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Estimating time trends for WPP21: Lessons learned from B3 et al.

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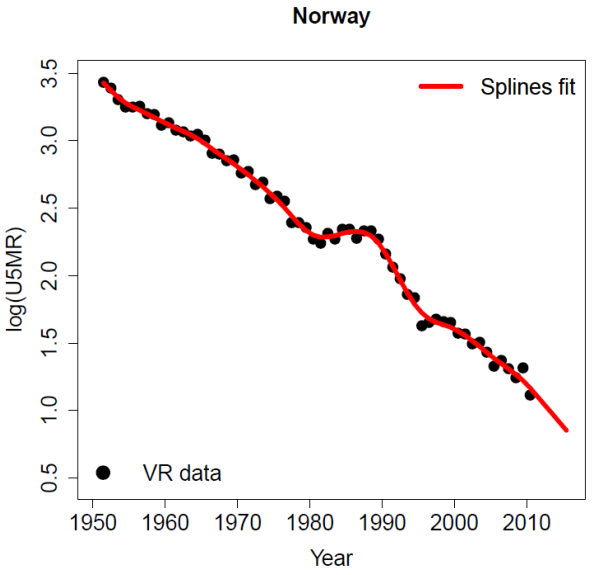
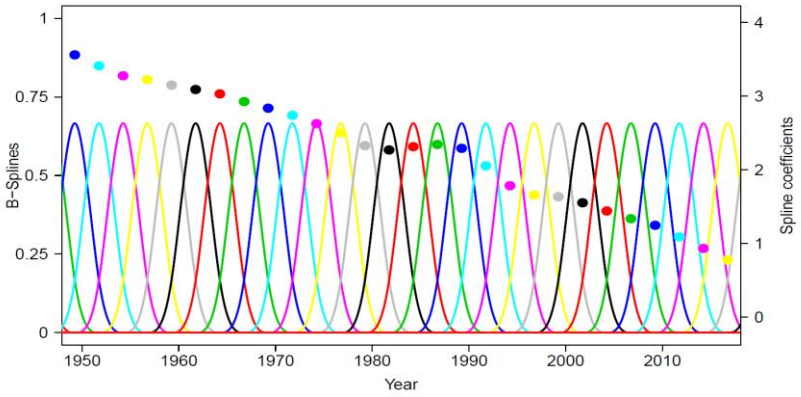
Notes are based on modeling experience with a range of different indictors with funding provided by UNICEF (child mortality), WHO (maternal mortality) and the Bill and Melinda Gates Foundation (family planning, still birth rates).

B3: Bayesian penalized B-splines regression model

(5q0 Alkema and New 2012; 5q10 Masquelier et al 2019)

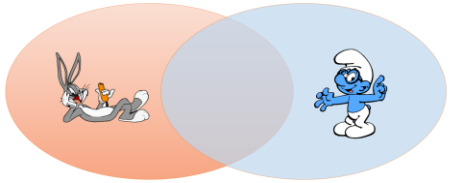
- Process model (describes the indicator):
  - Splines regression
    $U5MR(t) = b_1(t)*a_1 + .. + b_K(t)*a_K$
  - RW(2) on the spline regression coefficients =RW(1) on rate of change
  - Improve projections, rate of change converges to global rate of change
- Data model (how do data relate to the truth):
  - Level and slope biases for survey series
  - Variance = Stochastic variance or Sampling variance + Non-sampling variance
  - Outliers, data as min/max
- Hierarchical models
  - survey biases, country-specific variance in RW(2)
  - NOT used for country's levels or rates of change





Bayesian penalized B-splines regression model (B3)

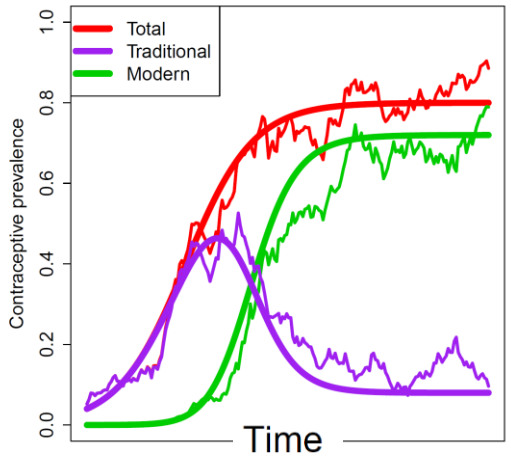
- Lesson learned: 90-10 rule
  - 90% of development and post-development meeting time was spent on 10% of country-years
    - need for additional "rules",
    - data inclusion/exclusion

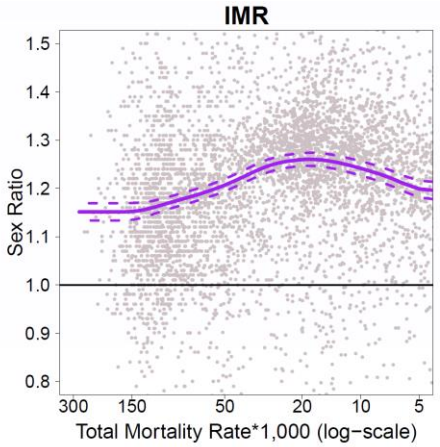


- Is B3 the way to go for WPP21?
  - Put into context of menu of modeling options for process and data model, and
  - experience modeling other indicators (family planning, MMR, NMR, sex ratios, ..)

