How to estimate a population proportion if data are possibly subject to misclassification error? The case of estimating contraceptive prevalence based on self-reported usage.

Chuchu Wei and Leontine Alkema
University of Massachusetts Amherst[1]

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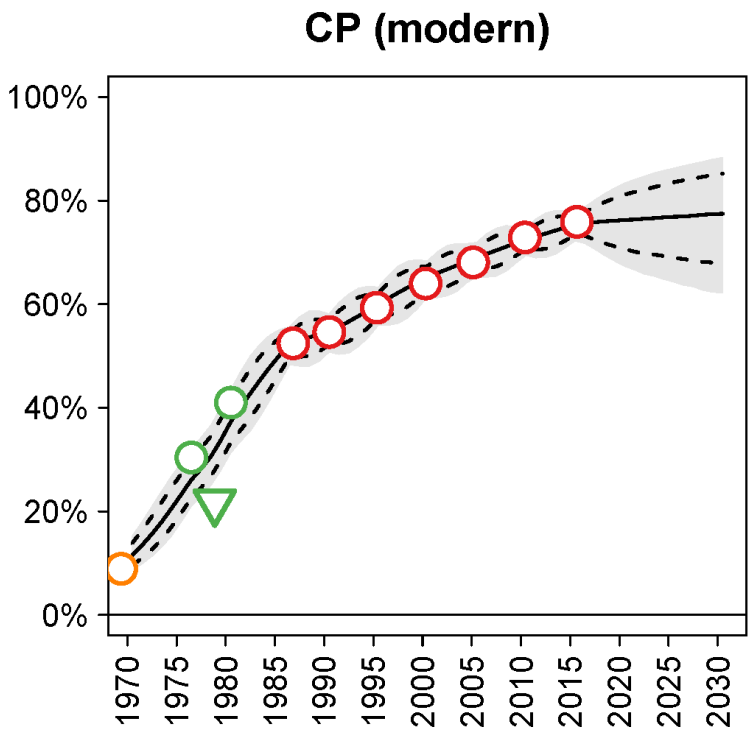
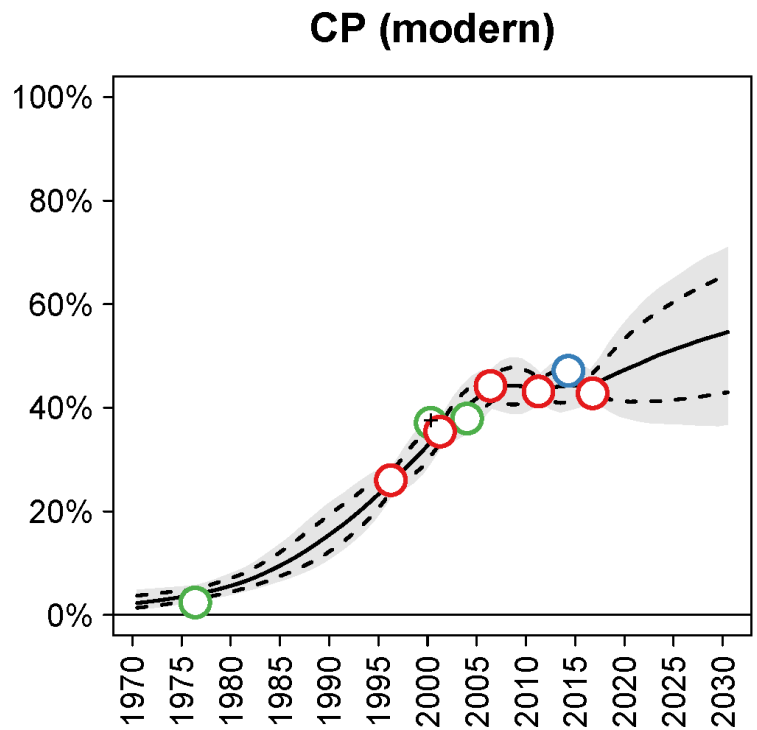
Introduction

- Motivating question:
  How to estimate contraceptive prevalence using self-reported data collection, i.e. demographic health surveys (DHS)
- Approach: Family Planning Estimation Model (FPEM, Cahill et al., 2018)

Colombia (South America)



Nepal (Southern Asia)



Survey data on self-reported usage

- Self-reported usage for estimating FP indicators: observed modern/traditional contraceptive prevalence rates (mCPR/tCPR) and unmet need + sampling error
- Commonly available data sources: Demographic and Health Surveys (DHS), Multiple Indicator Cluster Surveys (MICS), national surveys, etc.
- Sampling error available for DHS, but non-sampling error info is not available

How is the data used in FPEM?

