A Comparison of Fertility Estimation Methods: The Global Burden of Disease and World Population Prospects

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Abstract: Demographic estimates are central to epidemiological, sociological, and economic analysis. Fertility rates are important drivers of population growth and can be key indicators of social and economic development. Thus, it is vital that we have accurate estimates of age-specific fertility. We present a comparison of fertility methods used and estimates produced as part of the 2019 Global Burden of Disease (GBD) study with those published in the United Nation's 2019 World Population Prospects (WPP). For the GBD study, we produce single calendar year estimates of age-specific fertility for five-year age groups using a two-stage spatiotemporal Gaussian process regression model. This model incorporates splitting of non-age-specific data, adjustment of biased data, and smoothing over space and time to produce estimates in 204 countries and territories. The WPP estimates are generated through a decentralized process using country-level data, which is selected by analysts and adjusted when needed in order to ensure consistency with population data. We show that the GBD estimates differ mainly from the WPP estimates in that they are able to more closely follow abrupt temporal changes in fertility in locations with reliable vital registration data and follow adjusted versions of data based on estimated biases rather than raw data in locations with sparser data and varied data sources.

BACKGROUND

Demographic estimates are central to epidemiological, sociological, and economic analyses. Along with migration, fertility is an important driver of population growth. Thus, in order to produce accurate population estimates and projections, it is necessary to have reliable estimates of fertility rates. Population estimates are foundational to analyses in a number of fields including epidemiology and economics. Fertility rates are also valuable social outcomes on their own. Fertility can be an important indicator of women's status in society. In particular, age-specific fertility rates (ASFR) give insight into patterns of childbearing. Higher fertility at younger ages can have different social implications than in the older age groups.

Since 1951, the UN Population Division at the Department of Economics and Social Affairs (UNPOP) has produced demographic estimates. These estimates are published as part of the biennial World Population Prospects (WPP). Estimates are produced for five-year periods from 1950 through the present and projections are made for all five-year periods up until 2100. These estimates cover 235 distinct countries or areas.[3] Beginning in 2017, ASFR estimates have also been produced as part of the Global Burden of Disease (GBD) Study. The goal of the GBD estimation process is to estimate ASFR for 204 countries and territories for all years between 1950 and 2019 using standardized and replicable methods. The production of independent ASFR estimates also allows for internal consistency among our demographic and epidemiological estimates.

Here, we present a detailed look at how the methods of GBD differ from those of UNPOP. We then compare the final estimates of age-specific fertility in GBD 2019 and WPP 2019 to see the implications of these methodological differences. We will show that, in locations with annual vital registration data, the spatiotemporal Gaussian process regression model used in GBD estimation allows the model to capture abrupt temporal shifts in ASFR, while the WPP's 5-year estimation process creates smoother time trends. The GBD's use of reference sources to adjust biased data leads to differences in estimates where annual complete vital registration is not available and other, less reliable sources must be used.

METHODS

Global Burden of Disease

In the GBD estimation process, we use a two-stage spatiotemporal Gaussian process regression to estimate ASFR for ages 10 to 54 years. In the first stage, age-specific data from complete birth history (CBH) and vital registration (VR) is used. The prior for the Gaussian process regression is first estimated for women aged 20 to 24 years using a simple linear regression of ASFR on mean years of education for women in that age group for a given location and year. The priors for the other age groups are estimated using mean years of education and a spline on the estimated ASFR for women aged 20 to 24. The priors are both fit with a location-source random intercept. Reference sources are identified for each location by choosing complete VR when it is available, CBH when it is not, and no reference source when neither is available for a particular location. Data from non-reference sources are then adjusted using the difference in the reference-source random intercepts and their own random intercepts. The prior is smoothed over space and time, weighting regional data and temporally distant data more heavily in locations with less data. Gaussian process regression is used to create a full time series and estimate uncertainty.

In the second stage of the model, data from summary birth history (SBH) and total births data are split based on the estimates from the first stage. The SBH data are split using the ratio between children ever born alive reported in a given data source from each 5-year cohort of women and the cohort completed fertility for these cohorts that was implied by the first-stage estimates. These data are incorporated and ASFR is then re-estimated using the same process as in the first stage.