Process model menu part 1: structured vs smoothing component

- **Should WPP21 models include a structured component, a smoothing component, or both?**
- Structured component; parametric function to capture dynamics
  - Mathematical function to describe level/trends, i.e.
    - logistic curve for contraceptive use in FPET;
    - double logistic for TFR projections
  - Covariates, i.e.
    - Demographic, i.e. model sex ratios of U5MR using U5MR, NMR using U5MR;
    - Other (GNI, …)
- Smoothing component
  - Splines (B3 for U5MR)
  - AR(1) (for deviations in sex ratios)





*1.Use structured **AND** smoothing component; same model for all countries; 2. Hierarchical models for parameters of structured component*

Process model menu part 2: Smoothing

- Many approaches to smoothing time series (splines, AR(1), RW(1), …)…
  - What matters?
  - What to focus on with limited time?

Smoothing choices for WPP21

- Splines vs ARIMA type models:
  - Splines result in trajectories with continuous derivate(s)
  - Reduction in # of parameters when using splines
  - Splines can be combined with ARIMA type models on spline coefficients
- AR(1) vs RW(1) vs RW(2) vs ARIMA(1,1,0) vs …
  - Differences easiest to understand based on extrapolations beyond years with data

Point projections

- RW(1): constant
- AR(1): convergence back to mean parameter
- RW(2) = RW(1) on rate of change -> constant rate of change
- ARIMA(1,1,0) = AR(1) on rate of change -> convergence back to mean rate of change

Width of projection intervals

- Stationary processes, i.e. AR(1): convergence to a distribution with fixed mean and variance
- Non-stationary RW(1), RW(2), ARIMA(1,1,0): width keeps increasing (fanning out)

1. Focus on choice of structural component + point projections associated with the smoothing term (get 10% right)
2. Start with simplest/most convenient option for smoothing option, esp. for initial fitting

Data model: observation = truth + bias + random error

- Data are messy so make your modeling life easier, as per B3 et al:
  - Add sampling and non-sampling variance
  - Consider (survey) bias terms
  - Include observations as minimum/maxima if that's all you can learn from them
  - Consider fat-tailed distributions to reduce effect of outliers
- Headache ++: what to do with outlying data points?
  - How to automate approach for data exclusion/down-weighting?

Bias:	**Variance**

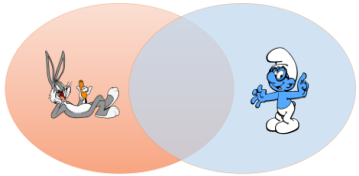
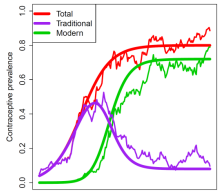
• Note difference between
  • Estimating bias terms when fitting model (b3, level and slope bias for surveys), vs
  • Fix point estimates and associated uncertainty (SBR, MMR)
	• Stochastic errors for VR-ish data.
	  • currently estimates are based on binomial/poisson w/o overdispersion and thus too small (but not clear how to estimate overdispersion)
	• Sampling errors for survey data
	• Non-sampling errors: YES do add!
	  • Consider fixing a priori

Computation

- Use of hierarchical models means that model needs to be fitted to data from all/large set of countries
  - Global model likely to be slow to fit for STAN/JAGS/your own XXMC, fast in INLA
- 1 country models come to the rescue
  - Fit model to data from 1 country only -> Much faster to run!
  - Fix non-country parameters at point estimates from global model, add additional uncertainty
  - Good example: Family planning (FPET)

Estimating time trends: Lessons learned from B3 et al.

- B3
  - With current rules, B3 works reasonably well for U5MR estimation but will need more adaption for WPP21 needs (backprojections, more countries)
  - Main lessons learned:
    - 90% of development time spent on 10% of country-years
    - Due to missing structural component?



- For any new modeling endavours specifically for WPP21:
  - Process model = structural component + smoother
    - Estimates can track high quality data and fall back to levels and rates of change implied by the structural component if there are no data or if data are too uncertain.
    - Same model set-up for all countries
  - Data model:
    - Consider biases and non-sampling errors
    - Open question: how to exclude data?
  - 1 country models reduce computational burden