A Global Male Fertility Database: Rationales, Objectives, and First Results[1]

Abstract for the 2025 IPC Conference

Bruno Schoumaker[2] (UCLouvain), David A. Sánchez Páez (University of Valladolid, UCLouvain), Chaimae Drioui (UCLouvain)

1. Introduction

Research on human fertility – i.e., whether people have children, how many, when, and why – has traditionally focused on women. However, men's fertility, a crucial aspect of human populations, has largely been overlooked in demographic research (Andro and Desgrées du Loû 2009; Coleman 2000; Dudel and Klüsener 2019; Zhang 2011; Greene and Biddlecom 2000). While the importance of analyzing both men and women in areas like mortality and migration is widely recognized, this idea has not yet fully permeated fertility research (Andro and Desgrées du Loû 2009; Schoumaker 2019; Zhang 2011). This gap is evident in the scarcity of international databases on male fertility, which poses a challenge for comparative research.

Male fertility, often overlooked, is key in several respects. Given the fundamental role of reproduction in people's lives and human societies, understanding even basic facts about male fertility is important to our knowledge of human populations. Theoretical approaches to fertility transitions have also long recognized the role of males in fertility behavior, but these theories have largely remained "in search of evidence" (Coleman 2000). Better indicators of male fertility are also necessary for mortality research, for instance, for documenting paternal and double orphans (Hillis et al. 2021) or for indirect mortality estimates (Paget and Timaeus 1994; Timaeus 1991). It also has implications for evolutionary perspectives in demography (Tuljapurkar, Puleston, and Gurven 2007) or for modeling kinship networks through male lines of descent (Caswell 2022), to name a few.

In this paper, we present the construction of a Global Male Fertility Database, an effort aimed at providing comprehensive data on male fertility worldwide. We discuss the rationales for such a database, the objectives, some challenges, and the first results. The primary goal of this project

[1] This work is supported by FRS-FNRS, Grant T.0205.23 « Male fertility around the world and over time: constructing a world male fertility database .»
[2] Corresponding author: Bruno Schoumaker, Centre for Demographic Research, UCLouvain, L2.08.03 Place Montesquieu, 1348 Louvain-la-Neuve, Belgium (bruno.schoumaker@uclouvain.be).

is to reconstruct past and project future male fertility around the world. The need for this database is underscored by the fact that the levels and trends of male fertility differ from female fertility in many settings. Comparative data on male fertility are necessary to draw a "full picture" of fertility transitions and document how fertility transitions differ between men and women. Beyond their interest from a demographic perspective, these indicators are influenced by social and economic changes and reflect broader societal changes.

2. Background

Despite the lack of research on men's fertility, research in diverse contexts has shown that reproductive experiences can be very different among men and women (Coleman 2000; Schoumaker 2019; Kuczynski 1932; Pison 1982; Nordfalk, Hvidtfeldt, and Keiding 2015; Ratcliffe, Hill, and Walraven 2000; Dudel and Klüsener 2019). In most countries, and probably for most of human history, men's fertility has been higher, and often much higher, than women's fertility (Schoumaker 2019). For instance, in several sub-Saharan African countries, men have twice as many children as women at the end of their reproductive lives (Schoumaker 2019; Ratcliffe, Hill, and Walraven 2000; Pison 1982; Donadjé 1992). In contrast, men's fertility is now slightly lower than women's in Western countries, which is also expected to happen in developing countries (Schoumaker 2019). However, this shift from a "male advantage" to a "female advantage" has largely gone unnoticed in the demographic literature.

Men's fertility also occurs later than women's in all the world countries (Schoumaker 2019) because of the age gap between partners (Field et al. 2016; Mignot 2010). In some countries, mainly in sub-Saharan Africa, men have children on average 10 to 15 years later than women (Schoumaker 2017; 2019). As shown in previous work, the age gap between partners and the population's age structure is a critical factor in the differences in the number of children men and women have. While later age at fertility among men is well-established (Schoumaker 2019; Paget and Timaeus 1994), changes in the age patterns of men's fertility during and after the fertility transition have been much less studied. In European countries, recent research has shown that the mean age at fatherhood has increased at the same pace as the mean age at motherhood (Dudel and Klüsener 2021). In contrast, men tend to have their children (on average) much younger than before in several African countries (e.g., Ghana), leading to quickly decreasing differences between men and women. Yet, in other countries, the mean age at fatherhood has remained stable (Schoumaker 2019), and so has the difference between age at fatherhood and age at motherhood. These different trends in age patterns of male fertility may, for instance, reveal changes or resistance to changes in gender relations and highlight different paths in fertility transitions. Changes in the variance in age at fatherhood is another indicator that has received little attention. Yet, it is likely to decrease substantially during the transition, indicating a concentration of male fertility in a smaller age range. Age at first birth has also mainly been analyzed using data from women. The recent increase in men's age at first child is well documented in Western countries (Stykes 2011). However, such information is currently lacking in most countries of the world. Research in Sub-Saharan Africa has shown that trends in age at first birth may also differ between men and women (Kinziunga Lukumu and Schoumaker 2018) and that trends among men are very different from those observed in Europe.

Finally, another critical indicator of fertility is the spread of childlessness. Childlessness has increased among women in Western countries (Sobotka 2017) and has gained ground in the Global South's low and medium-fertility countries (Pérez 2021). Existing data indicate it is often more frequent among men than women (Tanturri et al. 2015; Verkroost and Monden 2022), especially among men with low social status. However, the measurement of final childlessness among men is affected by considerable uncertainty (Sobotka 2017) and has received much less attention than women's childlessness.

3. Objectives

The Global Male Fertility Database has the ambition to reconstruct past and project future male fertility around the world in as many countries as possible. The database will focus on the following male fertility indicators, as well as their equivalent for female fertility:

1. Male age-specific fertility rates
2. Total fertility rates and completed cohort fertility
3. Number of births by age of the father
4. Mean age at fatherhood and variance in age at fatherhood
5. Mean and median age at first birth
6. Percentage of childless men by age groups and final childlessness

In this paper, we present the first phase of the database's construction, focusing on the estimation of male age-specific fertility rates in 185 countries. Male age-specific fertility rates will also be used to compute derived indicators such as total fertility rates, mean age at fatherhood, variance in age at fatherhood, and the number of births by fathers' age. All these indicators will be compared with female fertility indicators. In this abstract, we briefly present and comment on some of these preliminary results.

The database will be made available in open access. A Shiny app (under construction, male-fertility.shinyapps.io/ShinyApp_MFDb/) will allow users to access and visualize the data (e.g., trends at the country level or comparisons across countries). More information on the project and methods will also be made available online (sites.uclouvain.be/male-fertility).

4. Computing and estimating male age-specific fertility rates

The lack of data is frequently mentioned as a reason for the limited knowledge of male fertility in many countries (Goldscheider and Kaufman 1996; Greene and Biddlecom 2000; Andro and Desgrées du Loû 2009; Coleman 2000; Schoumaker 2017; Zhang 2011). Data quality issues may also hamper research on male fertility. As shown in several research, underreporting of births by men may occur in surveys, especially among young men (Joyner et al. 2012; Schoumaker 2017; Rendall et al. 1999). In countries with deficient civil registration and vital statistics systems (CRVS), registered births may only be a fraction of the total number of births. Missing information on age is also more frequent for fathers than for mothers (Dudel and Klüsener 2019). Despite these limitations, a large amount of untapped data exists, and we expect to produce reliable – though imperfect – estimates of male fertility rates in a large number of countries.

4.1. The data

The estimation and reconstruction of male age-specific fertility rates worldwide rely on several data sources. In Western countries, civil registration and vital statistics systems (CRVS) are the primary sources of data on male fertility data. These are published in the United Nations Demographic Yearbooks and by some National Statistical Offices. Some researchers have also reconstructed time series for 17 countries (Dudel and Klüsener 2021; Brouard 1977). However, surveys and censuses are the main data sources for empirical estimates in most countries. Our work will rely on around 700 surveys and censuses conducted worldwide (e.g., DHS, MICS, RHS, censuses on the IPUMS database, including historical data, etc.).

4.2. Obtaining or computing male age-specific fertility rates

The first step consists of obtaining or computing male age-specific fertility rates using different data sources.

Data from CRVS

At this stage, CRVS data were obtained from two sources: United Nations Demographic Yearbooks (UNDY, unstats.un.org/unsd/demographic/products/dyb/) from 2007 to 2021[3] and data on male fertility from the Human fertility collection (www.fertilitydata.org). Data published in the UNDY are presented by 5-year age groups for single calendar years (see example in Appendix Figure 1). In some instances, only births in wedlock are available for the computation of male age-specific fertility rates[4]. The Human Fertility collection covers 17 countries (Appendix Table 1), mostly between the late 1980s and mid-2010s. Age-specific fertility rates are provided by single ages and single years. Data from the UNDY are available for 89 countries; all the HFC countries but Taiwan are also in the UNDY, often with more recent data. In some countries, data is available for most years between 2007 and 2021, while others only have a few data points (Appendix Table 2). In total (HFC and CRVS), data is available for at least one date in 90 countries.

Data from DHS, MICS, and PAPFAM surveys and censuses

As shown in previous work, surveys and censuses can be used to reconstruct male fertility trends over several decades using the household roster data and the own-children method (Schoumaker 2017; 2019). The method is described in detail and compared with other methods in Schoumaker (2017). It uses data collected on living children and their biological fathers to compute male age-specific fertility rates between 15 and 79. This can be done for periods up to 15 years preceding a survey. When several surveys are available – as is often the case – births and exposure from successive surveys can be pooled, allowing the computation of rates over close to 50 years in some cases. Up to now, we have estimated male age-specific fertility rates in 74 countries by 5-year periods with DHS data, covering the period from the early 1980s to the late 2010s in most countries (See Appendix Table 3). Some of these 74 countries (e.g., Albania, Armenia) are also covered by CRVS. Still, for most of them, these surveys provide the only available estimates of male age-specific fertility rates. Data from MICS and PAPFAM were also used in 34 countries to compute male age-specific fertility rates (See Appendix Table 4). At this stage, we focused on countries that had missing information from other sources, but more MICS and PAPFAM surveys could be used for our purpose. Finally, census data – obtained from IPUMS international (international.ipums.org) – were also used in a limited

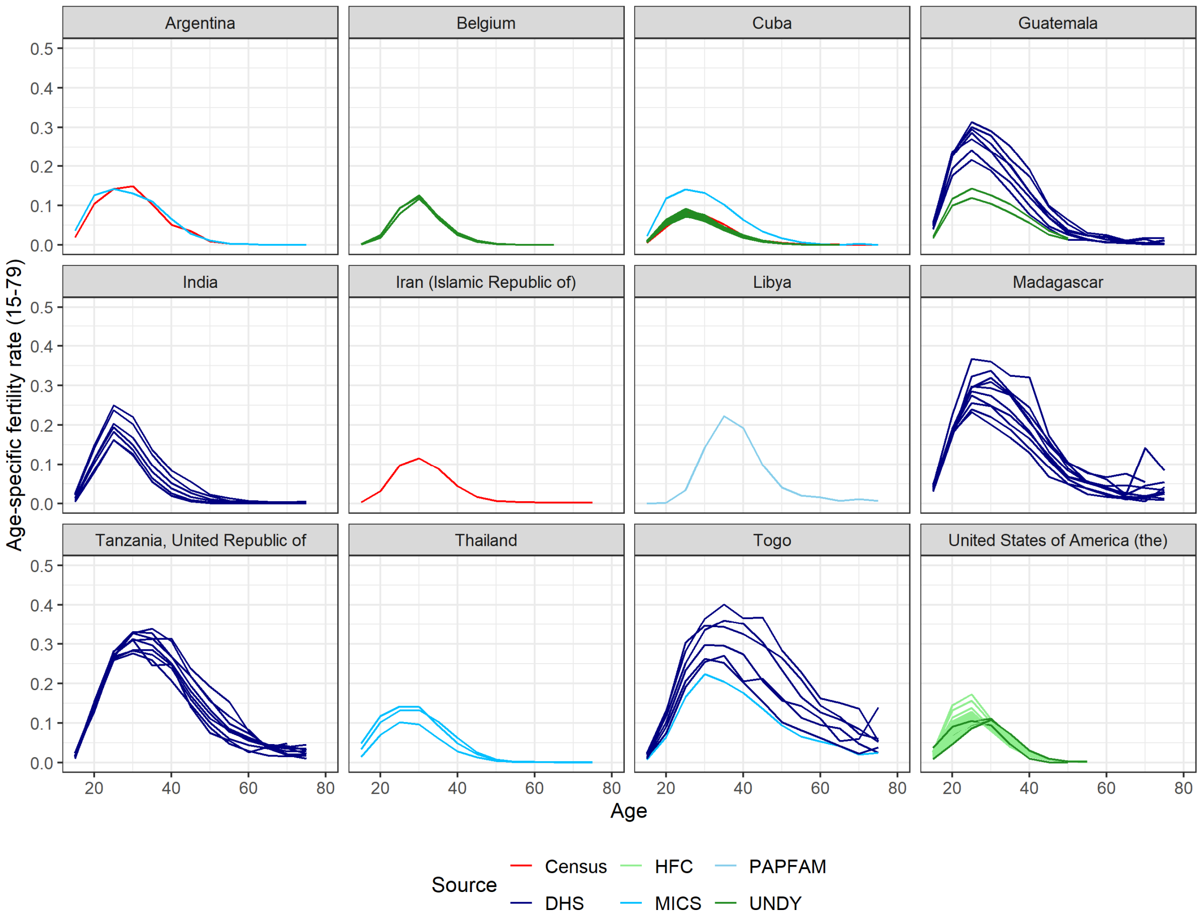
[3] Data from earlier UNDY, sometimes going back to the 1940s, will be exploited later.
[4] In these cases, the rates were adjusted upwards by a factor equal to the ratio of the total number of births (obtained from women's data) to the number of births in wedlock. By doing so, we assume the share of births out of wedlock is constant across ages.

number of countries (7). The own-children method was also used in a slightly different way. The main difference is related to the use of external information (UNWPP data) to reverse-survive children and fathers. Although a much larger number of censuses could be used, especially for past estimates, we have currently focused on the most recent ones.