Because data for the 10 to 14 and 50 to 54 age groups is sparse, we estimate ASFR for these age groups using a different method. For fertility in the 10-14 age group, we use a linear regression of the log of the ratio of the ASFR of girls aged 10 to 14 years to the ASFR for girls aged 15 to 19 years as a function of the ASFR for girls aged 15 to 19 years. For the 50 to 54 age group, we assume the ratio of ASFR for women aged 50 to 54 years to ASFR for women aged 45 to 49 years to be constant. After fertility rates have been estimated for all 5-year age groups, TFR is calculated based on the estimated age-specific rates.

World Population Prospects

For the WPP estimation process, analysts collect available data from censuses, surveys, and vital registration. If data sources provide conflicting estimates, a variety of techniques are used to determine the time series of fertility that is most likely. Analysts look at evidence of incompleteness or implausibility in the data and perform adjustments to the data as needed. In countries without data or where data is sparse, fertility is estimated using demographic models. Fertility estimates are then used in a cohort component projection framework for projecting population. If the input fertility produces implausible population estimates using this method, the estimates are adjusted. In addition to five-year estimates, WPP provides single-year estimates by interpolation using a modified Beer's formula.[3]

RESULTS

The use of a spatiotemporal Gaussian process regression model allows GBD estimates to closely follow available vital registration data when we believe the vital registrations to be complete and reliable. We can see evidence of this in countries such as Japan, where complete vital registration data is available for the entire time series from 1950 to 2018. According to vital registration data, the TFR in Japan in 1966 dropped to about 1.55 from 2.08 in the previous year. Evidence shows this dip is not a data error, but instead an actual drop due to the Japanese zodiac.[2] Since WPP estimates are for 5-year periods, and the dip is contained to the year 1966 with fertility quickly recovering by 1967, there is no evidence of any drop in the UNPOP estimates. This interpolated annualized TFR includes estimates of 2.02, 2.03, and 2.04 for the years 1995, 1996, and 1997, respectively. We see no evidence of any decline in 1966 as the data suggest. The GBD estimates TFR in Japan to be 2.07, 1.79, 1.82, and 2.14 for the years 1964, 1965, 1966, and 1967, respectively. We can see that, due to temporal smoothing, the decline is estimated to have begun in 1965, rather than 1966, but the dip is still present in 1966 (Figure 1).

According to vital registration data, Romania similarly experienced an abrupt change in fertility in the 1960s. However, rather than a dip, Romania saw a surge in fertility in 1967. The data reported the TFR to be 3.52 in 1967, a sizable increase from the reported TFR of 1.83 in 1966. This sudden spike coincides with the October 1966 authorization of Decree 770, which banned abortion with a few exceptions for women over a certain age and situations involving medical complications.[1] Based on the interpolated data provided in WPP 2019, total fertility in Romania increased steadily from 2.22 in 1962 to 2.71 in 1967. The estimates from GBD align more closely with the data, increasing much more steeply from 1.82 in 1965 to 3.56 in 1967 (Figure 2).