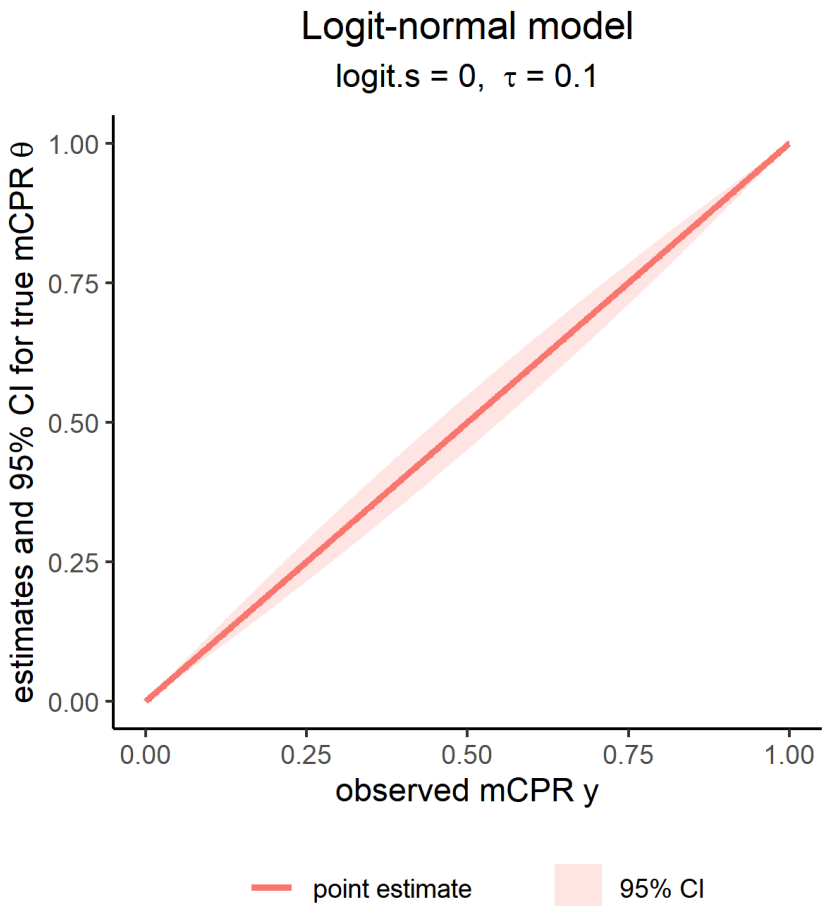
- FPEM: **data model** + process model
  - **data model**: describe how observed data relate to true modern contraceptive prevalence (mCPR)

$$\text{logit}(y) \sim N(\text{logit}(\theta), \text{logit}.s^2 + \eta^2)$$

- Notation
  - y observed mCPR,
  - θ true mCPR,
  - logit.s sampling error,
  - η non-sampling error
- Visualization: posterior median and 95% CIs based on the posterior:

$$p(\theta|y) \propto p(\theta)p(y|\theta)$$

  - prior $\theta \sim U(0, 1)$
  - $p(y|\theta)$ given by logit-normal data model



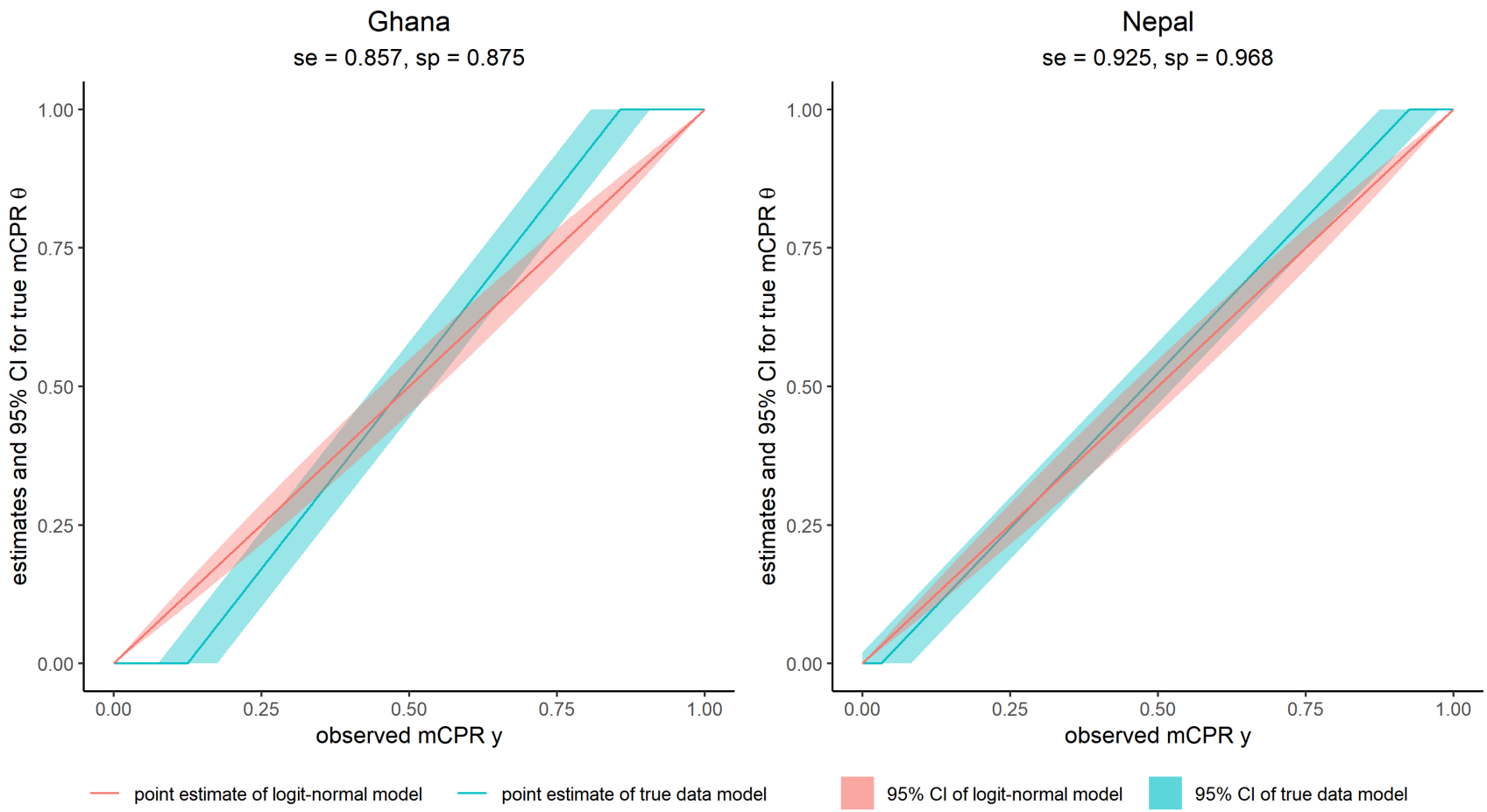
Data on non-sampling error in self-reported modern contraceptive use