Illustration of raw estimates of male age-specific fertility rates

Figure 1 illustrates raw estimates of male age-specific fertility rates for 12 selected countries on several dates. In some countries, rates can be obtained or computed from different types of sources. Estimates can be consistent across sources (e.g., as in Argentina, estimates from the census and the MICS) or differ widely (e.g., in Guatemala, where CRVS data from UNDY are much lower than survey estimates). We also find that some estimates of male age-specific fertility rates, especially those from demographic surveys, can be erratic because of small sample sizes and/or data quality issues. This is especially clear in Togo and Madagascar (DHS estimates). We discuss this issue later.

Figure 1: Male age-specific fertility rates at several dates in 12 selected countries

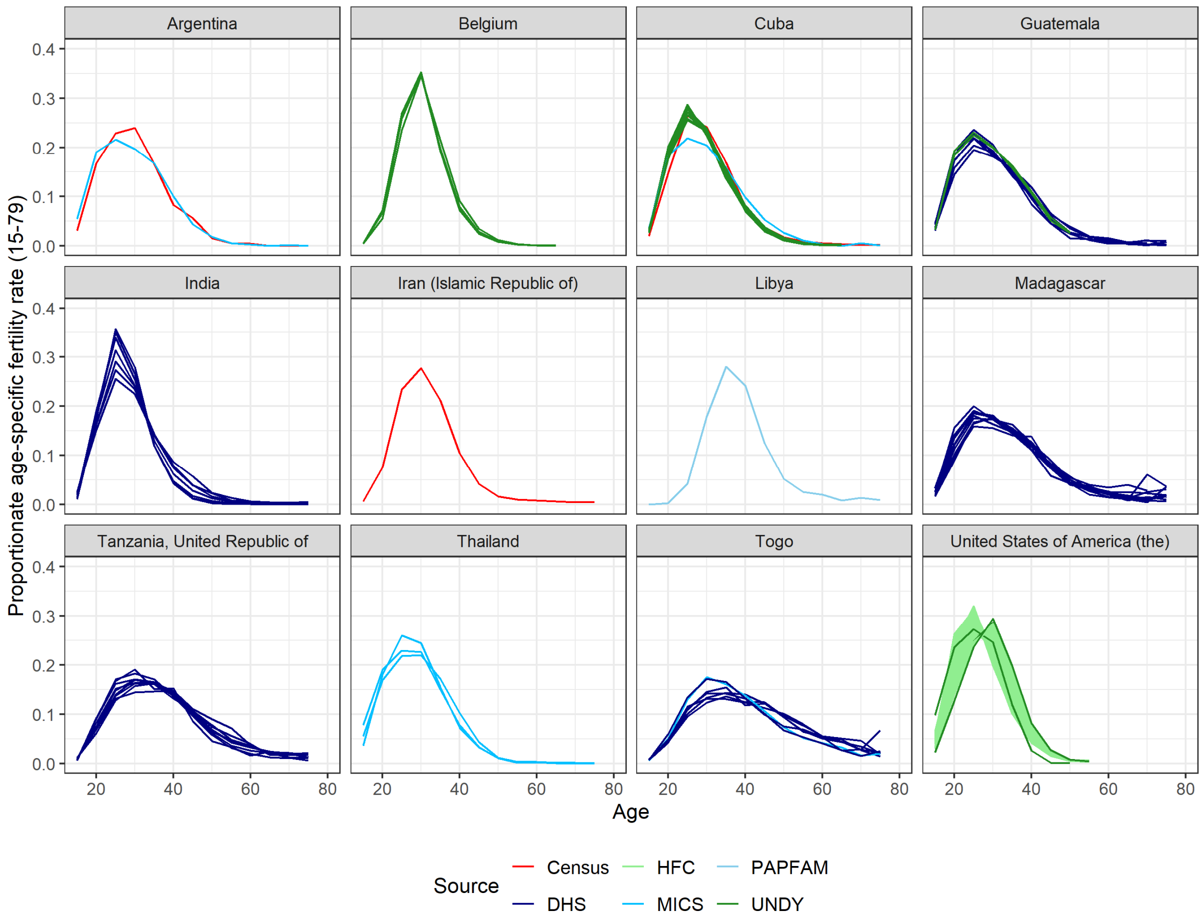


4.3. Computing and smoothing age patterns of male fertility

Relative age patterns

As explained below, we will also use the age patterns of fertility rather than just the age-specific male fertility rates. We compute proportionate age patterns by dividing each age-specific rate by the sum of the rates so that the sum of these values equals one. Figure 2 shows that, despite differences in levels of fertility across sources (as in Guatemala), age patterns tend to be highly consistent across data sources. In some countries, these patterns have been stable over time (e.g., Madagascar), but they have shifted to higher ages in some countries (e.g., India and the United States).

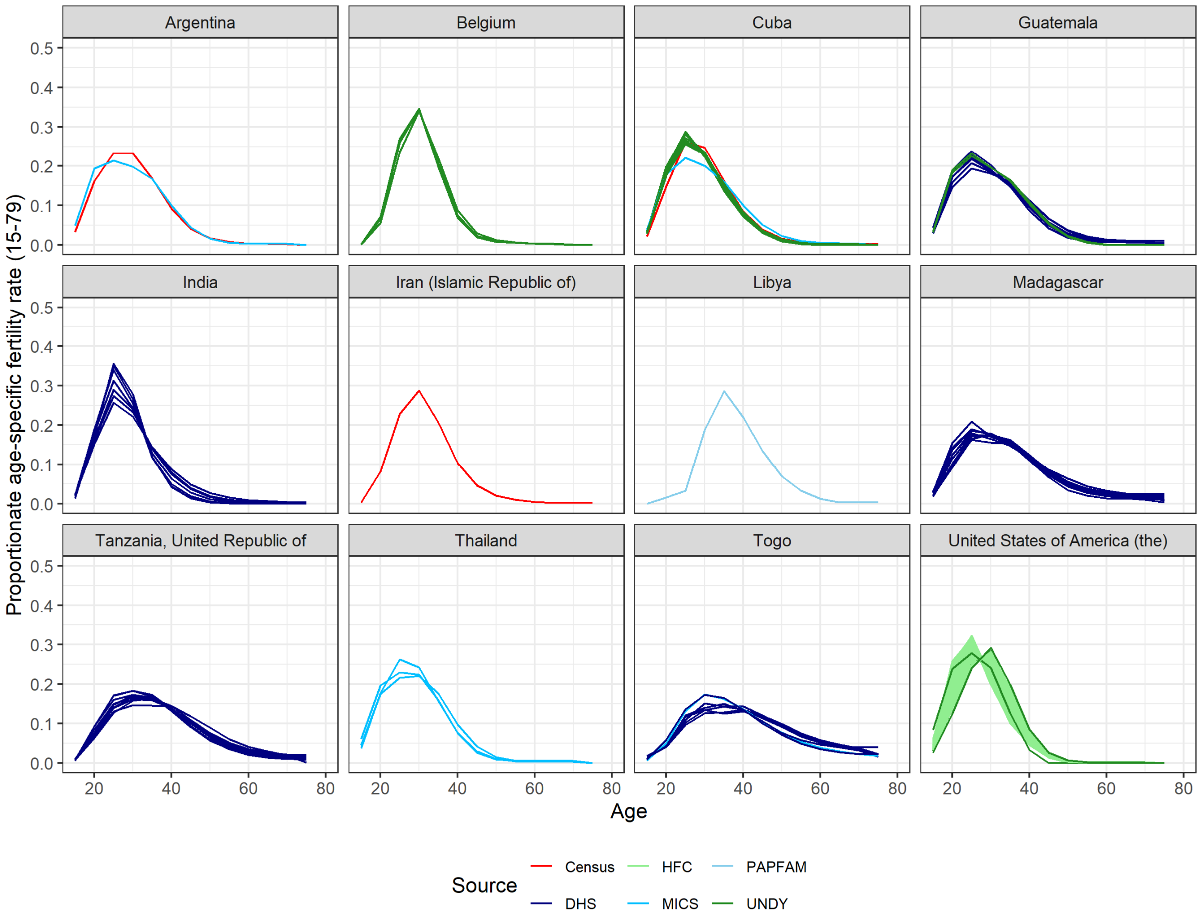
Figure 2: Proportionate male age-specific fertility rates on several dates in 12 selected countries



Smoothing age patterns with principal components analysis

The proportionate age patterns are still affected by data quality issues and random fluctuations. To correct these erratic variations, we smoothed all the rates using principal components analysis. Briefly stated we use a matrix of 1699 series (columns) and 13 age groups (lines) to identify a small number of components that summarize these age patterns. We find that 5 components account for most of the variance. Next, for each of the 1699 series of proportionate male age-specific fertility rates (combination of country and year), the 5 components are used as independent variables in a regression to predict proportionate age-specific fertility rates (dependent variable). Predicted values are the smoothed estimates of the male age patterns of fertility. We make two adjustments in a few instances: negative predicted values are replaced by zeros, and we ensure that rates do not increase with age above age 50, i.e., we replace a rate with the rate of the preceding age group if needed to respect that constraint. As is visible in Figure 3, smoothing mainly affects survey-based estimates (e.g., Togo, Madagascar, Tanzania).

Figure 3: PCA-smoothed proportionate male age-specific fertility rates at several dates in 12 selected countries



Imputing, interpolating, and extrapolating age patterns

In this first version of the database, we restrict estimates to four 5-year periods: 2000-2005, 2005-2010, 2010-2015, and 2015-2020. We used linear interpolation to obtain age patterns in the years 2003, 2008, 2013, and 2018. If the earliest age pattern was after 2003, we considered the earliest age pattern to be constant. If the latest age pattern was before 2018, we considered the age pattern to be constant after that date. Finally, in ten countries with no data on age patterns of male fertility, we borrowed the age patterns from similar countries (see Appendix Table 6). These estimates will be refined later by using imputation methods to identify age patterns.

4.4. Computing male age-specific fertility rates from age patterns, age structures, and number of births

The next step consists of combining the age patterns of male fertility with published estimates of the number of births and men's age structure from the United Nations World Population Prospects. The idea behind this approach point is that male age-specific fertility rates (and the total fertility rate) should generate the same number of births as those obtained with female age-specific fertility rates (Schoumaker 2019).

We have estimates of the population of males by age for different periods (past or future) as well as the total number of births during these periods. As a result, one needs only define a series of proportionate age-specific male fertility rates (that sum to 1) to estimate the male total fertility rate from the number of births. The male total fertility rate for year t is obtained with the following formula:

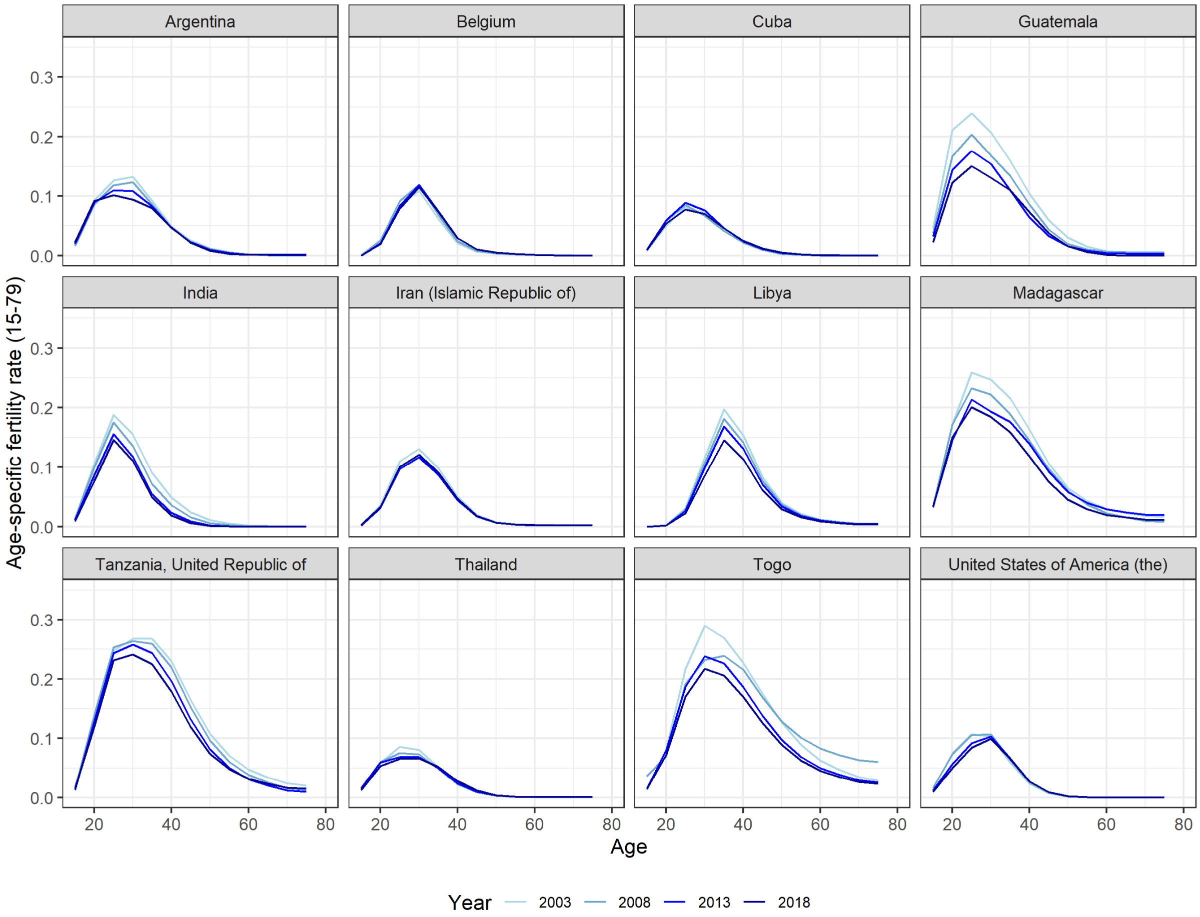
$$TFR^{m}(t) = \frac{B(t)}{\sum_{x=15}^{79} f_x^{0m}(t).M_x(t)} \qquad \text{[Eq. 1]}$$

