How Informative are Vital Registration Data for Estimating Maternal Mortality? A Bayesian Analysis of WHO Adjustment Data and Parameters

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Background and Motivation

- Millennium Development Goal 5: reducing the maternal mortality ratio (MMR = # maternal deaths / # live births) by 75% between 1990 and 2015.
- Estimating trends in maternal mortality is challenging because of:
  i. Few observations;
  ii. Poor quality of data (underreporting, misclassification, and inconsistent definitions).
- In the WHO 2012 estimation approach (Wilmoth et al., 2012; WHO et al., 2012):
  i. PM is used as an input for modelling:
  PM = # maternal deaths / # female deaths aged 15-49
  ii. VR data is adjusted for data quality issues based on a combination of external data and expert opinion:
  $$PM^{adj} = PM^{obs} \cdot \gamma$$
  where γ quantifies the extent to which maternal deaths have been misclassified.
  iii. The WHO expert distribution for VR adjustment parameters for countries without external information on γ is given by:
  $$\log(\gamma) \sim N(\log 1.5 - 0.05^2/2,\ 0.05^2)$$
- Objective for this project: Develop a Bayesian estimation approach that better takes account of available data on VR misclassification errors for all countries.

Data

- 35 observed VR adjustment biases are from 19 countries. 9.7 country-years of data are available for each country on average.

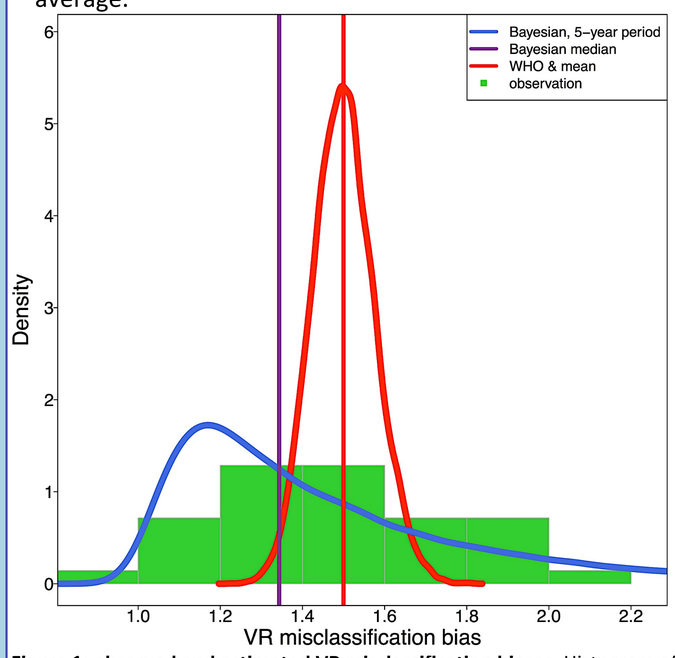

Figure 1: observed and estimated VR misclassification biases. Histogram of observed VR misclassification biases and density functions for the WHO and Bayesian VR adjustment of 5-year observation period in a country without external information on the VR misclassification error.

Methods

- We developed a Bayesian hierarchical time series model to estimate VR adjustments for all country-years.
- Let $P_{c,t}$ be the proportion of maternal deaths that are correctly reported as maternal deaths in country c =1, …, C during year t,
  $$P_{c,t} = R_{c,t} / M_{c,t},$$
  where $R_{c,t}$ is the reported number of maternal deaths for the country-year while $M_{c,t}$ is the true number of maternal deaths.
- The $P_{c,t}$'s were modeled with an autoregressive time series model of order one (AR(1)) with truncation:
  $P_{c,t} \sim TN_{[1/3,1]}(p_c + \rho(P_{c,t-1} - p_c), \sigma_{AR}^2)$, for t=1979, …, 2012, where p_c's were estimated with a hierarchical model on country level.
- Data model:
  $$\frac{1}{W_{c,k}} \sim TN_{[0,\infty)}\left(\frac{1}{T_{c,k}} \sum_{t=t_{c,k}}^{t_{c,k}+T_{c,k}-1} P_{c,t}, \sigma_W^2\right)$$
  where $W_{c,k}$ is the k^{th} observed VR adjustment from country c with observation period ($t_{c,k}$, $t_{c,k}+T_{c,k}-1$).
- Two ways to estimate maternal mortality:
  i. Model I: estimate VR adjustments based on the external data first. Then use these adjustments in the WHO maternal mortality estimation model;
  ii. Model II: estimate VR adjustments and maternal mortality simultaneously by using the data model for observed PM from non-AIDS countries.