- Two post-survey studies of DHS provides data on non-sampling errors in the form of misclassification
  - sensitivity (se) = proportion of modern users who reported themselves as such
  - specificity (sp) = proportion of non-modern users who reported themselves as such
- Findings:
  - 2014 Ghana DHS (Staveteig, 2017) (sample size = 48)
    $se = 0.857 \pm 0.106, sp = 0.875 \pm 0.094$
  - 2016 Nepal DHS (Staveteig et al., 2018) (sample size = 194)
    $se = 0.925 \pm 0.037, sp = 0.968 \pm 0.025$

Visualization of true prevalence θ vs self-reported use y with misclassification

True data model when data are subject to misclassification (simplified, s refers to sampling error):

$$y \sim N_{[0,1]}(se \cdot \theta + (1 - sp)(1 - \theta), s^2),$$



How to estimate a population proportion if data are possibly subject to misclassification error?

- Conclusion so far:
  - Two small post-DHS studies suggest that self-reported mCPR is subject to misclassification
  - The additional uncertainty related to non-sampling error in FPEM does not capture the relationship implied by the studies
- Generalizability problem: only two studies in specific settings
  $\Rightarrow$ do not apply bias-adjustments to self-reported use for all DHS data points based on two studies only
- What we can do:
  Update the data model to better reflect uncertainty associated with potential misclassification errors

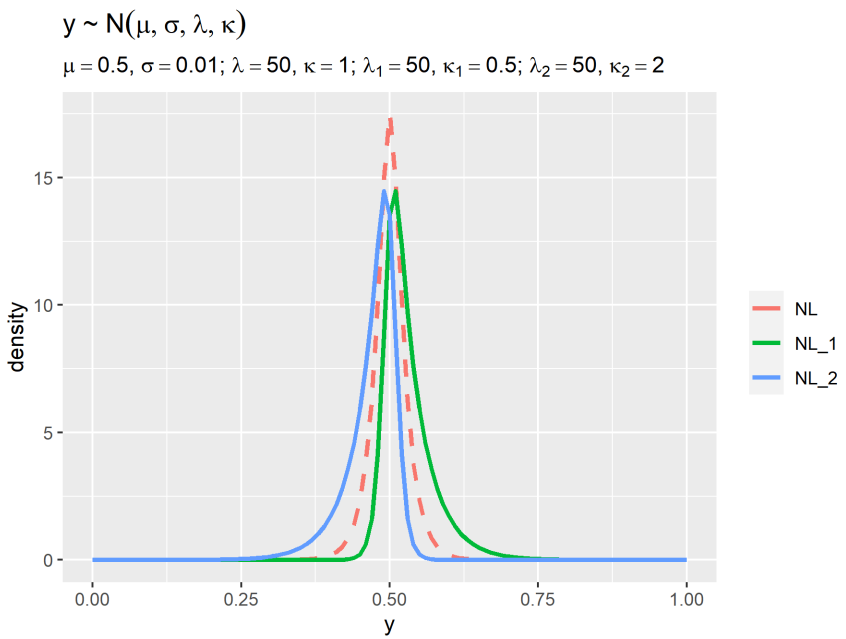
Proposed new data model based on a Normal-Laplace distribution

- Goal: data model to better reflect uncertainty associated with potential misclassification errors
- Aims for the posterior associated with the new data model with assumed sensitivity se^a and specificity sp^a (and $U(0,1)$ prior):
  - $\hat{\theta} = y$
  - If no misclassification: 95% CI determined by sampling error s
  - If misclassification: 95% CI determined by s, se^a, sp^a