Where $B(t)$ is the annual number of births during period t, $f_x^{0m}(t)$ are proportionate age-specific male fertility rates at age x during period t (age pattern) and $M_x(t)$ is the number of males aged x at mid-period *t*. $B(t)$ and $M_x(t)$ are obtained from the United Nations World Population Prospects (United Nations Population Division 2019)[5].

We use this method to transform the age patterns obtained in the previous steps into male age-specific fertility rates (Figure 4). As explained later, the method can be used either retrospectively or for projections if reasonable estimates of age patterns of male fertility can be obtained. The method also ensures consistency between female fertility estimates and male fertility estimates, i.e., they lead to the same number of births.

[5] Currently, the 2019 revision is used. Updates will be based on the most recent version of the World Population Prospects.

Figure 4: Adjusted male age-specific fertility rates dates in 12 selected countries in 2003, 2008, 2013, and 2018



5. Preliminary results

We focus on male age-specific fertility rates produced for 185 countries and four time periods (2000-2005, 2005-2010, 2010-2015, and 2015-2020). These rates are compared with World Population Prospects female age-specific fertility rates and can be aggregated at the regional or global level. Derived indicators, such as the number of births by father's age, are also briefly explored. Appendix Figures 2 to 5 illustrate the types of outputs currently available on the Shiny application (under construction).

5.1. Male age-specific fertility rates around the world (2000-2020) and comparisons with female age-specific fertility rates

Figure 5 shows male age-specific fertility rates for 12 selected countries for four periods. It illustrates, for instance, the significant variations in male age-specific fertility rates across countries. In Sub-Saharan African countries, male fertility remains high well beyond age 50, as shown in previous works (Pison 1986; Ratcliffe, Hill, and Walraven 2000; Schoumaker 2019).

Figure 5 also illustrates that changes tend to be more rapid at high ages than at young ages, which translates into a decrease in the mean age at fatherhood in many countries. Figure 6 further shows the age-specific fertility for the 185 countries by sub-regions in the most recent period (2015-2020). As is apparent, sub-Saharan Africa has a distinct pattern, with overall much higher male fertility than elsewhere.

Figure 7 and Figure 8 illustrate the differences between male and female fertility in selected countries and by subregions in 2015-2020. While differences between male and female fertility are minor in Western countries – in line with existing literature on the topic (Dudel and Klüsener 2021; Coleman 2000; Bagavos and Tragaki 2017; Schoumaker 2019) – they are much more prominent in high-fertility countries, especially in sub-Saharan Africa. In all countries, men have their children later than women, but this is especially pronounced in sub-Saharan Africa – as in Senegal – where men often have their children on average 10 years later than women. This large difference in the age at which men and women have their children contributes to the large differences in total fertility rates (Schoumaker 2019).

Finally, Figure 9 represents the relationship between male and female total fertility and their changes over time. This again illustrates the fact that the male TFR is higher than the female TFR in high-fertility countries but tends to be slightly lower in low-fertility countries (Coleman 2000; Schoumaker 2019). This figure also shows that in most countries, both male and female fertility have declined. At high fertility levels, male fertility declines faster than female fertility and converges at around 2 children. We come back to these changes in the last section on the reconstruction of long-term changes in male fertility.

Figure 5: Male age-specific fertility rates in 12 selected countries on four dates

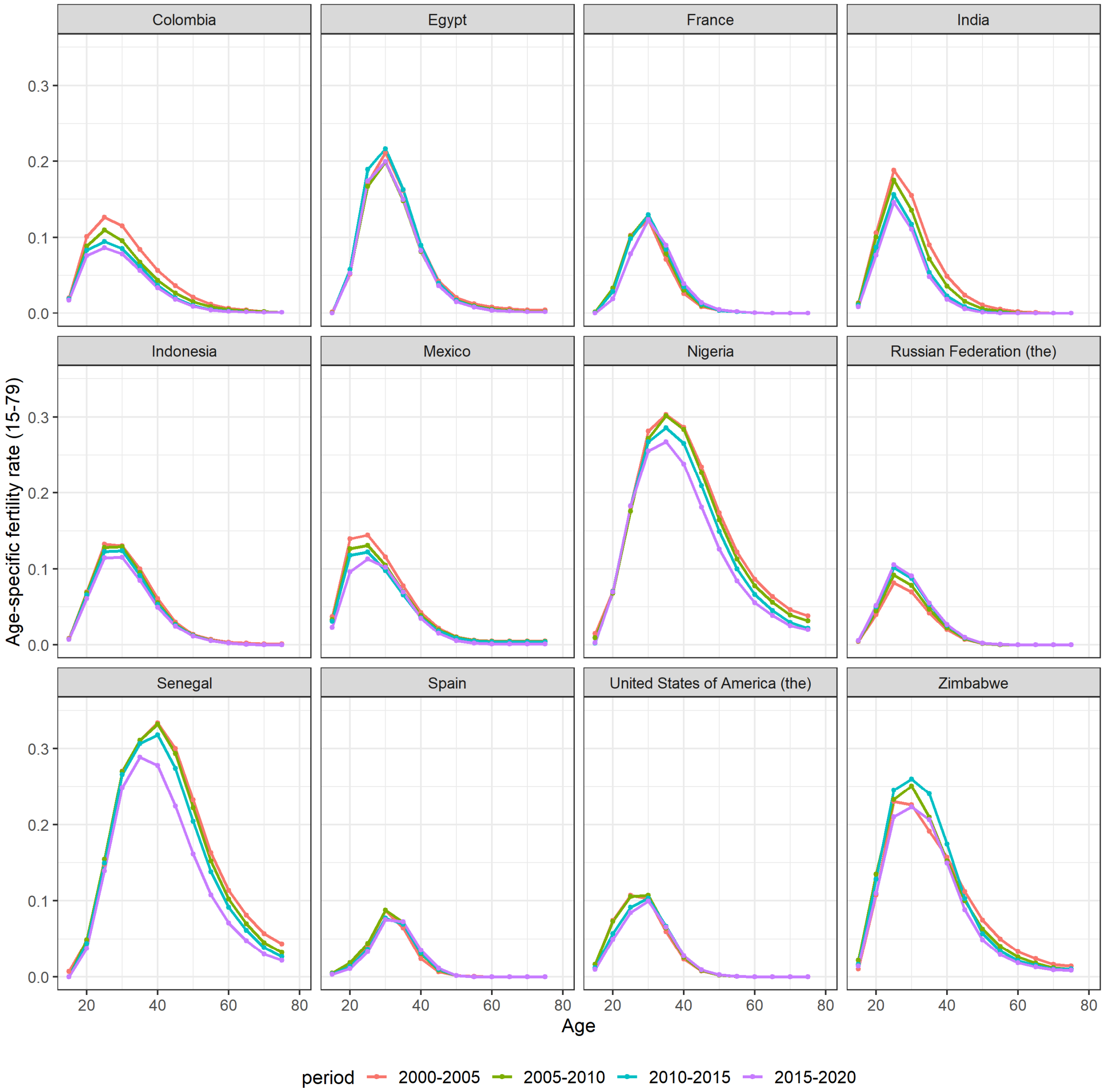


Figure 6: Male age-specific fertility rates in 185 countries by subregions (2015-2020)

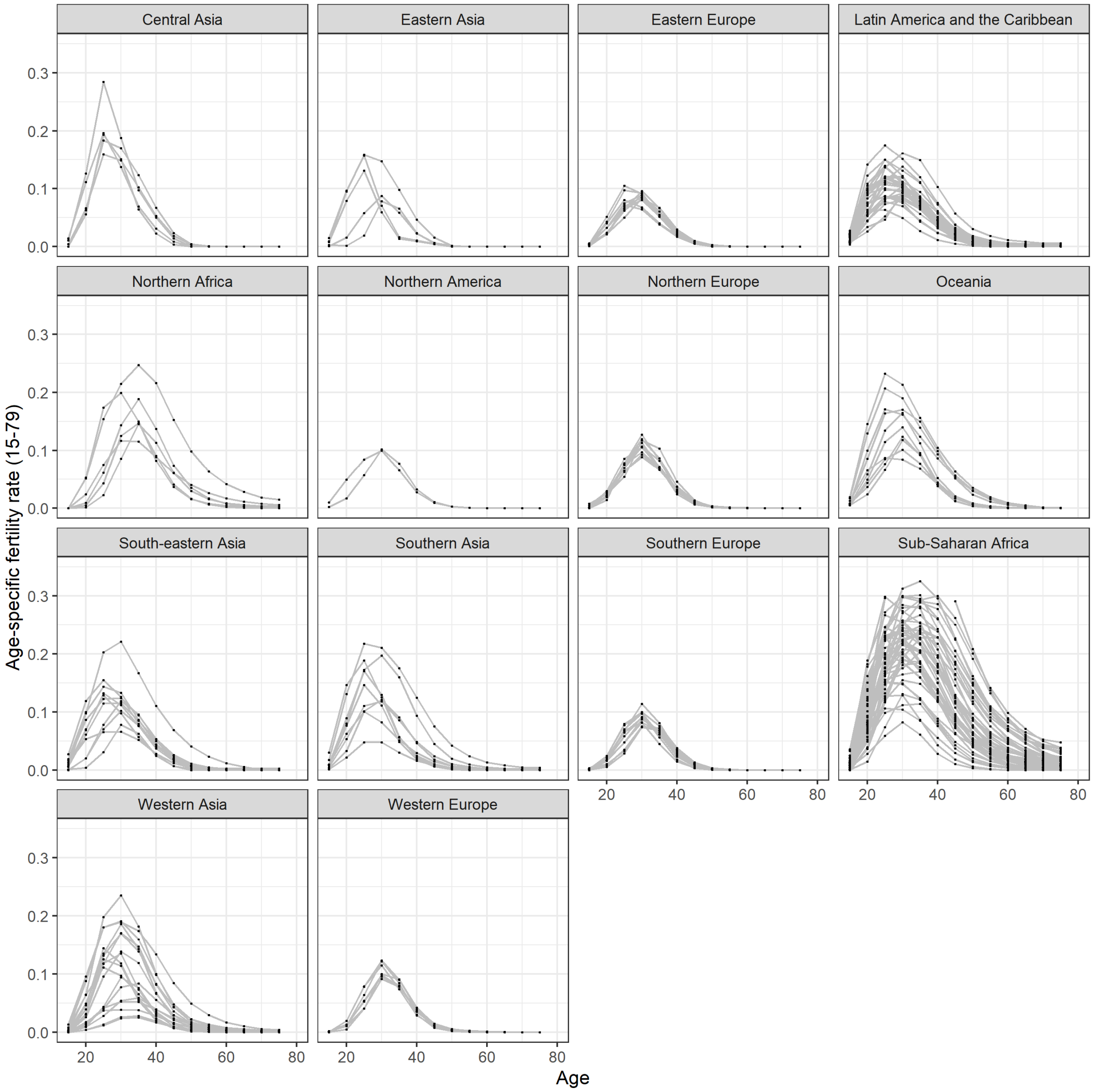


Figure 7: Male and female age-specific fertility rates in 12 selected countries (2015-2020)