Result A: VR adjustment estimates from Model I

- Our Bayesian estimates for countries with external information on VR adjustment suggest a variation in misclassification biases between countries and within each country over time (Figure 2).

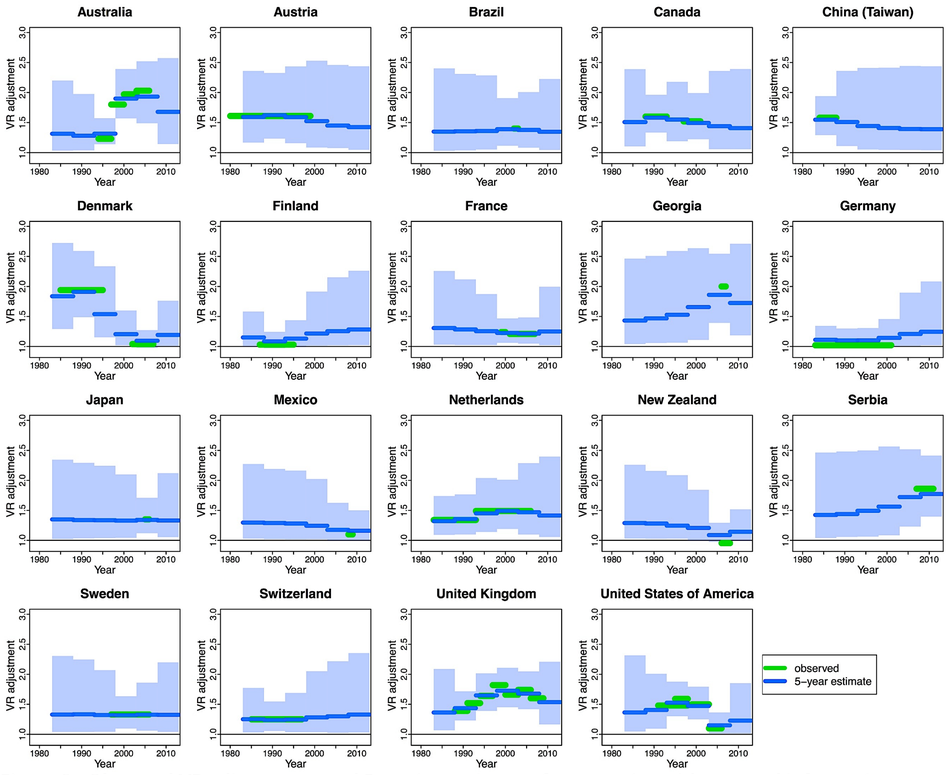

Figure 2: Observed VR adjustments and Bayesian estimates for countries with external information on VR misclassification biases. The green line segments represent the observed VR adjustments. Bayesian posterior median estimates for VR adjustments of 5-year period (the default period used in the WHO modeling approach) are added in blue line segments, and blue shades represent 95% credible bounds. The line span corresponds to the observation period.

- Compared to the WHO density (Figure 1), Bayesian estimates for a 5-year period are more spread out and more weighted toward lower levels of VR misclassification biases.
- We compared the adjustment factors for maternal mortality for a 1-year period of the Bayesian model to the one implemented in Naghavi et al. (2010). The Bayesian mode is slightly higher and larger VR adjustments are more likely (Figure 3).

