INVESTIGATING THE BIAS OF ALTERNATIVE STATISTICAL INFERENCE METHODS IN MIXED-MODE SURVEYS

Dissertation Research

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Outline

- Motivations behind Mixed-Mode Surveys
- Typical Assumption in Mixed Mode Surveys: All modes produce correct data (no Mode Effects)
  - Mode effects confounded with mode choice
  - Existing Methods
- Proposed Imputation Methods to assess and adjust for mode effects
- Simulation Study Results
- Conclusions and Current Research

Mixed-Mode Surveys - Motivations

- Decreasing response rates (Curtin, Presser, & Singer, 2005; de Leeuw, 2005; de Leeuw & de Heer, 2002; Steeh, Kirgis, Cannon, & DeWitt, 2001)
- Increasing survey costs (Groves & Heeringa, 2006)
- Better understanding of measurement properties (Tourangeau & Smith, 1996)
- Trends in technology use
  - 17% of cell-owner adults use their cell-phones to go online in the U.S. (Pew Center, Cell Internet Use Survey, 2012)
  - Increasing trends in computer use, Internet access and Broadband Internet access rates (U.S. Census Bureau, 2011)

Mode Effects

- **Single-mode surveys:**
  - Differences in overall results: Mode effects are part of trade-off analysis, no assumption about the ignorability of mode effects
- **Mixed-mode surveys:**
  - Assumption: No mode effects
    - Social desirability bias: Respondents are more likely to misreport their statuses on sensitive topics conditioned on their status in the presence of an interviewer (Tourangeau & Smith, 1996; Tourangeau & Yan, 2007)
    - In-person respondents may be more immune to social desirability tendencies (Holbrook, Green, & Krosnick, 2003)
    - E.g., Income is a sensitive topic in the U.S. (Moore, Stinson & Welniak, Jr, 2000), also an observable characteristic

Mode Effects in Mixed-Mode Surveys

- Mode choice: Nonrandomized Mode Assignment
  - E.g., Respondents with higher education are more likely to respond in telephone mode than in in-person compared to respondents who have less than a 12th Grade education (CPS, March 2012)

- Mode effects are confounded by mode choice in mixed-mode surveys

Existing Methods to Assess Mode Effects

- Randomization and control other error sources (Jäckle, Roberts, & Lynn, 2010; Biemer, 2001)
  - Assign modes randomly
- Comparison to a single mode survey (Vannieuwenhuyze, Loosveldt, & Molengberghs, 2010; 2012)
  - Mixture distribution
  - Representativity assumption
  - Limited to two modes

Existing Methods to Adjust for Mode Effects

- Calibrate the mode proportions to fixed proportions (Buelens & VandenBrakel, 2011)
  - Include mode in the calibration estimator
  - Does not eliminate bias, instead aim to calibrate bias to yield unbiased change estimates
- Selection models (Cobben, 2009; Cobben, Schouten, & Bethlehem, 2006)
  - Include the sequential nature of mode choice in nonresponse weights

Measurement Error Model for a Mixed-Mode Survey

$$y_j = \mu(X_j, \beta^{(\mu)}) + R_{jT} B_{jT} + R_{jI} B_{jI} + \varepsilon_j$$