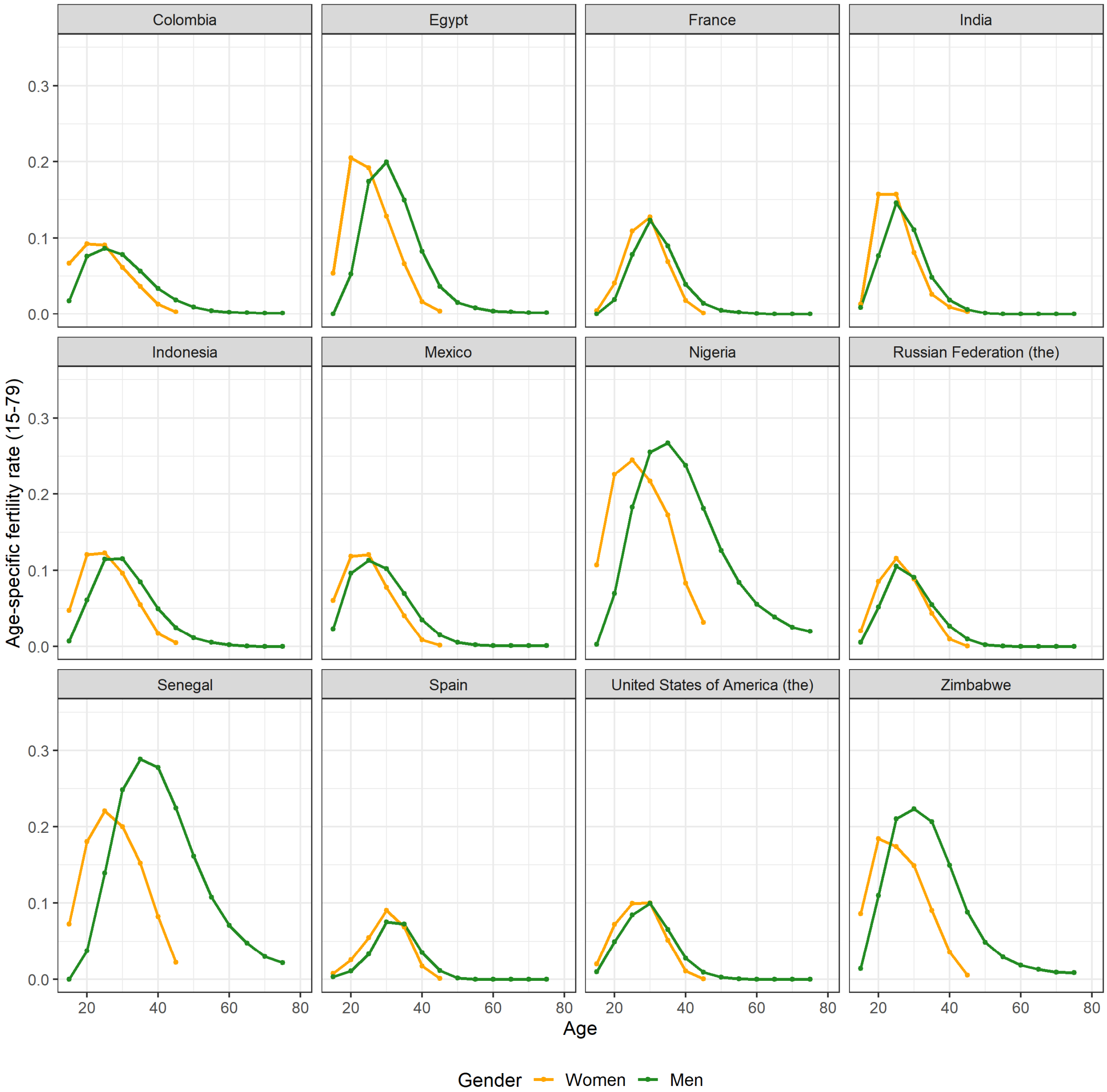


Figure 8: Male and female age-specific fertility rates in 14 subregions (2015-2020)

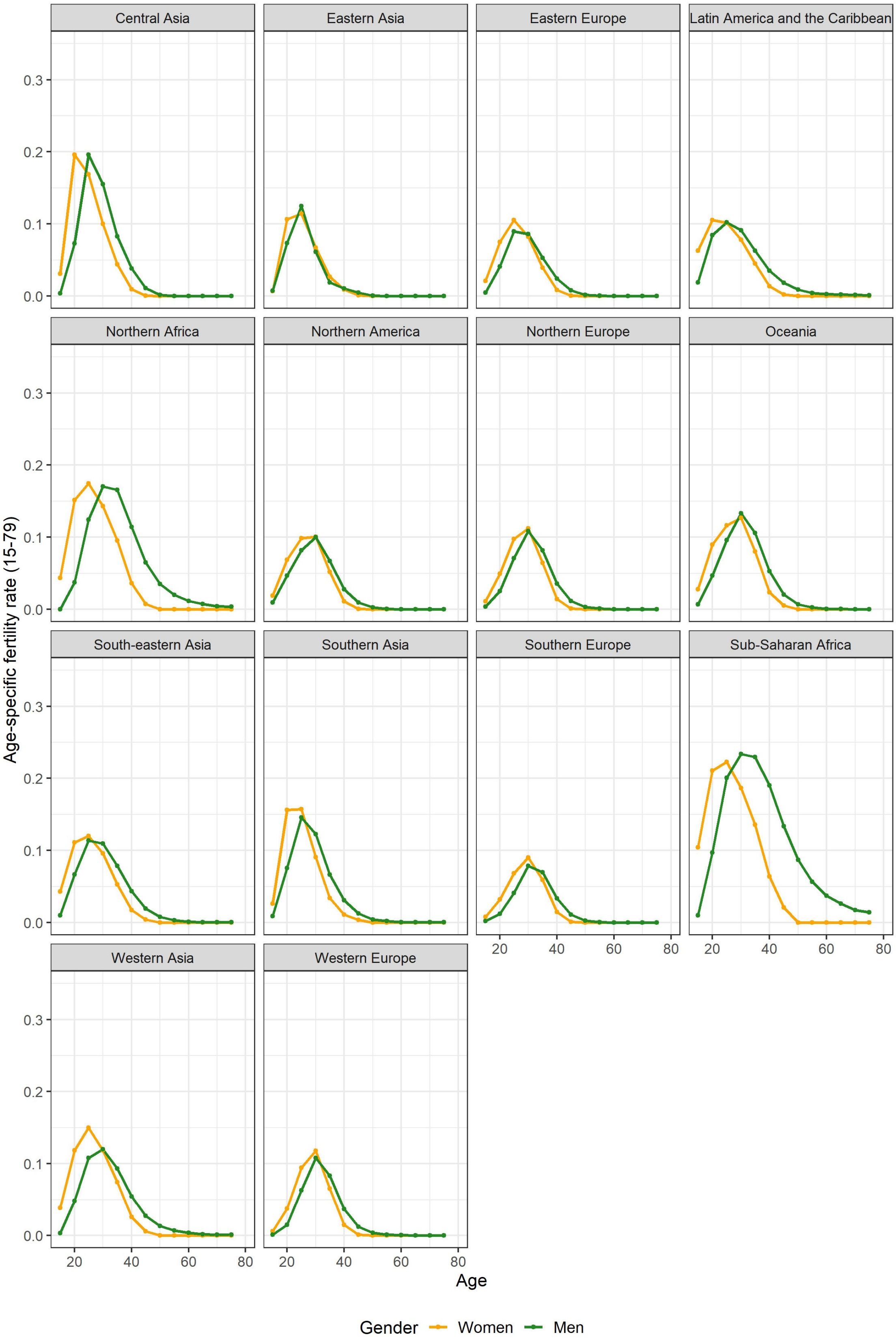
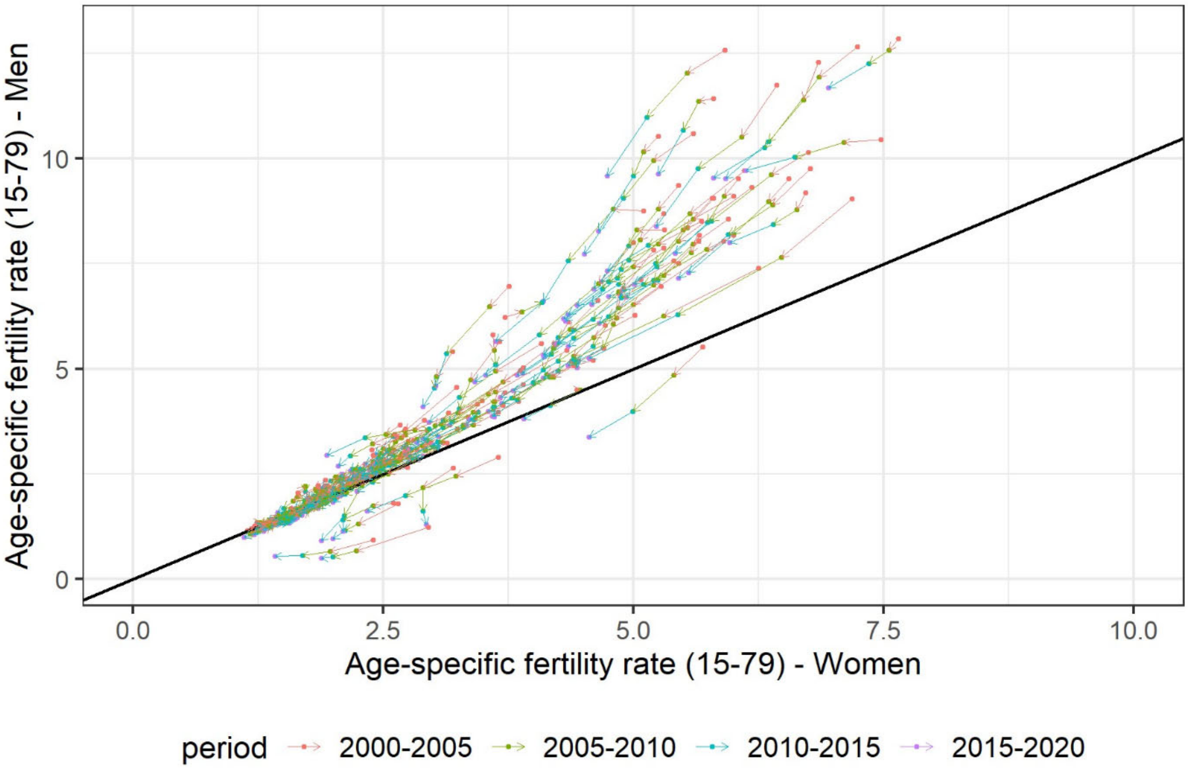


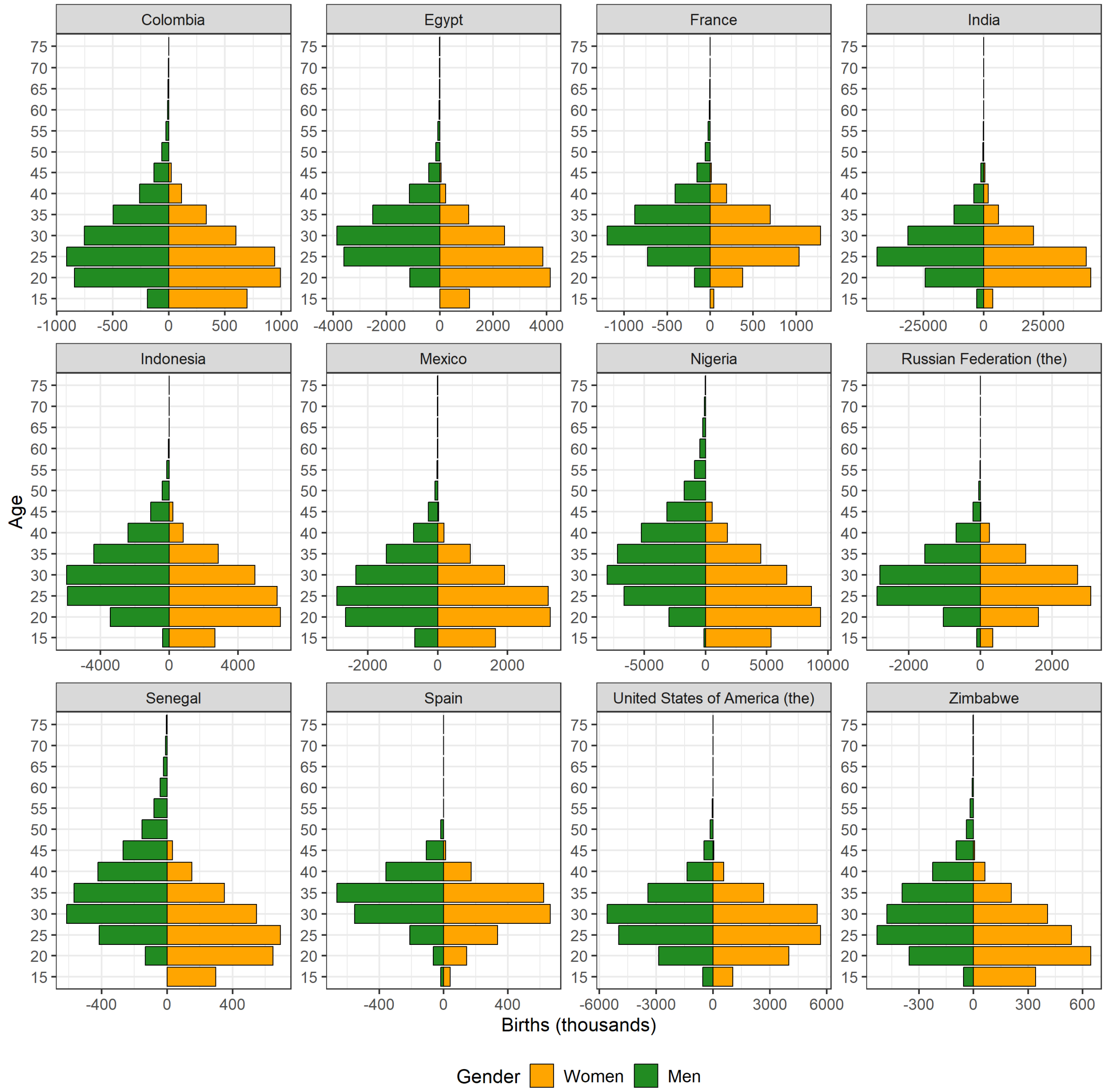
Figure 9: Male and female total fertility rates (TFR) in 185 countries for four periods (2000-2020)



5.2. Distribution of births by age of the father and age of the mother at birth

The combination of male age-specific fertility rates and the number of men by age groups also allows computing the number of births by the age of the fathers at birth. Figure 10 compares the distribution of births by age of the father and age of the mother at birth in 12 countries. A few key features are visible: first, not surprisingly, births from adolescent mothers (below age 20) are much more frequent than births from adolescent fathers. However, situations vary widely across counties. For instance, numbers are close in India and the United States; in contrast, the differences are much larger in African countries. We also find a substantial number of births from fathers aged 50 and over in Africa, while this is more limited in other countries. Such data may be of interest in research on the links between a father's age and children's health, for instance.