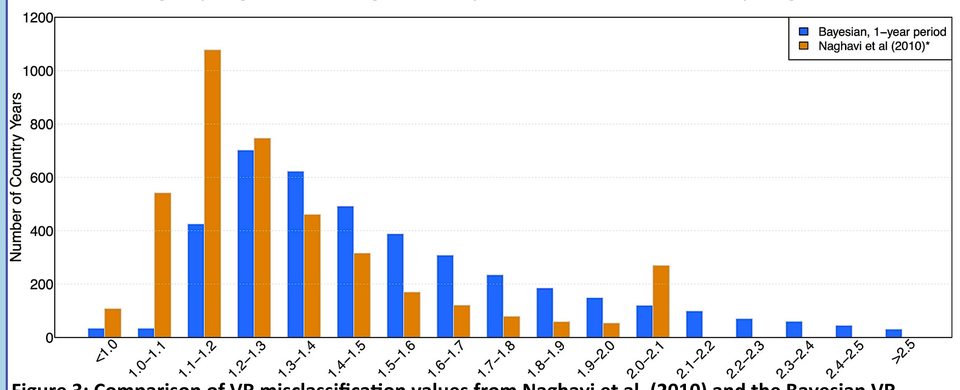

Figure 3: Comparison of VR misclassification values from Naghavi et al. (2010) and the Bayesian VR adjustment model. The Bayesian estimates are based on 1-year observation periods. *Values greater than 2 were aggregated in the Naghavi et al. results.

Result C: Maternal mortality estimates from Model II

- Among the 17 non-AIDS countries with VR data but without external information on VR misclassification biases, Bayesian PM estimates are notably higher than the modified WHO estimates for several countries (Figure 5).

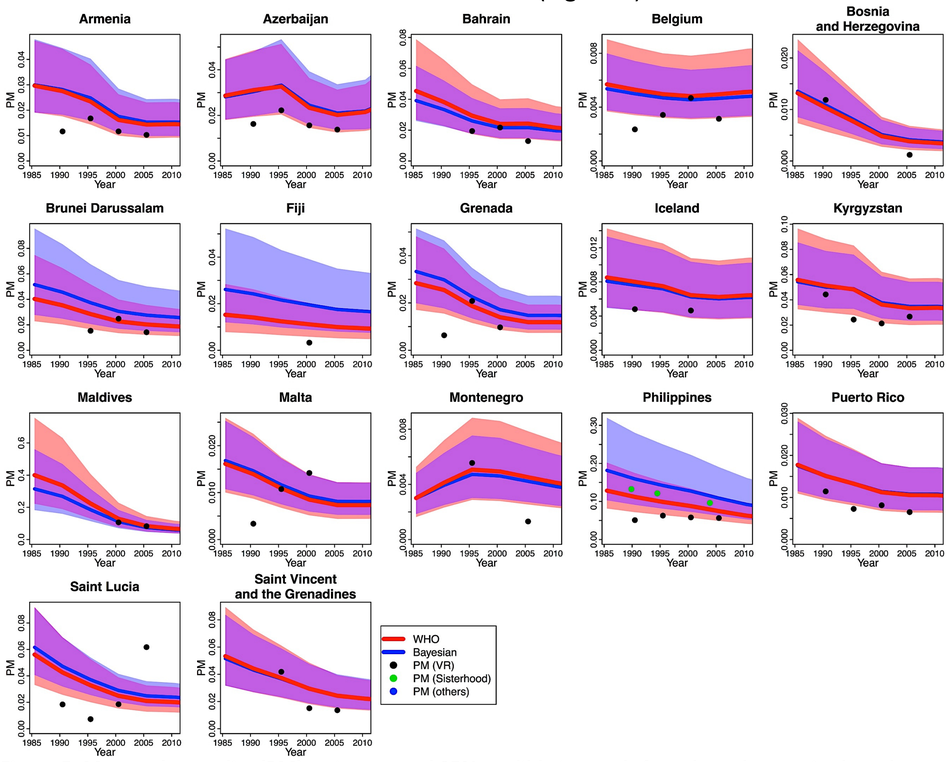

Figure 5: Maternal mortality (PM) estimates and 95% credible intervals for selected countries based on the modified WHO model (red) and the fully Bayesian model (blue). Observations are displayed by source type. The selected countries are the non-AIDS countries with VR data but without external information on the VR misclassification, for which the WHO used a multi-level model for constructing PM estimates.

Results B: VR adjustment estimates from Model II

- Our Bayesian estimates suggest that the VR adjustments biased differ across non-AIDS countries (Figure 4).