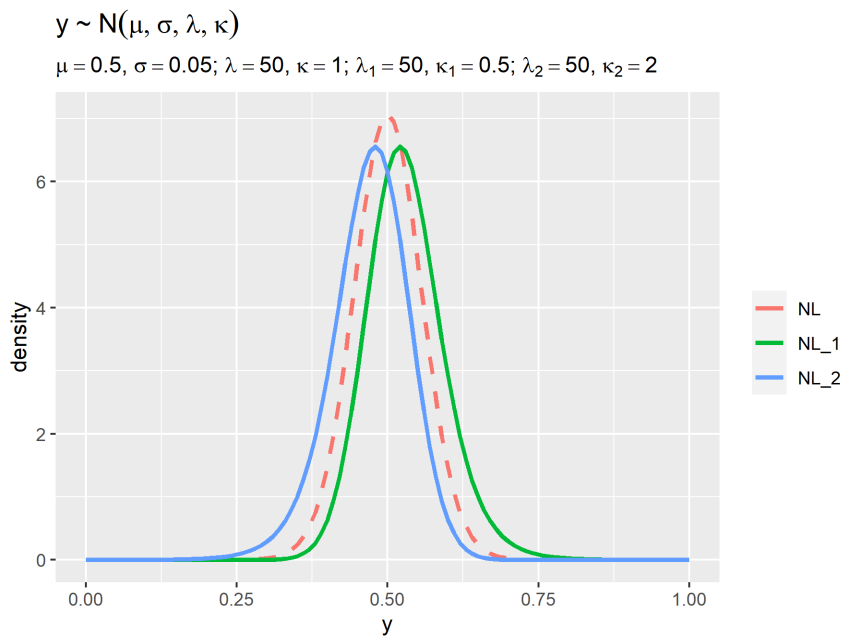
Model specification

The proposed new data model

- Normal-Laplace (NL) distribution (Reed, 2006) for the normalized likelihood,
- Posterior w/ U(0,1) prior given by $p(\theta|y) \sim NL_{[0,1]}(\mu, \sigma, \lambda, \kappa)$
- NL parameters are optimized from y, s, se^a, sp^a to meet aims



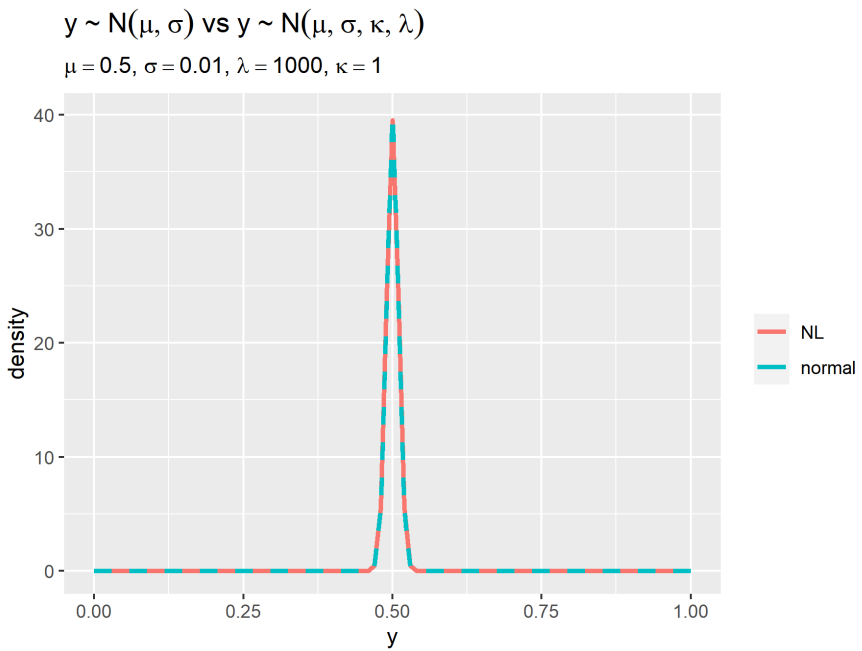
(a) $\sigma = 0.01$



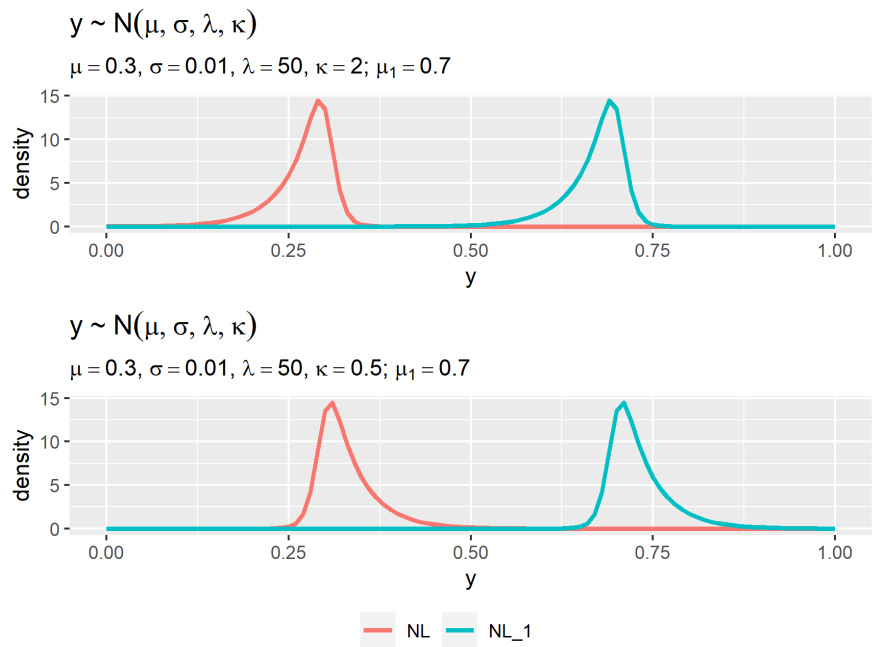
(b) $\sigma = 0.05$

Symmetry vs asymmetry

- $\kappa = 1$: Symmetric shape with $\lambda = 1000 \Rightarrow$ implies no misclassification
- $\kappa \neq 1$: Fixed skewness with varying level of $y \Rightarrow$ same misclassification across varying y