Figure 10: Distribution of births by age of the father and age of the mother at birth in 12 selected countries (2015-2020)



6. Beyond recent estimates: a path to reconstructing and projecting male fertility over long periods

Estimating past and future age patterns of male fertility over long periods is necessary for reconstructing and projecting male fertility rates. We briefly outline a method for estimating such age patterns and using them for this purpose. The method is based on the idea that it should be possible to derive the age pattern of male fertility using data on female fertility.

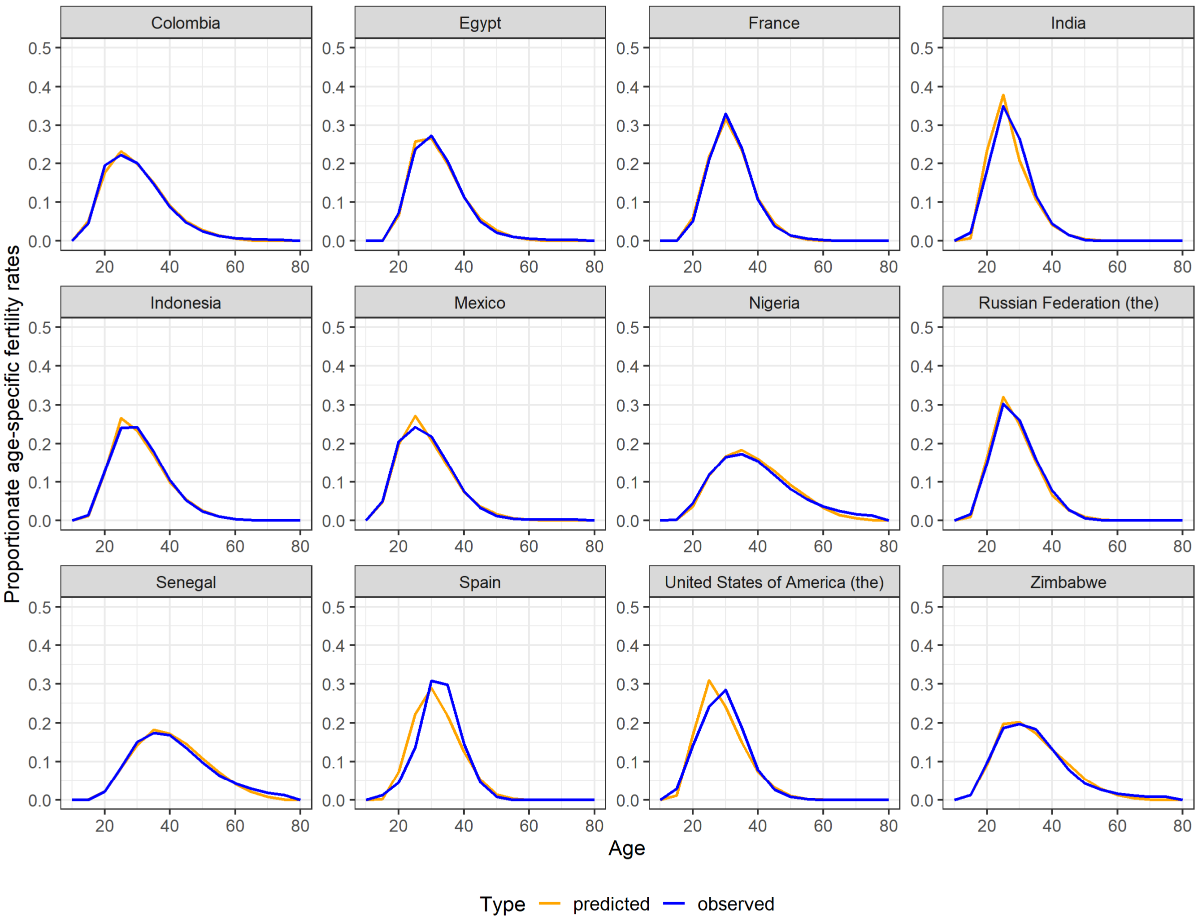
For each year and country in the database (185*4), we use a relational Gompertz model to link the female age pattern and the male age pattern of fertility. We draw from ideas developed by

Paget and Timaeus (1994) in the development of their standard age pattern of male fertility. The first step is, for each year and country, to “stretch” the female age pattern of fertility, for it to vary between 15 and 80 instead of 15 and 50. Age 20 is thus transformed into 15+5/35*65=24.3, etc. Proportionate age-specific fertility rates are interpolated at exact ages (15, 20, 25,…80). Next, we use the relational Gompertz model to estimate two parameters (α and β) that can be used to transform the female age pattern into the male age pattern. The model is written as follows (Paget and Timaeus 1994)

$$Y_m(x) = \alpha + \beta \times Y_f(x) \qquad \text{[Eq.1]}$$

Where $Y_f(x) = -\ln\left(-\ln\left(F_f(x)\right)\right)$ and $Y_m(x) = -\ln\left(-\ln\left(m(x)\right)\right)$, with $F_f(x)$ and $F_m(x)$ equal to the cumulated fertility by age in the female and the male age patterns respectively. We only use observations below age 50 for the estimation of the parameters, to avoid an excessive impact of values at high ages. The adjustment is very good in most countries, albeit not perfect in some of them (e.g. Spain, United States of America) (Figure 11).

Figure 11: Comparison of observed and predicted (with the relational Gompertz model) age patterns of male fertility in 12 selected countries (2015-2020)



These results suggest that these two parameters can be used to estimate the male age pattern of fertility from the female age pattern of fertility. We estimated these two parameters for each year and country. The next step is to find a way to impute the values of α and β for a specific country at a given date to translate them into age patterns of male fertility for past estimates and projections.

We use fixed-effect models, where the dependent variables are α_{it} and β_{it}, the independent variables are the female TFR and the mean age at childbearing (MAC) at time t in country i, δ_i are the country fixed effects, u_{ij} are the error terms.

$$\alpha_{it} = \delta_i + b_1 \times TFR_{it}^f + b_2 \times MAC_{it}^f + u_{ij} \qquad \text{[Eq.2]}$$

$$\beta_{it} = \delta_i^* + b_1^* \times TFR_{it}^f + b_2^* \times MAC_{it}^f + u_{ij} \qquad \text{[Eq.3]}$$

These equations are then used to predict the values of α_{it} and β_{it}, which can be used to estimate the male age patterns based on the female age pattern in country i at time t. The method was tested in the 185 countries.

Figure 12 shows trends in male and female TFRs between 1950 and 2080 in 12 countries. It illustrates the large differences between male and female fertility in the 1950s in some countries and the shift from higher male fertility to lower male fertility over time. In Western countries, male and female TFR are similar – although not the same. Figure 13 shows, for the same countries, the mean age at childbearing and the mean age at fatherhood. These figures suggest that the method for reconstructing age patterns of male fertility works well. However, further validation analyses need to be performed. For instance, the observed values in the early 2000s may indeed differ from the predicted values, leading to discontinuities in the trends in mean age at fatherhood (as in India or Russia). Yet, this has a limited impact on the value of the total fertility rates.

Figure 12: Reconstruction and projection of male and female total fertility rates in selected 12 countries (1950-2080)

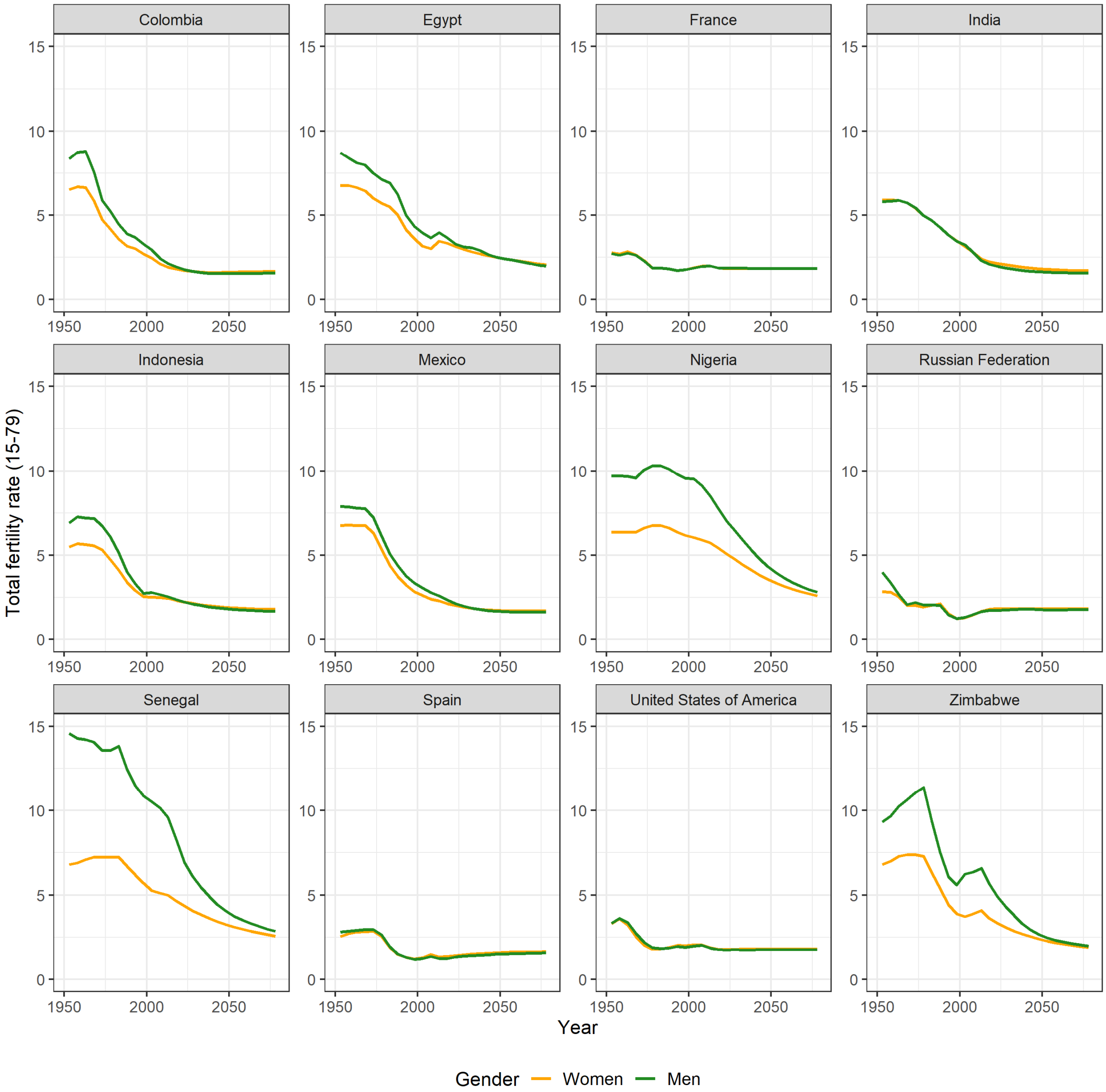
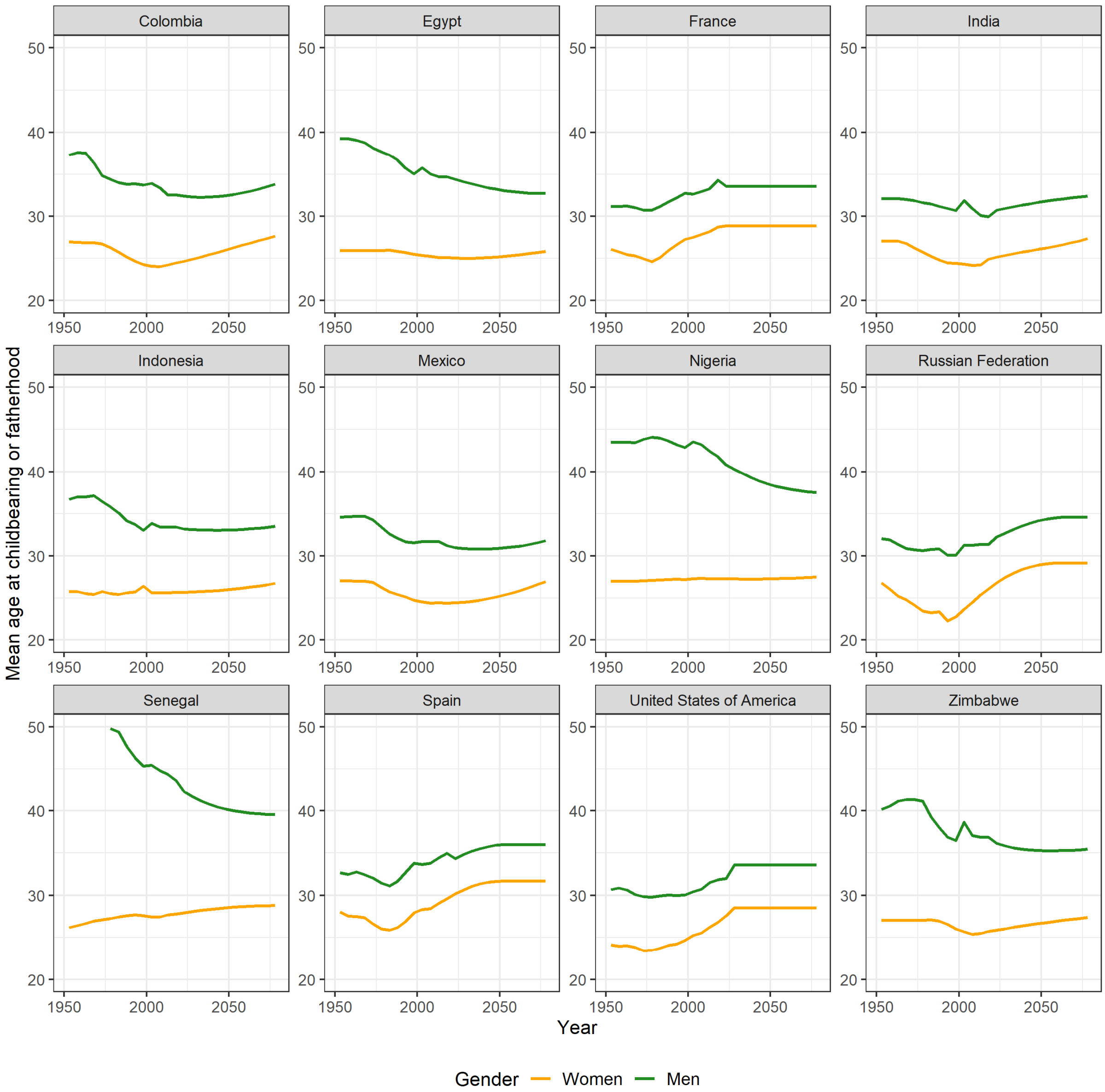


