

Statistical Modeling for WPP 2021

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Outline

- ▶ Producing robust annual time series of total fertility and accounting for uncertainty in estimation
- ▶ Extensions:
 - ▶ One-year age groups
 - ▶ Mortality
- ▶ Incorporating migration uncertainty into projections

Robust Annual Time Series Estimates and Projections of TFR Accounting for Estimation Uncertainty: Method⁴

- ▶ Based on UN World Fertility Data¹
 - ▶ Includes all estimates (VR, partial VR, Census, surveys, other) on which UN WPP 5-year estimates of TFR are based, time-stamped
- ▶ Estimate bias and measurement error variance for each type of data source for each country²
- ▶ Extend the UN's Bayesian hierarchical model for TFR³ (bayesTFR) to add an extra level for the measurements in WFD on which the WPP 5-year estimates are based
- ▶ Estimate it by MCMC
- ▶ Results: Annual time series estimates of TFR for all countries, with uncertainty about the past, accounting for estimation uncertainty in projections
- ▶ Good performance in out-of-sample validation

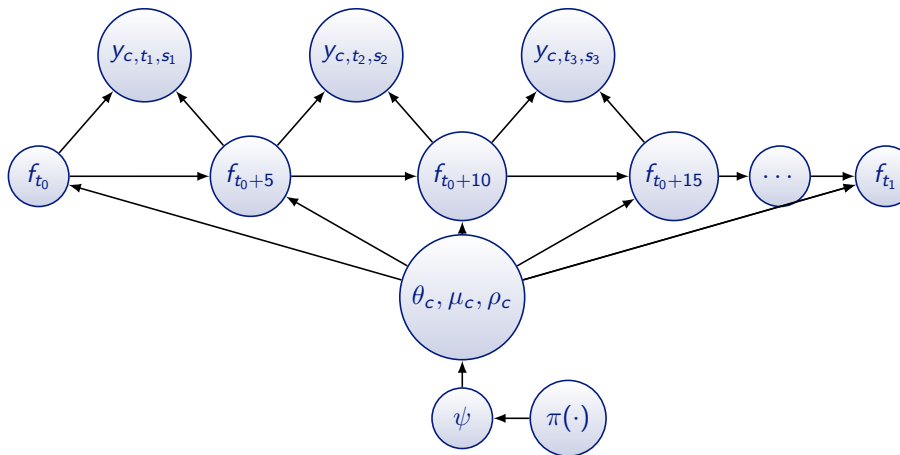
¹Andreev, Biddlecom, Kantorová (2015); 2019 revision

²Alkema, Raftery, Gerland, Clark, Pelletier (2012, *Demographic Research*)

³Alkema, Raftery, Gerland, Clark, Pelletier, Buettner (2011, *Demography*)

⁴Liu & Raftery (2020, *Annals of Applied Statistics*)

Extended model for measurement error



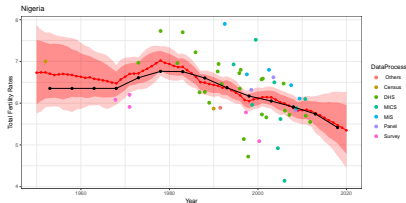
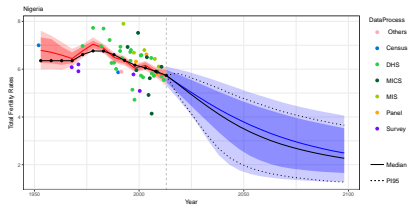
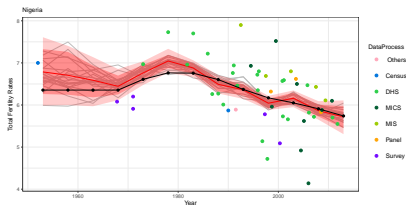
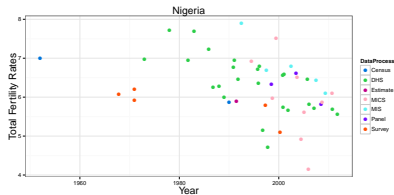
$y_{c,t,s}$ = observed TFR, measurements

$f_{c,t}$ = true unknown TFR values

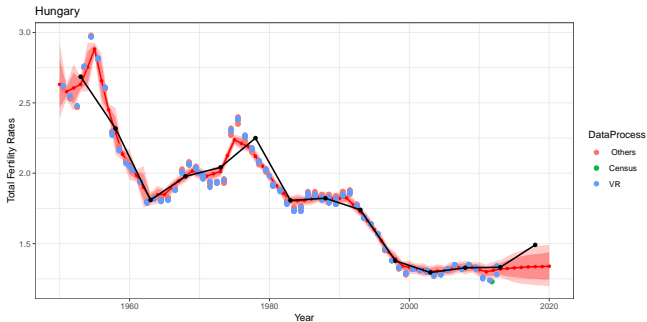
θ_c = country-specific parameters

ψ = global parameters.

Example Results without Good VR: Nigeria



Example Results with Good VR: Hungary



- ▶ For the 90 or so countries with good VR (out of 201), the method essentially tracks the VR estimate (more closely than the 5-year WPP estimates), with small assessed uncertainty

Extensions

- ▶ One-year age groups:
 - ▶ UN's current methods for breaking TFR down to 5-year age groups⁵ based on convergence to low fertility age pattern
 - ▶ Extensible from 5-year age groups to 1-year age groups
- ▶ Mortality:
 - ▶ Similar method to TFR should work for e_0 , e.g. using mortality estimates from the data sources in the UN World Mortality Report 2019 Data Inventory
 - ▶ UN's current methods for translating probabilistic e_0 forecasts to age-specific mortality for 5-year age groups use the coherent rotated Lee-Carter method⁶, or the PMD method⁷, implemented in the MortCast R package
 - ▶ Should be extensible to one-year age groups
 - ▶ 1×1 probabilistic population projections available by applying the cohort-component method to the output of the fertility and mortality methods (extension of bayesPop R package)

⁵Ševčíková, Li, Kantorová, Gerland, Raftery (2016, *Dynamic Demographic Analysis*)

⁶Li, Lee, Gerland (2013, *Demography*)

⁷Andreev, Gu, Gerland (2013, *PAA*)

Incorporating Migration Uncertainty

- ▶ WPP projections are currently based on assumption that net migration mostly stays constant at current level until 2050, and then declines linearly, reaching zero in 2150.
 - ▶ Uncertainty about migration not yet incorporated
- ▶ Methods for probabilistic projection of net migration exist⁸.
- ▶ Methods for probabilistic population projection based on this have been developed⁹.
 - ▶ Applied to WPP 2017 data
 - ▶ Projections available at bayespop.csss.washington.edu/download/#probmig

⁸Azose & Raftery (2015, *Demography*)

⁹Azose, Ševčíková, Raftery (2016, *PNAS*)

Summary

- ▶ Statistical methods have been developed for
 - ▶ Robust single-year estimation and projection of TFR
 - ▶ Including estimation uncertainty
 - ▶ Incorporating uncertainty about international migration in population projections
- ▶ Feasible for these to be ready for WPP 2021