Mode choice

R_{jT}, R_{jI} : indicator variables for response mode

$\mathrm{E}_R(R_{jT}) = g(X_j; \psi) \equiv g_j$

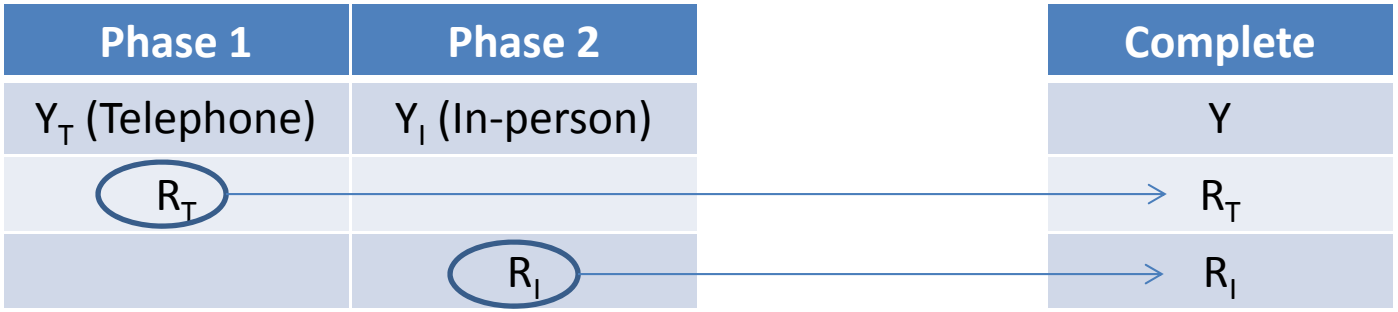
Mode effects

$\mu_j = \mu(X_j, \beta^{(\mu)})$

B_{jT}, B_{jI} : mode effects

Alternatively, $B_{jT} = Z_j^T B_T$, $B_{jI} = Z_j^T B_I$

Population Mean Ignoring Mode Effects



$$\bar{Y}_0 = \frac{1}{N}\left[\sum_{j\in U_T} y_j + \sum_{j\in U_I} y_j\right]$$

U_T = Telephone respondents

U_I = Inperson respondents

$$\mathrm{E}_M[\bar{Y}_0 - \bar{Y}] = \overline{(gB)}_U$$

a weighted average of telephone and in-person mode effects

Alternatively, Multiple Imputation Method

Phase 1	Phase 2
Y_T (Telephone)	Y_I (In-person)
R_T	NR_I
NR_T	R_I

$$\bar{Y}_T^*$$

$$\bar{Y}_T^* = \frac{1}{N}[\sum_{j \in U_T} y_j + \sum_{j \in U_I} y_{jT}^*]$$

$$\mathrm{E}_M \mathrm{E}_I [\bar{Y}_T^* - \bar{Y}] = B_{jT}$$

$$\bar{Y}_I^*$$

$$\bar{Y}_I^* = \frac{1}{N}[\sum_{j \in U_I} y_j + \sum_{j \in U_T} y_{jI}^*]$$

$$\mathrm{E}_M \mathrm{E}_I [\bar{Y}_I^* - \bar{Y}] = B_{jI}$$

How to Combine Mode-Specific Estimates?

$$\bar{Y}^{*} = \alpha \bar{Y}_{T}^{*} + (1-\alpha)\bar{Y}_{I}^{*} \qquad 0 \le \alpha \le 1$$

Empirical Alternative Combination Methods:

Method 1 (CM_1) – Simple average estimator:

$$\alpha = \frac{1}{2}$$

Method 2 (CM_2) – Weighted inversely according to the variances of the estimated means :

$$\alpha = \frac{1}{Var(\bar{Y}_{P}^{*})} \Big/ \sum_{P} \frac{1}{Var(\bar{Y}_{P}^{*})}$$

Method 3 (CM_3) – Weighted inversely according to the mean square errors of the estimated means:

$$\alpha = \frac{1}{MSE(\bar{Y}_{P}^{*})} \Big/ \sum_{P} \frac{1}{MSE(\bar{Y}_{P}^{*})}$$

Evaluate Alternative Combination Methods and Competing Method

$$\text{RelBias}_{CM_l} = \left(\frac{\bar{Y}^* - \bar{Y}}{\bar{Y}^*} \right)$$

where *l=1,2,3* is the combination methods

$$\text{RelBias}_{MODES\_IGNORED} = \left(\frac{\bar{Y}_0 - \bar{Y}}{\bar{Y}_0} \right)$$

Simulation Study Description

- Simulation study: Total Family Income
  - Create hypothetical populations using Current Population Survey (CPS), 1973, and Social Security Records: Exact Match Data
- CPS March Supplement
  - Rotating panel survey
  - Produces data on the U.S. labor force
  - The rotation scheme follows a 4-8-4 pattern
  - The majority of first and fifth waves are in-person interviews
  - For the other waves, respondents are given the choice to do the interview by telephone or in-person visits
  - Majority of interviews from the other waves are telephone