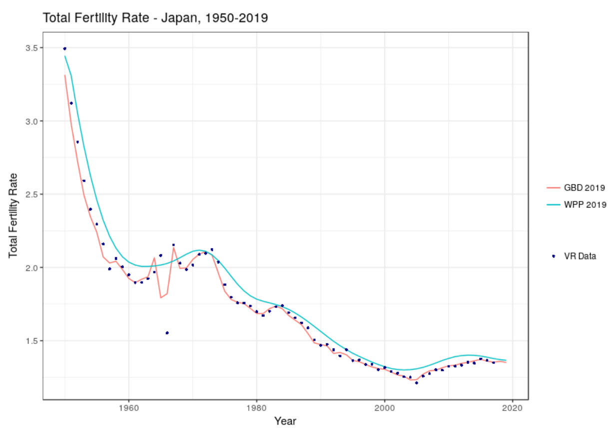

Figure 1. TFR in Japan, 1950-2019

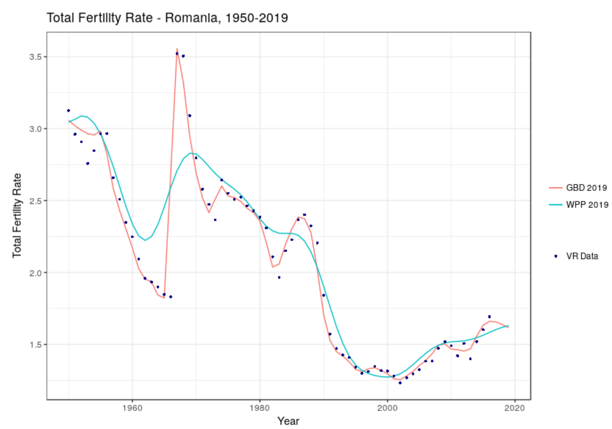

Figure 2. TFR in Romania, 1950-2019

The use of reference sources and adjustments in the GBD method also causes differences in GBD and WPP estimates in locations where no complete VR is available so a variety of sources must be used. In Djibouti, for example, although vital registration data is available throughout the 1960s and 1970s, this vital registration is designated as incomplete. Instead, complete birth history data from the Pan Arab Project for Family Health (PAPFAM) Survey is designated as reference. An adjustment is calculated using the difference between the random intercept for the PAPFAM CBH data and the incomplete VR data, causing the VR data to be adjusted up. For the 15 to 19 age group, we can see that the WPP estimates follow the original VR data while the GBD estimates follow the adjusted data, causing the GBD estimates of ASFR to be over double those from WPP from 1950 through 2000 in an attempt to correct for under enumeration (Figure 3).

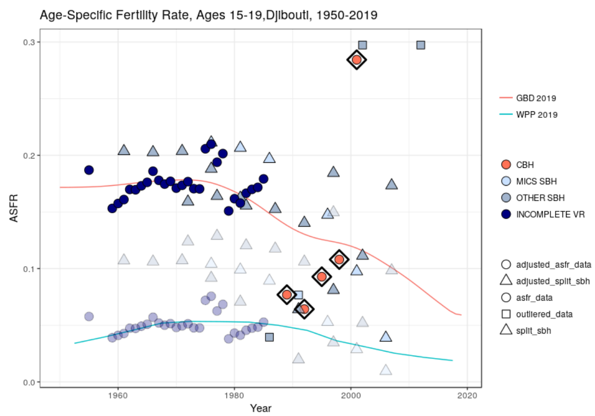

Figure 3. ASFR 15-19 in Djibouti, 1950-2019

CONCLUSION

While the estimates produced for GBD and WPP align for many locations during many time periods, multiple features of the method used to produce GBD fertility estimates contribute to differences between the two. This is in spite of the fact that the two estimation processes often use the same data sources, meaning the discrepancies in these cases can be attributed entirely to methodological differences. The use of spatiotemporal GPR to produce annual estimates closely following vital registration data and the identification of reference sources to adjust potentially biased data results in estimates that deviate from those in the WPP. These features can be advantageous in situations where we have high-quality VR data with abrupt temporal changes that can only be captured through annual estimates, or in those where we have multiple data sources, some of which we believe to be biased.

REFERENCES

1. Berelson, B. “Romanias 1966 Anti-Abortion Decree: The Demographic Experience of the First Decade.” Population Studies 33, no. 2 (1979): 209. https://doi.org/10.2307/2173528.
2. Kaku, Kanae. “Are Physicians Sympathetic to Superstition? A Study of Hinoe-Uma.” Social Biology 19, no. 1 (1972): 60–64. https://doi.org/10.1080/19485565.1972.9987966.
3. United Nations, Department of Economic and Social Affairs, Population Division (2017). World Population Prospects: The 2017 Revision, Methodology of the United Nations Population Estimates and Projections, Working Paper No. ESA/P/WP.250. New York: United Nations.