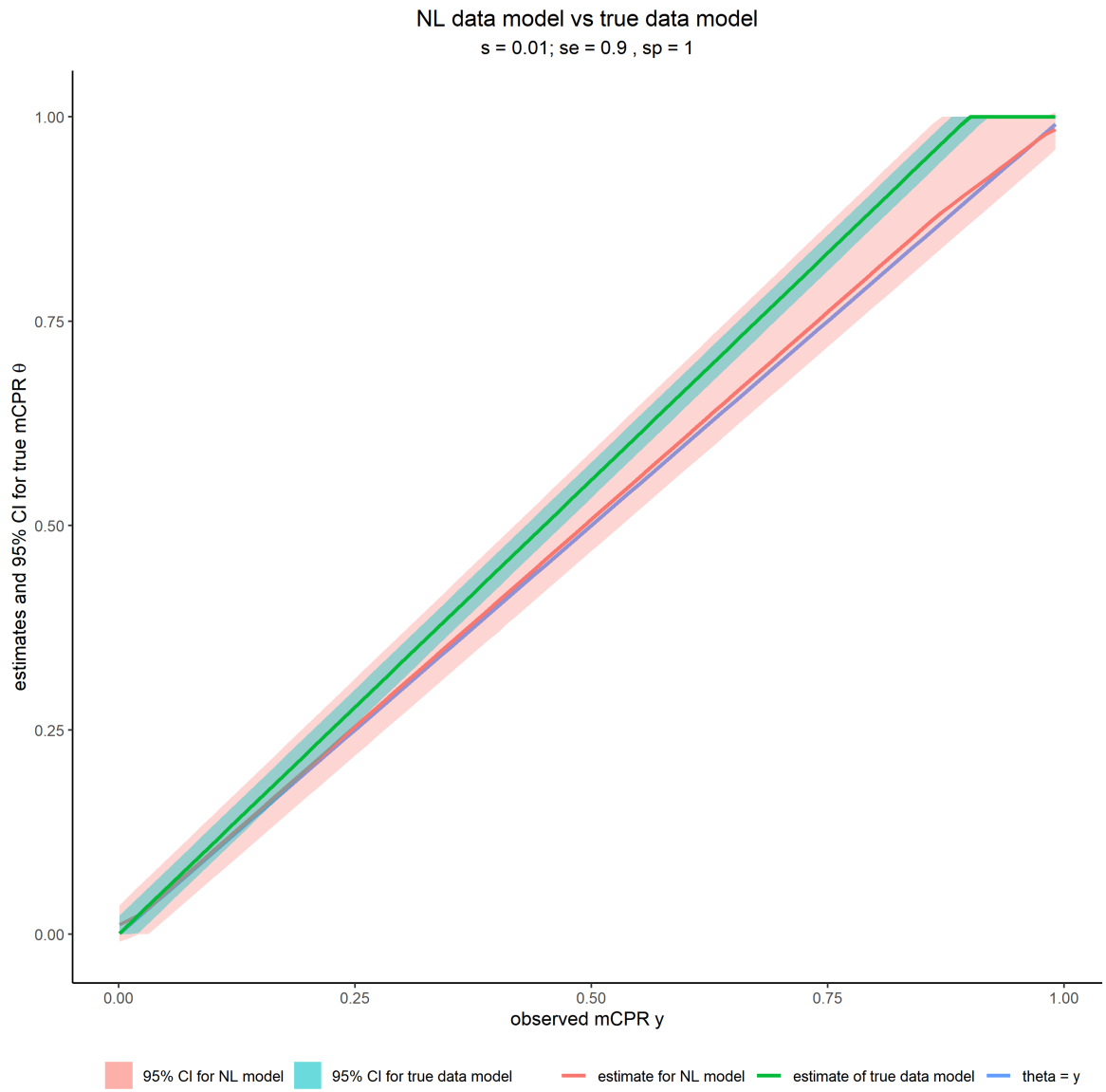
(a) Symmetric NL with $\lambda = 1000, \kappa = 1$



(b) Fixed skewness

Illustration of the new data model

- Visualization: true data model and NL data model
- True relation: $s = 0.01, se = 0.9, sp = 1$
- NL: $s = 0.01, se^a = 0.9, sp^a = 1$, such that $\hat{\theta} = y$ and upper bound of 95% CI increases with y



Simulation study

- We fixed $\theta^{\text{true}} = 0.3, 0.5, 0.7$, use different combinations of true misclassification se, sp and assumed misclassification se^a, sp^a, and generate 100 data sets per setting.
- Compare posterior estimates from
  FPEM logit-normal data model vs proposed NL model
- Findings (as expected):
  1. (bias in) point estimates are comparable between the logit-normal and NL model;
  2. 95% CIs are conservative with coverage exceeding 95%, when assumed misclassification $>$ true misclassification;
  3. NL model improves upon logit-normal model in terms of coverage of 95% CIs when misclassification is present and accounted for.