Simulation Study Description

- Total Family Income is constructed by summing up eight income types as reported in CPS over the household head and spouse
- The data exclude the records with item missing in any of the CPS income type and CPS Total Family Income
- Top-coded income values are excluded
- Adjusted Gross Income (AGI) as matched from IRS records used as benchmarks
  - Since Received Welfare Amount is not reported in as part of AGI, a control variable is used in the models to reflect the differences in the income constructs

Simulation Study Description

- X covariates: Race-ethnicity, Living Quarters Type, Region, Industry Type, Job Type, Spouse Work Status, Presence of Children, Respondent Status of Householder

- Regression analysis suggests that there are not differences between modes for this subset
  - Distribution is skewed for whites (94%), laborer (5%)

Hypothetical Populations

Varying Mode Effects:

$$Y_{Ij} = \beta^{(AGI)} Y_j^{(AGI)}$$

$$Y_{Tj} = \beta^{(AGI)} Y_j^{(AGI)}$$

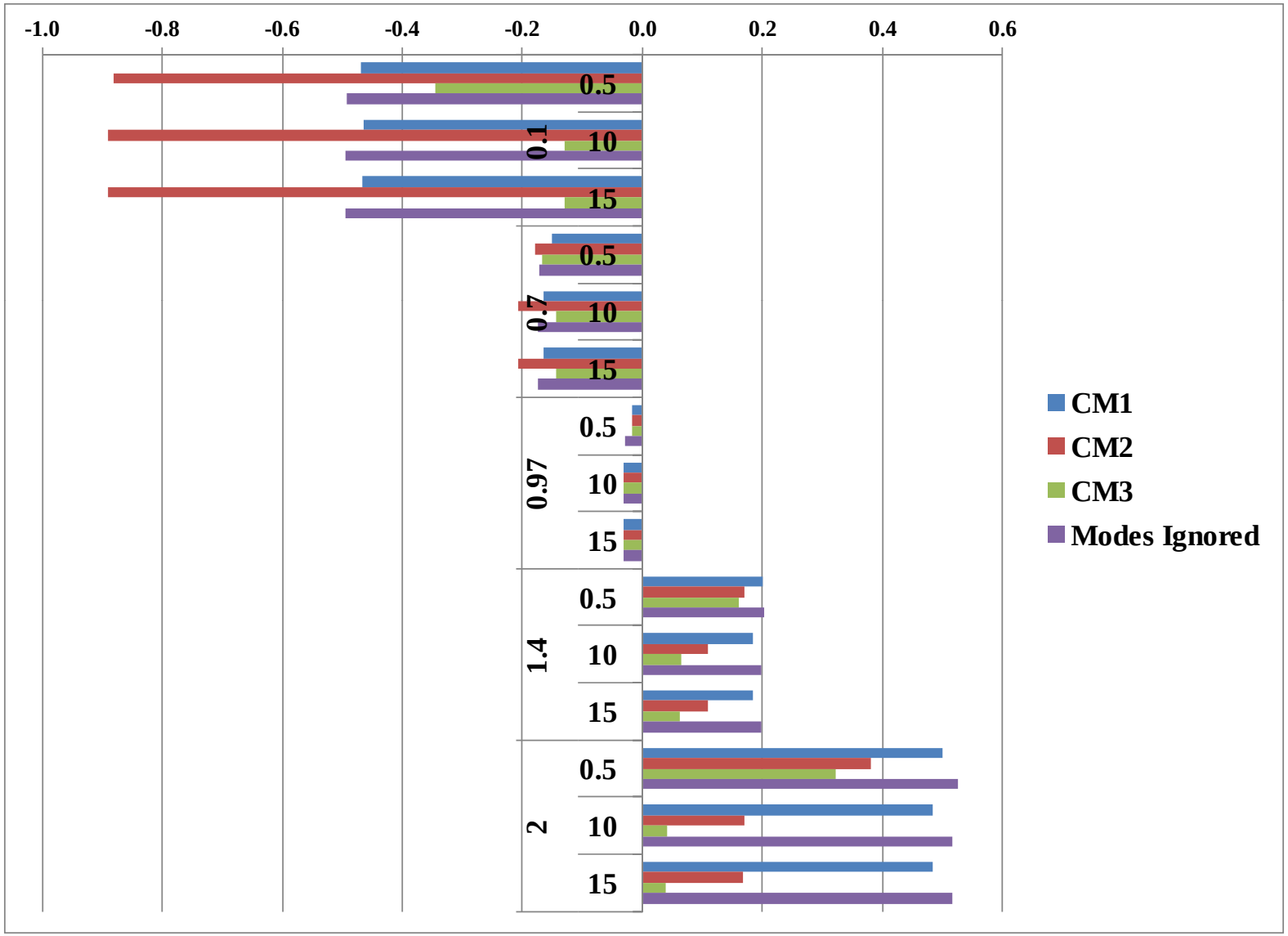
- Beta constant for in-person varies between 0.1-2.0 based on AGI
- Corresponds to Relative Bias of (-0.9 to 1)