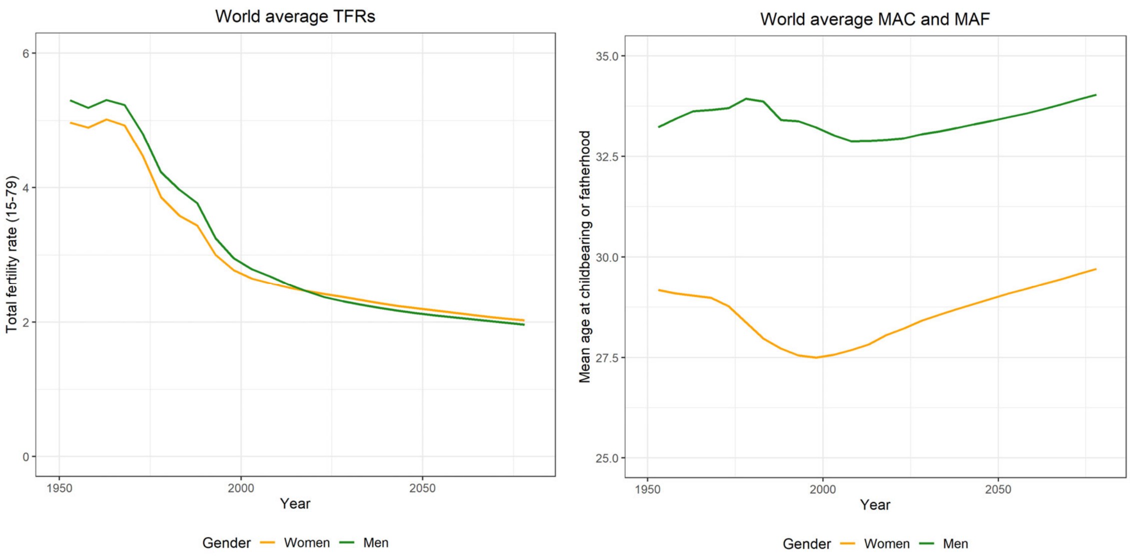
Figure 13: Reconstruction and projection of the mean age at childbearing and age at fatherhood in selected 12 countries (1950-2080)



Global trends in male fertility and mean age at childbearing or fatherhood

A final illustration of the use of the database is provided in Figure 14. Since the numerators and denominators of age-specific fertility rates are estimated for all the periods and countries, they can be aggregated at the global level to compute world average male age-specific fertility rates, as well as total fertility rates and mean ages at fatherhood. Figure 14 clearly shows the shift from higher male fertility to lower male fertility around the world, with the crossing point around the year 2020. According to these data, men have their children on average 4-5 years later than women in the world. As discussed before, differences vary widely across regions, with small differences in some Asian countries and very large differences in African countries.

Figure 14: Reconstruction and projection of the TFR and mean age at childbearing or fatherhood, world averages (1950-2080)



7. Preliminary conclusions

We showed that existing data can be tapped to compute male age-specific fertility rates, as well as some derived indicators, in most countries of the world for the last two decades. The imputation of age patterns of male fertility allows for the reconstruction and projection of male fertility over long periods. The method described in this paper is preliminary and needs further validation, and the results are presented for illustrative purposes. However, they show a few key features that are likely to hold regardless of the refinement in the methodological approaches.

They illustrate the wide variety of situations of male and female fertility around the world and over time (Schoumaker 2019). Estimates of past male and female fertility and projections indicate that the shift from higher male to higher female fertility is over in most Western countries as well as in some developing countries or will occur in the coming decades in low fertility settings. At the global level, we are at the crossing point from higher male fertility (compared to female fertility) to lower male fertility. However, male fertility will remain substantially higher than female fertility in many less developed countries for the coming decades (especially in sub-Saharan Africa), even though male fertility tends to decline faster than female fertility. Currently, differences between male and female fertility are highest in sub-Saharan Africa and lowest in Europe and North America.

Further work will address the following points:

- An in-depth assessment of data quality, including through a systematic comparison of data sources.
- Additional data sources (censuses, other surveys, and vital statistics) will be used to compute age patterns of male fertility for longer periods.
- Other approaches and assumptions for the imputation of age patterns of male fertility will be tested to evaluate the impact of these assumptions on trends in male fertility.
- Other indicators will be progressively included in the database.

References

Andro, Armelle, and Annabel Desgrées du Loû. 2009. "La place des hommes dans la santé sexuelle et reproductive : Enjeux et difficultés." *Autrepart* n° 52 (4): 3–12.

Bagavos, Christos, and Alexandra Tragaki. 2017. "The Compositional Effects of Education and Employment on Greek Male and Female Fertility Rates during 2000–2014." *Demographic Research* 36 (47): 1435–52. https://doi.org/10.4054/DemRes.2017.36.47.

Brouard, Nicolas. 1977. "Evolution de la fécondité masculine depuis le début du siècle." *Population* 32 (6): 1123–58. https://doi.org/10.2307/1531392.

Caswell, Hal. 2022. "The Formal Demography of Kinship IV: Two-Sex Models and Their Approximations." *Demographic Research* 47: 359–96.

Coleman, David. 2000. "Male Fertility Trends in Industrial Countries: Theories in Search of Some Evidence." In *Fertility and the Male Life-Cycle in the Era of Fertility Decline*, edited by Caroline Bledsoe, Susana Lerner, and Jane Guyer, 29–60. Oxford: Oxford University Press.

Donadjé, Florentin. 1992. "Nuptialité et Fécondité Des Hommes Au Sud-Bénin : Faits et Opinions." *Cahiers Québécois de Démographie* 21 (1): 45–65.

Dudel, Christian, and Sebastian Klüsener. 2019. "Estimating Men's Fertility from Vital Registration Data with Missing Values." *Population Studies* 73 (3): 439–49. https://doi.org/10.1080/00324728.2018.1481992.

———. 2021. "Male–Female Fertility Differentials Across 17 High-Income Countries: Insights From A New Data Resource." *European Journal of Population* 37 (2): 417–41. https://doi.org/10.1007/s10680-020-09575-9.

Field, Erica, Vera Molitor, Alice Schoonbroodt, and Michèle Tertilt. 2016. "Gender Gaps in Completed Fertility." *Journal of Demographic Economics* 82 (2): 167–206. https://doi.org/10.1017/dem.2016.5.

Goldscheider, Frances K., and Gayle Kaufman. 1996. "Fertility and Commitment: Bringing Men Back In." *Population and Development Review* 22: 87–99. https://doi.org/10.2307/2808006.

Greene, Margaret E., and Ann E. Biddlecom. 2000. "Absent and Problematic Men: Demographic Accounts of Male Reproductive Roles." *Population and Development Review* 26 (1): 81–115. https://doi.org/10.1111/j.1728-4457.2000.00081.x.

Hillis, Susan D, H Juliette T Unwin, Yu Chen, Lucie Cluver, Lorraine Sherr, Philip S Goldman, Oliver Ratmann, et al. 2021. "Global Minimum Estimates of Children Affected by

COVID-19-Associated Orphanhood and Deaths of Caregivers: A Modelling Study." *The Lancet* 398 (10298): 391–402. https://doi.org/10.1016/S0140-6736(21)01253-8.

Joyner, Kara, H. Elizabeth Peters, Kathryn Hynes, Asia Sikora, Jamie Rubenstein Taber, and Michael S. Rendall. 2012. "The Quality of Male Fertility Data in Major U.S. Surveys." *Demography* 49 (1): 101–24. https://doi.org/10.1007/s13524-011-0073-9.

Kinziunga Lukumu, Felly, and Bruno Schoumaker. 2018. "Fatherhood in Sub-Saharan Africa Patterns, Trends and Differentials in Men's Age at First Birth." In *Meeting of the Population Association of America*. Denver. Handle: http://hdl.handle.net/2078.1/197436.

Kuczynski, Robert René. 1932. *Fertility and Reproduction;Methods of Measuring the Balance of Births and Deaths,*. New York,. http://hdl.handle.net/2027/uc1.$b49920.

Mignot, Jean-François. 2010. "L'écart d'âge entre conjoints." *Revue française de sociologie* 51 (2): 281–320. https://doi.org/10.3917/rfs.512.0281.

Nordfalk, Francisca, Ulla A. Hvidtfeldt, and Niels Keiding. 2015. "TFR for Males in Denmark: Calculation and Tempo-Correction." *Demographic Research* 32 (52): 1421–34. https://doi.org/10.4054/DemRes.2015.32.52.

Paget, W. John, and Ian M. Timaeus. 1994. "A Relational Gompertz Model of Male Fertility: Development and Assessment." *Population Studies* 48 (2): 333–40.

Pérez, Cristina M. 2021. "Male Childlessness across the Adult Life Course: A Case Study Addressing a Potentially 'Vulnerable' Population." *Advances in Life Course Research* 49 (September): 100414. https://doi.org/10.1016/j.alcr.2021.100414.

Pison, Gilles. 1982. *Dynamique d'une Population Traditionnelle : Les Peul Bandé (Sénégal Oriental)*. Travaux et Documents. Paris: INED-PUF.

———. 1986. "La démographie de la polygamie." *Population* 41 (1): 93–122. https://doi.org/10.2307/1533182.

Ratcliffe, A. A., A. G. Hill, and G. Walraven. 2000. "Separate Lives, Different Interests: Male and Female Reproduction in the Gambia." *Bulletin of the World Health Organization* 78 (5): 570–79.

Rendall, Michael S., Lynda Clarke, H. Elizabeth Peters, Nalini Ranjit, and Georgia Verropoulou. 1999. "Incomplete Reporting of Men's Fertility in the United States and Britain: A Research Note." *Demography* 36 (1): 135–44. https://doi.org/10.2307/2648139.

Schoumaker, Bruno. 2017. "Measuring male fertility rates in developing countries with Demographic and Health Surveys: An assessment of three methods." *Demographic Research* 36 (28): 803–50.

———. 2019. "Male Fertility Around the World and Over Time: How Different Is It from Female Fertility?" *Population and Development Review* 45 (3): 459–87. https://doi.org/10.1111/padr.12273.