Estimate FP indicators in local FPEM

Local FPEM

- A scaled-down implementation of Global FPEM to estimate and forecast the trends of contraceptive prevalence and unmet need for a specific population.
- In Local FPEM, non-country-specific parameters are fixed at estimates obtained from global FPEM.
- We compare the effect of differences in data models using local FPEM (so keeping global parameters fixed across fits).

Data models for mCPR

- Old data model

$$\text{logit}(y) \sim N(\text{logit}(\theta), \text{logit}.s^2 + \eta^2)$$

- New data model

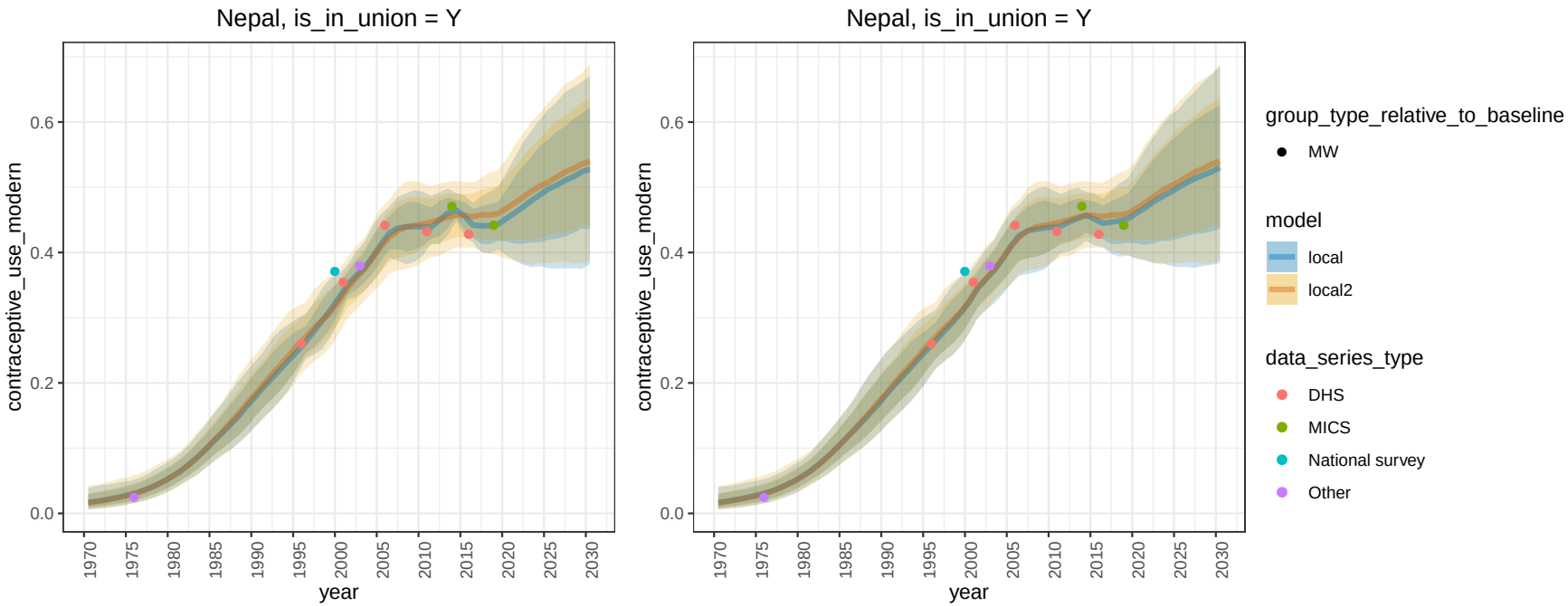
$$p(\theta|y) \sim NL(\mu, \sigma, \lambda, \kappa)$$

- Misclassification assumptions for the new data model:
  1. $se^a = 0.9, sp^a = 1,$
  2. $se^a = sp^a = 0.9.$

Results

LEFT: se = 0.9, sp = 1; RIGHT: se = sp = 0.9

'local2': the local run with logit−normal data model



- mCPR trends and CI from old and new model with same global parameters from old model
- BLUE = new data model, YELLOW = old data model