Varying Goodness of Model Fit :

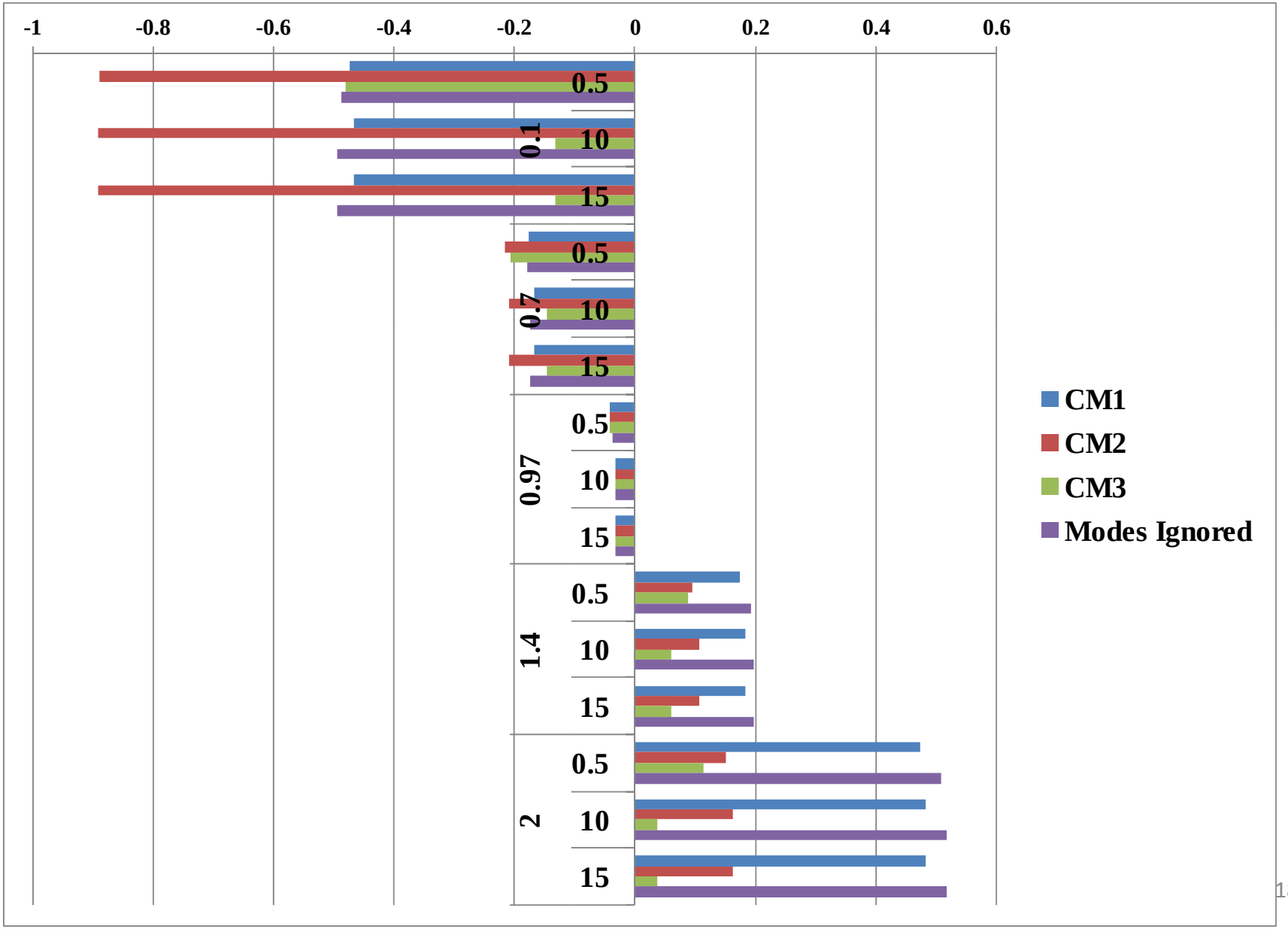
$$\hat{Y}_j = X_j^{(Y)} \hat{\beta}^{(Y)} + e_j$$