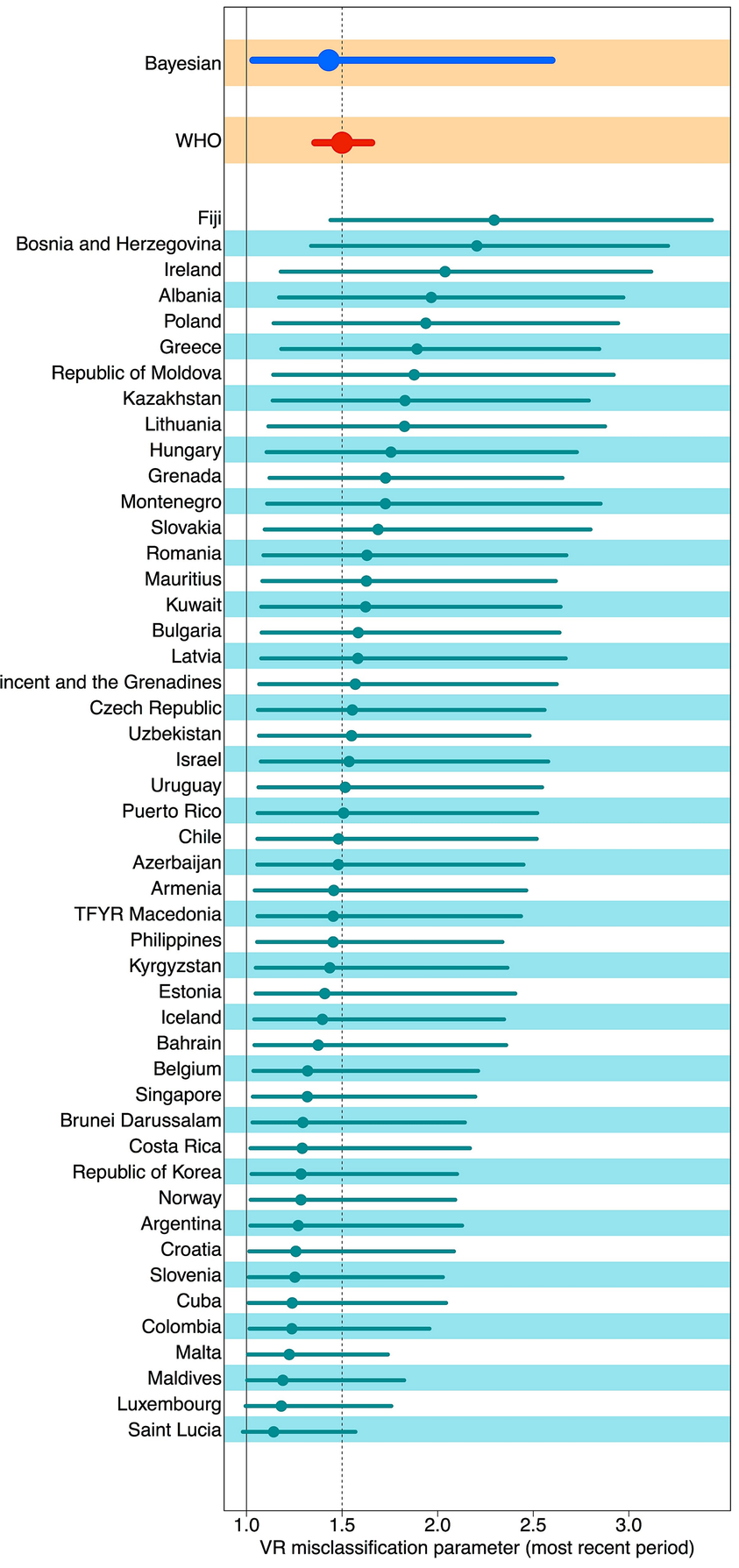

Figure 4: Bayesian posterior VR adjustment parameters in the most recent observation period for selected countries. Point estimates (dots) and 95% credible intervals (lines). The selected countries are all non-AIDS countries with VR data but without external information on VR misclassification biases. The posterior Bayesian adjustment for a "new country" without information on p_c and the WHO adjustment are added for comparison.

Discussion

- We used a Bayesian hierarchical time series model to capture time trends within countries and variation between countries.
- Our Bayesian modeling approach can be used to provide more objective and data-driven insights into maternal mortality estimates and data adjustment parameters.
- Given the limited number of data points, formal cross-validation exercises are challenging. More data collection to assess VR data quality is needed to truly validate any VR adjustment modeling approach.

References

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