Sobotka, Tomáš. 2017. "Childlessness in Europe: Reconstructing Long-Term Trends Among Women Born in 1900–1972." In *Childlessness in Europe: Contexts, Causes, and Consequences*, edited by Michaela Kreyenfeld and Dirk Konietzka, 17–53. Demographic Research Monographs. Cham: Springer International Publishing. https://doi.org/10.1007/978-3-319-44667-7_2.

Stykes, J. 2011. "Fatherhood in the U.S.: Men's Age at First Birth, 1987-2010," 2011. http://ncfmr. bgsu.edu/pdf/ family_profiles/ file99036.pdf.

Tanturri, M., M. Mills, A. Rotkirch, T. Sobotka, J. Takács, A. Miettinen, C. Faludi, Venetia Kantsa, and D. Nasiri. 2015. "State-of-the-Art Report. Childlessness in Europe." Families and Societies Working Paper 32. Brussels. https://www.semanticscholar.org/paper/State-ofthe-art-report-Childlessness-in-Europe-Tanturri-Mills/dabbc07c2e1512371f95f1357374eb5b1cb80cd4.

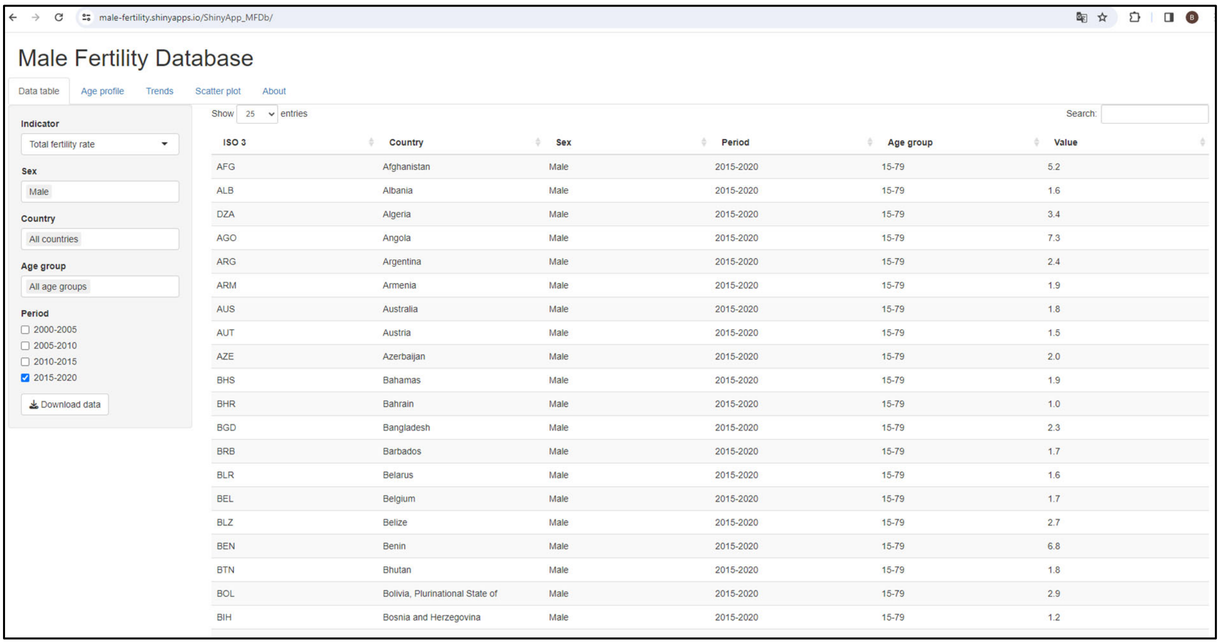
Timaeus, Ian M. 1991. "Estimation of Mortality from Orphanhood in Adulthood." *Demography* 28 (2): 213–27. https://doi.org/10.2307/2061276.
Tuljapurkar, Shripad D., Cedric O. Puleston, and Michael D. Gurven. 2007. "Why Men Matter: Mating Patterns Drive Evolution of Human Lifespan." *PLoS ONE* 2 (8): e785. https://doi.org/10.1371/journal.pone.0000785.
United Nations Population Division. 2019. "World Population Prospects: The 2019 Revision." http://esa.un.org/unpd/wpp/.
Verkroost, Florianne C. J., and Christiaan W. S. Monden. 2022. "Childlessness and Development in Sub-Saharan Africa: Is There Evidence for a U-Shaped Pattern?" *European Journal of Population*, March, 1–34. https://doi.org/10.1007/s10680-022-09608-5.
Zhang, Li. 2011. *Male Fertility Patterns and Determinants*. The Springer Series on Demographic Methods and Population Analysis. Dordrecht: Springer Netherlands.

Appendix Figure 1. Example of data on male fertility from the United Nations Demographic Yearbook

11. Live-births and live-birth rates by age of father: latest available year, 1998 - 2007
Naissances vivantes et taux de natalité selon l'âge du père : dernière année disponible, 1998 - 2007

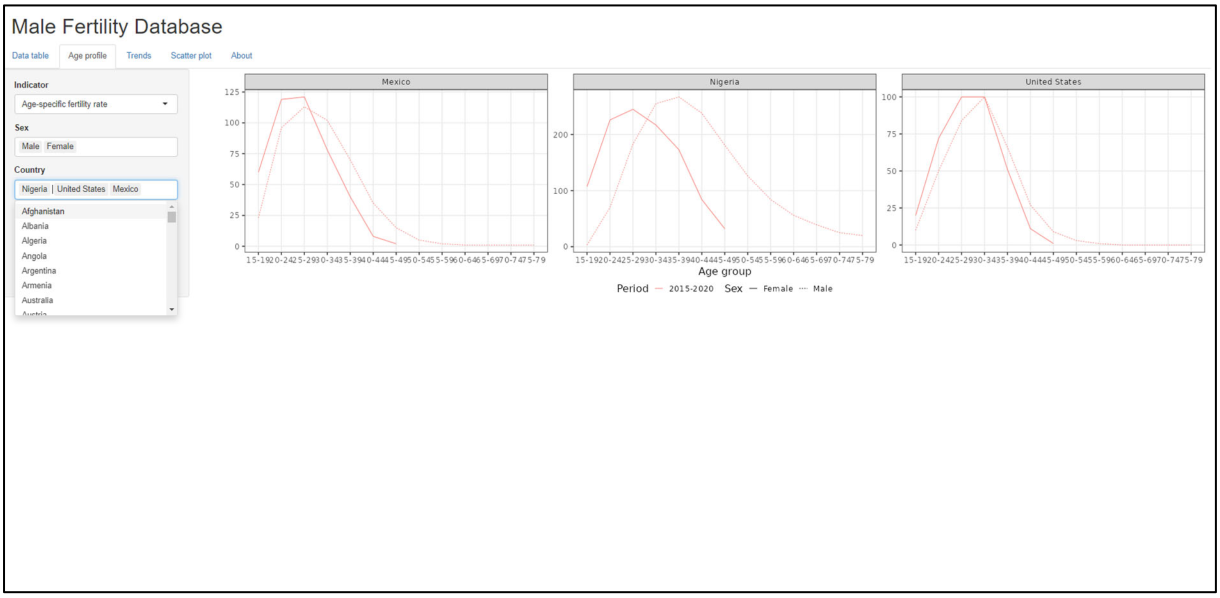
Continent, country or area, year, code and age of father (in years) Continent, pays ou zone, année, code et âge du père (en années)	Number Nombre	Rate Taux
AFRICA - AFRIQUE		
Egypt - Égypte		
2007 (C)		
Total	1 949 569	...
0 - 19	3 926	...
20 - 24	142 740	...
25 - 29	358 052	...
30 - 34	401 283	...
35 - 39	273 238	...
40 - 44	138 236	...
45 - 49	56 181	...
50 - 54	21 178	...
55 - 59	9 281	...
60 +	7 179	..
Unknown - Inconnu	537 275	..
Mauritius - Maurice		
2007 (C)		
Total	16 894	40.3
0 - 19	232	4.6
20 - 24	1 666	37.1
25 - 29	4 480	83.8
30 - 34	4 683	102.1
35 - 39	2 827	64.4
40 - 44	1 466	30.3
45 - 49	472	10.9
50 - 54	105	2.8
55 - 59	41	1.4
60 - 64	8	..
65 +	4	..
Unknown - Inconnu	910	..

Appendix Figure 2. Shiny App for the Global Male Fertility Database: accessing age-specific fertility rates and total fertility rates (https://male-fertility.shinyapps.io/ShinyApp_MFDb/)

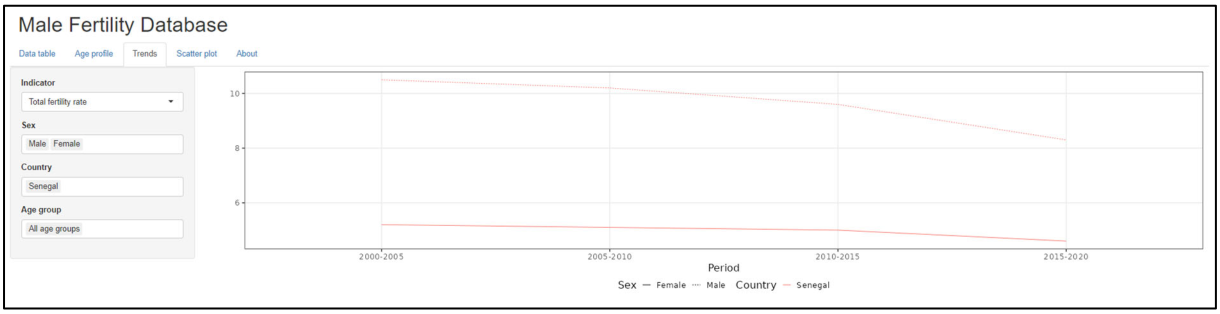


ISO 3	Country	Sex	Period	Age group	Value
AFG	Afghanistan	Male	2015-2020	15-79	5.2
ALB	Albania	Male	2015-2020	15-79	1.6
DZA	Algeria	Male	2015-2020	15-79	3.4
AGO	Angola	Male	2015-2020	15-79	7.3
ARG	Argentina	Male	2015-2020	15-79	2.4
ARM	Armenia	Male	2015-2020	15-79	1.9
AUS	Australia	Male	2015-2020	15-79	1.8
AUT	Austria	Male	2015-2020	15-79	1.5
AZE	Azerbaijan	Male	2015-2020	15-79	2.0
BHS	Bahamas	Male	2015-2020	15-79	1.9
BHR	Bahrain	Male	2015-2020	15-79	1.0
BGD	Bangladesh	Male	2015-2020	15-79	2.3
BRB	Barbados	Male	2015-2020	15-79	1.7
BLR	Belarus	Male	2015-2020	15-79	1.6
BEL	Belgium	Male	2015-2020	15-79	1.7
BLZ	Belize	Male	2015-2020	15-79	2.7
BEN	Benin	Male	2015-2020	15-79	6.8
BTN	Bhutan	Male	2015-2020	15-79	1.8
BOL	Bolivia, Plurinational State of	Male	2015-2020	15-79	2.9
BIH	Bosnia and Herzegovina	Male	2015-2020	15-79	1.2

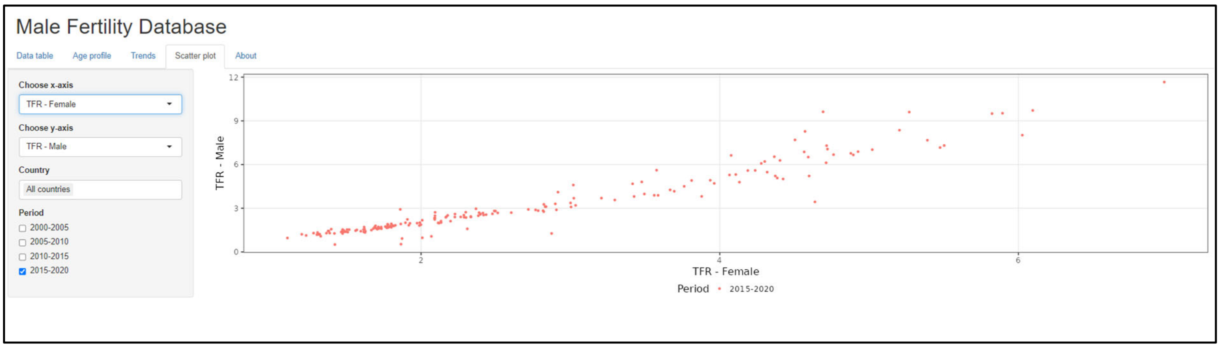
Appendix Figure 3. Shiny App for the Global Male Fertility Database: comparing male and female age-specific fertility rates (https://male-fertility.shinyapps.io/ShinyApp_MFDb/)



Appendix Figure 4. Shiny App for the Global Male Fertility Database: trends in male and female total fertility rates (https://male-fertility.shinyapps.io/ShinyApp_MFDb/)



Appendix Figure 5. Shiny App for the Global Male Fertility Database: scatter plot of male and female total fertility rates (https://male-fertility.shinyapps.io/ShinyApp_MFDb/)



Appendix Table 1: Countries and periods covered by the human fertility collection, male age-specific fertility rates