Results

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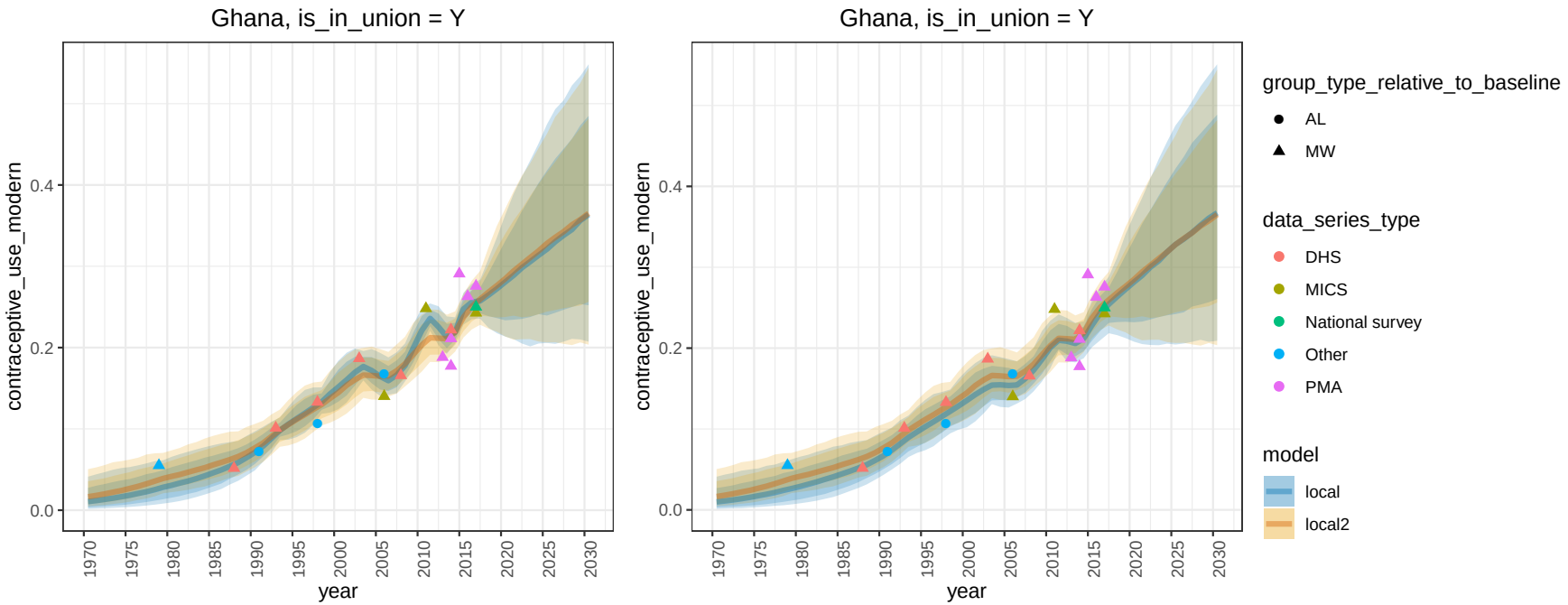
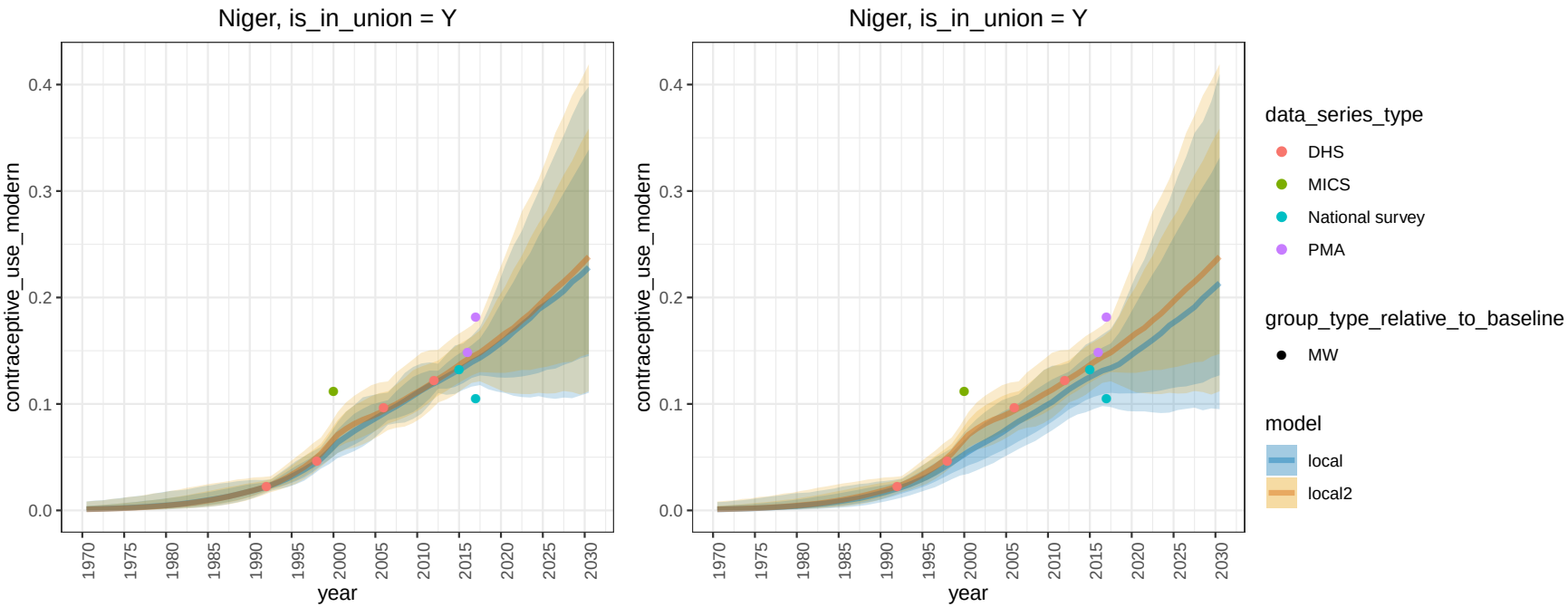
'local2': the local run with logit−normal data model



- Typical performance for many countries with the new data model
- Similar estimated trends between old/new data model, wider CI at low level of mCPR

