diseases Edlund, 2005; Edlund et al., 2013; C. Tucker and Van Hook, 2013. Another risk is a cultural backlash regarding progress in gender equality.

Another finding of this study is that male fertility can be readily approximated with a regression-based approach using adult sex ratios and female TFR. While Keilman, Tymicki, and Skirbekk, 2014 suggested this approach and found only a lower model fit ($R^2 = 0.83$), we obtain excellent model performance statistics ($R^2 = 0.97$) and out of sample prediction error ($RMSE = 0.041$), especially with a model accounting for age-gaps between partners. Moreover, the regression-based approach seems to be superior in approximating male fertility compared to a naive standardization approach, which highlights the relevance of age gaps between partners (Dudel, Cheng, and Klüsener, 2023; Schoumaker, 2019). However, in certain cases, like in Ethiopia, the United Arab Emirates, and Qatar, our approximation may not provide correct estimates, due to sex-selective labour migration (Schoumaker, 2019; Shiferaw et al., 2025). We encourage future research to fine-tune this model further.

## 4.1 Limitations

The study has two major limitations. First, male fertility is not directly observed, but approximated through various indirect methods using population structures and female fertility rates. While these approximations yield a high out-of-sample fit (see Section 2.2.1) and observed data on male fertility have problems itself (Dudel and Klüsener, 2019; Joyner et al., 2012), the models assume a certain relationship between female TFR and population structure to male TFR, which may not hold. For instance, our results deviate in special cases like the United Arabic Emirates or Qatar from the results reported in Schoumaker, 2019, because male-dominated labor migration leads to changing population structures, but not fertility, rendering our approximation imperfect. Secondly, we only estimate average fertility, e.g. total fertility rates, and do not study parity-specific fertility. Previous research indicates that subnational population imbalances in Finland mainly affect childlessness of the abundant sex (Schubert and Dudel, 2025b), but this may play out differently in other contexts.

## 4.2 Outlook

The data from the United Nations suggests a growing masculinization of populations at reproductive age, which will come with challenges and opportunities. The challenges are mainly posed on those men who may remain unpartnered and childless, which is often associated with worse health and growing dependence on professional care at old age. We propose the following specific policy recommendations to address fertility disparities or their consequences (e.g., male childlessness, marriage market imbalances): strengthened position of women in societies to prevent artificially high sex ratios at birth, better education and creation of jobs to give childless and single men opportunities for a career and to reduce susceptibility for organized crime, and technical solutions for singles and childless individuals - AI buddies, friendship groups, artificial reproductive technologies. Failing to address the needs of these men will risk a cultural backlash regarding sex equality and societal conflicts.

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## Author contributions statement

H.S., V.S., and T.S. contributed to conceptualization of the project and wrote and reviewed the manuscript. H.S. conducted the formal analysis.

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