Country	Years
Australia	1975-2014
Canada	1974-2011
Denmark	1986-2015
Estonia	1989-2014
Finland	1987-2015
France	1998-2013
Germany	1991-2013
Hungary	1970-2014
Italy	1999-2014
Japan	2009-2016
Poland	1986-2014
Portugal	1980-2015
Spain	1975-2014
Sweden	1968-2015
Taiwan	1998-2014
UK, England and Wales	1982-2016
United States of America	1969-2015

Appendix Table 2: Countries and periods covered by the UNDY published from 2007 to 2021, male age-specific fertility rates

Country	Years
Åland Islands	2006 2010 2011 2012 2018 2019 2020
Albania	2004 2013 2017 2018 2019 2020
Armenia	2000 2018 2019 2020
Australia	2007 2008 2009 2010 2011 2012 2013 2015 2016 2017 2018 2019 2020
Austria	2007 2009 2010 2011 2012 2013 2015 2016 2017 2018
Azerbaijan	2004 2009 2010 2012 2013 2015 2016 2017 2018 2019
Bahrain	2007 2013 2014 2016 2017 2018 2019
Belarus	2007 2008 2009 2010 2011 2012 2013 2015 2016 2017 2018 2019
Belgium	2007 2008 2010 2014
Bosnia and Herzegovina	2010
Brunei Darussalam	2015 2016 2018 2019 2020
Bulgaria	2007 2008 2009 2010 2011 2012 2015 2016 2017 2018 2019 2020
Canada	2005 2007 2008 2009 2017 2018 2019 2020
Chile	2006 2008 2009 2010 2011 2012 2014 2015 2016 2017 2018 2019
Costa Rica	2007 2008 2010 2013 2014 2016 2017 2018 2019 2020 2021
Croatia	2007 2008 2009 2010 2012 2013 2015 2016 2017 2018 2019 2020
Cuba	2007 2008 2009 2010 2011 2013 2016 2017 2018 2019 2020
Cyprus	2006 2008 2011 2013 2016
Czechia	2007 2008 2009 2010 2011 2012 2013 2015 2016 2017 2018 2019 2020
Denmark	2007 2008 2009 2010 2011 2012 2013 2015 2016 2017 2018 2020
Egypt	2009 2010 2011 2012
El Salvador	2007 2011 2014
Estonia	2007 2008 2009 2010 2011 2012 2013 2015 2016 2017 2018 2019 2020
Faroe Islands	2015 2017 2018 2019 2021
Fiji	2004
Finland	2007 2008 2009 2010 2011 2012 2015 2016 2017 2018 2019
France	2007 2008 2009 2010 2012 2013 2015 2016 2017 2019 2020
French Guiana	2007
French Polynesia	2018 2020 2021
Georgia	2016
Germany	2007 2011 2012 2013 2015 2018 2019
Greece	2007 2008 2009 2011 2012 2015 2016 2018 2019 2020
Greenland	2006
Guadeloupe	2003
Guatemala	2016 2018 2020
Hong Kong	2005 2008 2009 2011 2013 2016 2017 2018 2019 2020
Hungary	2007 2008 2009 2010 2011 2012 2013 2015 2016 2017 2018 2019 2020
Iceland	2007 2008 2009 2010 2011 2012 2013 2015 2017 2018 2019
Ireland	2006
Israel	2007 2008 2009 2010 2011 2012 2013 2015 2016 2017 2018 2019 2020
Italy	2006 2007 2008 2009 2010 2011 2013 2014 2016 2017 2018 2019
Japan	2007 2008 2009 2010 2011 2012 2013 2015 2016 2017 2018 2019 2020
Kazakhstan	2006 2017 2018 2019 2020 2021
Korea	2008 2009 2010 2011 2012 2013 2015 2017 2018 2020
Kyrgyzstan	2007 2009 2011 2012 2016 2018 2020 2021
Latvia	2007 2008 2009 2010 2012 2013 2015 2016 2017 2018 2019 2021
Lithuania	2007 2008 2009 2010 2011 2012 2013 2015 2016 2017 2018 2019 2020
Luxembourg	2007 2008 2009 2010 2011 2012 2013 2014 2016 2017 2018 2019 2020

Macao	2007 2008 2009 2010
Malaysia	2008 2009 2011 2015 2016 2017 2018 2019 2020
Maldives	2010 2011 2012 2013 2014 2016 2017 2019
Malta	2007 2008 2009 2010 2011 2012 2013 2015 2016 2017 2018 2019 2020
Martinique	2007
Mauritius	2007 2008 2009 2010 2011 2012 2014 2016 2017 2018 2020 2021
Mexico	2014 2015 2016 2017 2018 2019
Moldova	2007 2008 2009 2010 2012 2018 2020
Mongolia	2018 2019 2020 2021
Montenegro	2007 2008 2009
Netherlands (the)	2010 2014
New Caledonia	2007 2010
New Zealand	2007 2008 2009 2011 2012 2013 2014 2016 2017 2020
Norway	2007 2008 2009 2010 2011 2012
Oman	2017 2019 2020 2021
Panama	2008 2009 2010 2013 2015 2016 2017 2018 2019 2020
Philippines (the)	2005 2007 2012 2015 2016 2017 2018 2019
Poland	2007 2009 2010 2011 2012 2015 2016 2017 2018 2019
Portugal	2007 2008 2009 2011 2012 2013 2015 2016 2017 2018 2020
Puerto Rico	2006 2008
Qatar	2007 2008 2009 2010 2015 2016 2020
Republic of North Macedonia	2007 2008 2009 2010 2012 2015 2016 2018
Réunion	2007
Romania	2007 2008 2009 2010 2011 2012 2013 2015 2017 2018 2019 2020
Russian Federation	2011 2012
San Marino	2004 2012 2013 2017
Serbia	2007 2008 2009 2010 2011 2012 2013 2015 2016 2017 2018 2019 2020
Singapore	2007 2008 2009 2010 2012 2013 2014 2016 2017 2019 2020
Slovakia	2007 2008 2009 2010 2011 2012 2013 2015 2016 2017 2018 2019
Slovenia	2007 2008 2009 2010 2011 2012 2013 2015 2016 2017 2018 2019 2020
South Africa	2016 2020
Spain	2007 2009 2010 2011 2012 2013 2016 2017 2018 2019 2020
Sweden	2007 2008 2009 2010 2011 2012
Switzerland	2006 2008 2009 2010 2011 2012 2015 2016 2017 2018 2019 2020
Turkey	2010 2012 2013 2015 2016 2017 2018 2019 2020
UK and Northern Ireland	2003 2009 2012 2016 2017 2018 2020
Ukraine	2007 2008 2010 2011 2012 2013 2016 2017
United States of America	2008 2009 2012 2015
Uruguay	2004 2015 2016 2017 2018 2019 2020
Uzbekistan	2015 2017 2018 2020 2021
Venezuela	1998 2007 2013

Appendix Table 3: Countries and periods covered by the DHS, male age-specific fertility rates

Country	**Years**
Afghanistan	1998 2003 2008 2013
Albania	1993 1998 2003 2008 2013 2018
Angola	2003 2008 2013 2018
Armenia	1988 1993 1998 2003 2008 2013 2018
Azerbaijan	1993 1998 2003 2008
Benin	1983 1988 1993 1998 2003 2008 2013 2018
Bolivia	1983 1988 1993 1998 2003 2008
Brazil	1978 1983 1988 1993 1998
Burkina Faso	1978 1983 1988 1993 1998 2003 2008 2013 2018 2023
Burundi	1998 2003 2008 2013 2018
Cambodia	1988 1993 1998 2003 2008 2013 2018 2023
Cameroon	1973 1978 1983 1988 1993 1998 2003 2008 2013 2018
Central African Republic	1978 1983 1988 1993
Chad	1983 1988 1993 1998 2003 2008 2013
Colombia	1983 1988 1993 1998 2003 2008 2013 2018
Comoros	1983 1988 1993 1998 2003 2008 2013
Congo	1993 1998 2003 2008 2013
Côte d'Ivoire	1978 1983 1988 1993 1998 2003 2008 2013 2018 2023
Dem. Rep. of the Congo	1993 1998 2003 2008 2013
Dominican Republic	1978 1983 1988 1993 1998 2003 2008 2013
Egypt	1988 1993 1998 2003 2008 2013
Eritrea	1983 1988 1993 1998 2003
Ethiopia	1988 1993 1998 2003 2008 2013 2018
Gabon	1988 1993 1998 2003 2008 2013 2018 2023
Gambia	1998 2003 2008 2013 2018
Ghana	1978 1983 1988 1993 1998 2003 2008 2013
Guatemala	1983 1988 1993 1998 2003 2008 2013
Guinea	1983 1988 1993 1998 2003 2008 2013 2018
Guyana	1993 1998 2003 2008
Haiti	1978 1983 1988 1993 1998 2003 2008 2013 2018
Honduras	1993 1998 2003 2008 2013
India	1993 1998 2003 2008 2013 2018 2023
Indonesia	1978 1983 1988 1993 1998 2003 2008
Jordan	1983 1988 1993 1998 2003 2008 2013 2018
Kazakhstan	1983 1988 1993 1998
Kenya	1978 1983 1988 1993 1998 2003 2008 2013 2018 2023
Kyrgyzstan	1983 1988 1993 1998 2003 2008 2013
Lesotho	1988 1993 1998 2003 2008 2013
Liberia	1993 1998 2003 2008 2013 2018
Madagascar	1978 1983 1988 1993 1998 2003 2008 2013 2018 2023
Malawi	1978 1983 1988 1993 1998 2003 2008 2013 2018
Maldives	1993 1998 2003 2008 2013 2018
Mali	1983 1988 1993 1998 2003 2008 2013 2018
Mauritania	2003 2008 2013 2018 2023
Morocco	1978 1983 1988 1993
Mozambique	1978 1983 1988 1993 1998 2003 2008 2013
Myanmar	2003 2008 2013 2018

Namibia	1978 1983 1988 1993 1998 2003 2008 2013
Nepal	1993 1998 2003 2008 2013 2018 2023
Nicaragua	1983 1988 1993 1998 2003
Niger	1973 1978 1983 1988 1993 1998 2003 2008 2013
Nigeria	1988 1993 1998 2003 2008 2013 2018
Pakistan	1998 2003 2008 2013 2018
Papua New Guinea	1998 2003 2008 2013 2018
Peru	1983 1988 1993 1998 2003 2008 2013
Philippines	1978 1983 1988 1993 2008 2013 2018 2023
Republic of Moldova	1993 1998 2003
Rwanda	1988 1993 1998 2003 2008 2013 2018
Sao Tome and Principe	1993 1998 2003 2008
Senegal	1978 1983 1988 1993 1998 2003 2008 2013 2018
Sierra Leone	1993 1998 2003 2008 2013 2018
South Africa	1983 1988 1993 1998 2003 2008 2013 2018
Swaziland	1993 1998 2003 2008
Tajikistan	1998 2003 2008 2013 2018
Timor-Leste	1993 1998 2003 2008 2013 2018
Togo	1983 1988 1993 1998 2003 2008 2013
Turkey	1978 1983 1988 1993 1998 2003 2008 2013 2018
Uganda	1983 1988 1993 1998 2003 2008 2013 2018
Ukraine	1993 1998 2003 2008
United Republic of Tanzania	1978 1983 1988 1993 1998 2003 2008 2013 2018
Uzbekistan	1983 1988 1993 1998
Yemen	1998 2003 2008 2013
Zambia	1978 1983 1988 1993 1998 2003 2008 2013 2018
Zimbabwe	1978 1983 1988 1993 1998 2003 2008 2013

Appendix Table 4: Countries and periods covered by the MICS and PAPFAM, male age-specific fertility rates

Country	**Years**
Algeria	2011 2017
Argentina	2018
Bangladesh	2011 2017
Barbados	2010
Belize	2004 2009 2013
Bhutan	2008
Central African Republic (the)	2004 2008 2017
Chad	2008 2017
Congo (the Democratic Republic of the)	2016
Costa Rica	2016
Cuba	2016
Djibouti	2004
Eswatini	2008 2012
Guinea-Bissau	2012 2017
Iraq	2004 2009 2016
Jamaica	2003 2009
Lao People's Democratic Republic (the)	2004 2009 2015
Libya	2005
Mauritania	2009
Mexico	2013
Mongolia	2011 2016
Palestine, State of	2008 2012 2018
Paraguay	2014
Saint Lucia	2010
Samoa	2017
Sao Tome and Principe	2017
Somalia	2004
South Sudan	2008
Sudan (the)	2008 2012
Suriname	2004 2008
Syrian Arab Republic	2004
Thailand	2003 2011 2019
Togo	2004
Trinidad and Tobago	2004 2009
Tunisia	2010 2016
Turkmenistan	2013 2017
Vanuatu	2005
Viet Nam	2012

Appendix Table 5: Countries and periods covered by Censuses, male age-specific fertility rates

Country	Years
Argentina	2008
Botswana	2009
China	1998
Cuba	2000
Ecuador	2009
Iran (Islamic Republic of)	2009
South Africa	2009

Appendix Table 6: Source of age pattern of male fertility when age pattern is missing

Country with a missing age pattern	Country used
Guam	Fiji
North Korea	China
Solomon Islands	Vanuatu
Kuwait	Qatar
Cape Verde	Sao Tome & Principe
Lebanon	Jordan
Sri Lanka	India
Bahamas	Jamaica
Saudi Arabia	Qatar
Equatorial Guinea	Sao Tome & Principe