Results

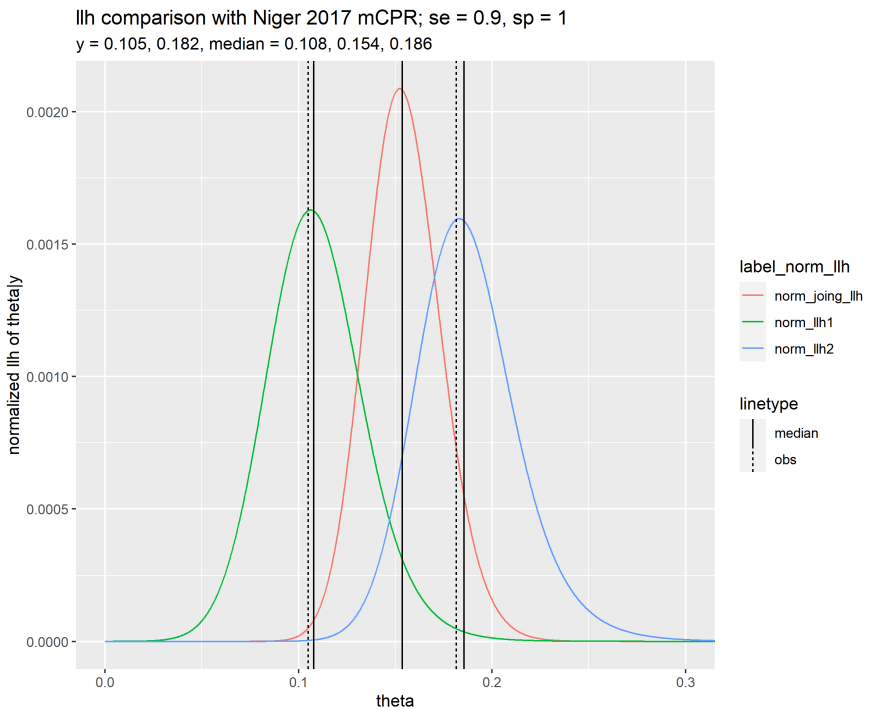
LEFT: se = 0.9, sp = 1; RIGHT: se = sp = 0.9
'local2': the local run with logit−normal data model



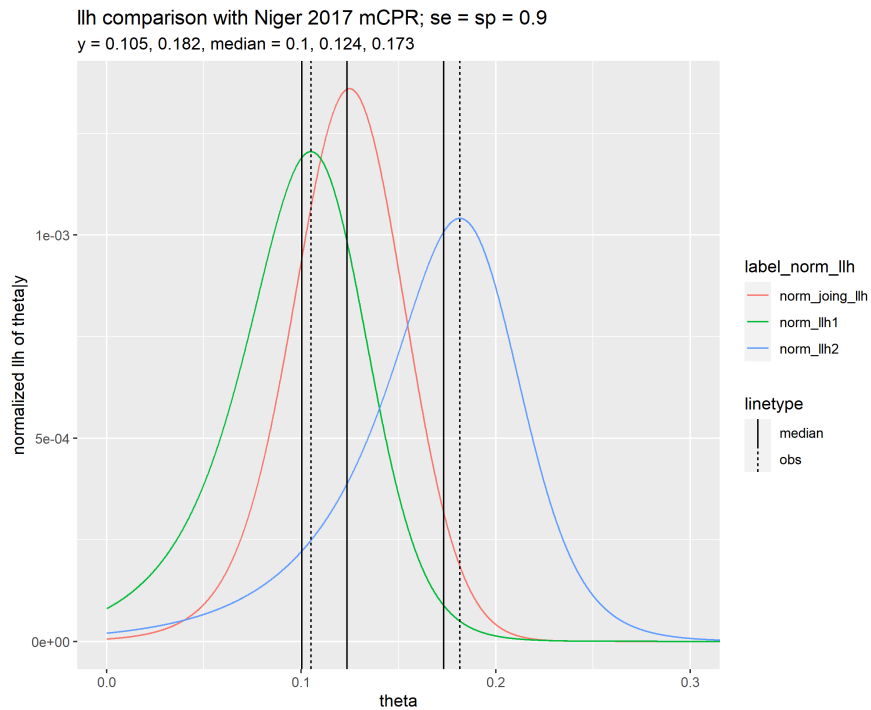
- Update in point estimates when sp = 0.9 (right).

Joint likelihood changes in Niger

- Joint normalized likelihood from two data points at 2017 in Niger
- The downward change and wider CI when SP $= 0.9$ are caused by the likelihood function for point at higher CP having more mass towards lower values



(a) $se = 0.9, sp = 1$



(b) $se = sp = 0.9$

Summary

- We investigated how to estimate a population proportion if data are possibly subject to misclassification error, motivated by reported evidence on misclassification in self-reported modern contraceptive use.
- We propose a new normal-laplace data model to account for increased asymmetric uncertainty associated with potential misclassification errors.
- Simulation study shows improvement in coverage of credible intervals when data are subject to misclassification.
- Usage of the new data model in FPEM results in changes in 95% CI and some changes in estimated trends.

Thank you!

Contact: Chuchu Wei (chuchuwei@umass.edu) and
Leontine Alkema (lalkema@umass.edu)