$$e_j \overset{iid}{\sim} N\left(0, \sigma^2 / c\right) \quad , \quad c \in (0.5, 10, 15)$$

Simulation Study Results: Relative Biases, Fixed Mode Choice



Simulation Study Results: Relative Biases, Variable Mode Choice



Conclusions and Current Research

- Possible severe bias in traditional method
- Evaluation of model assumptions
  - Feasibility
- Alternatively, sensitivity analyses can be conducted in the absence of benchmarks

Thank you.

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Bias of Sample Mean in Mixed-Mode Surveys

Measurement error model:

$$y_i = \mu_i + B_{p,g} + \varepsilon_i,\ \left(i \in U_{p,g},\ \varepsilon_i \sim (0, \sigma_\varepsilon^2)\right)$$

Sample mean:

$$\bar{y} = \sum_{i=1}^{n} y_i \Big/ n$$

The bias of $\bar{y}$:

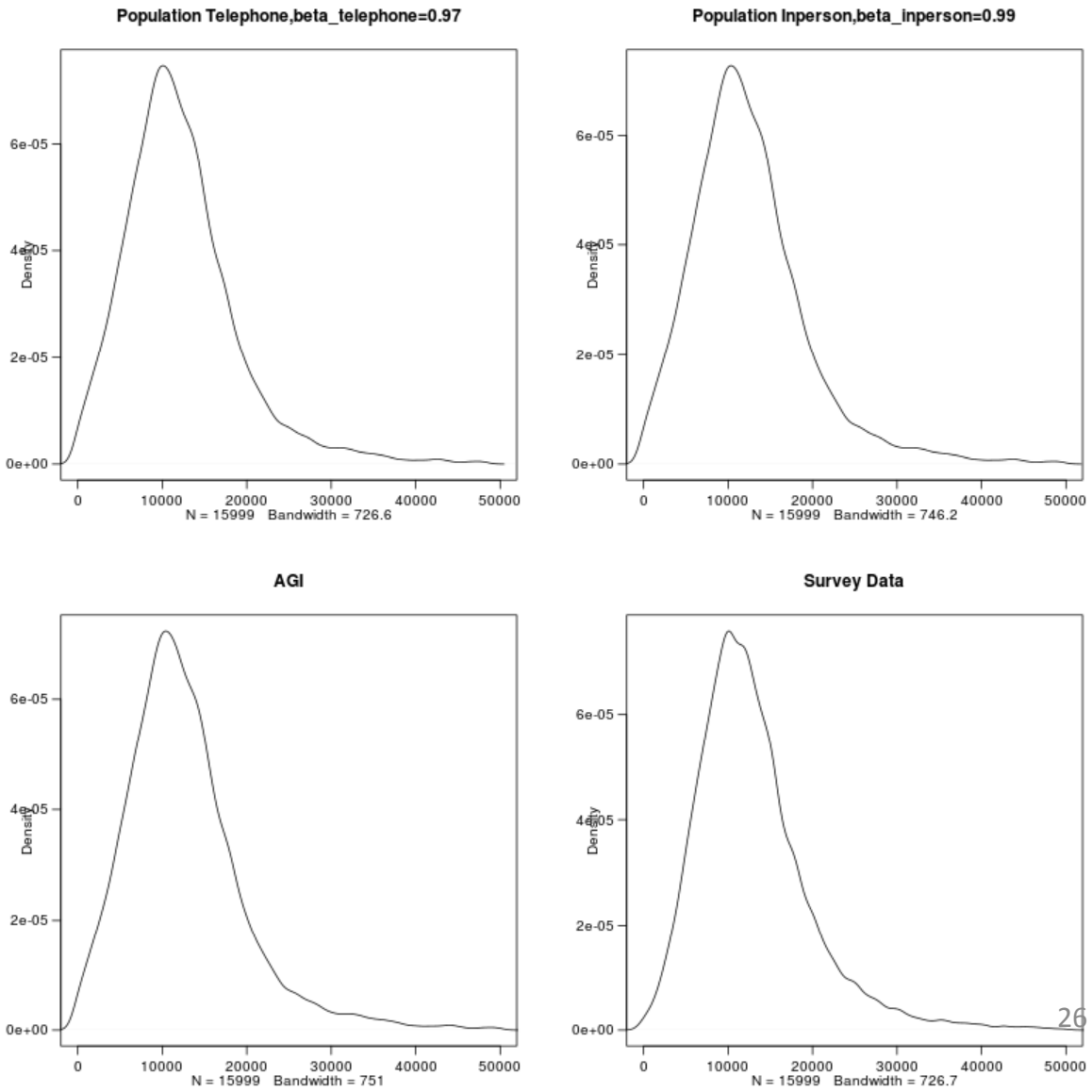
$$\sum_g P_{p,g} B_{p,g}$$

Simulation Study: Total Family Income Hypothetical Populations - Varying mode effects

$$Y_{iP} = \beta AGI_i$$

$$\begin{bmatrix} \beta_{Telephone} \\ \beta_{Inperson} \end{bmatrix} = \begin{bmatrix} 0.97 \\ (0.1, 0.97, 2.0 \end{bmatrix}$$

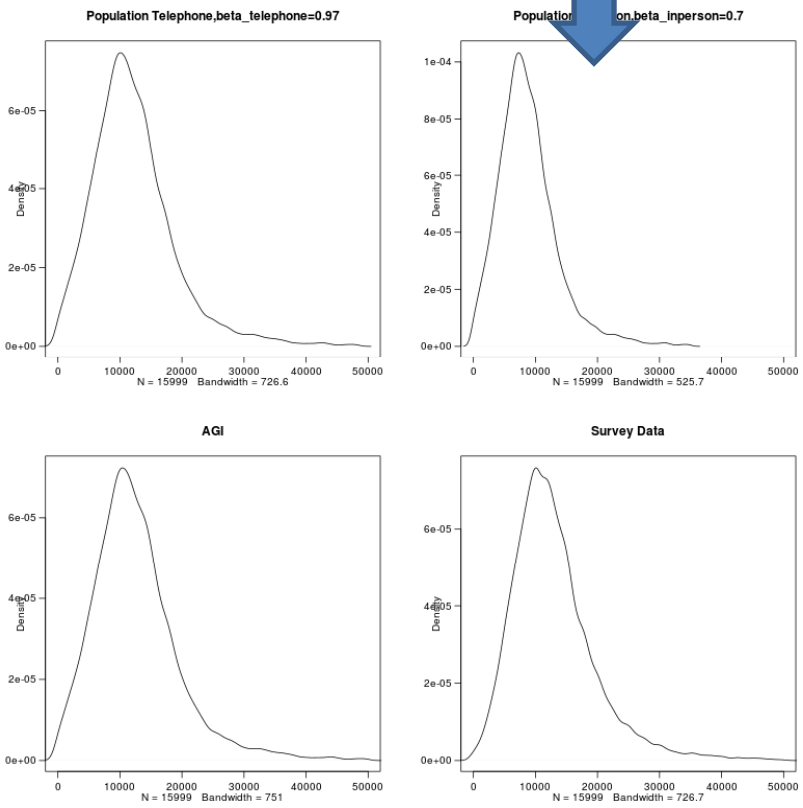
where *i* represents a respondent



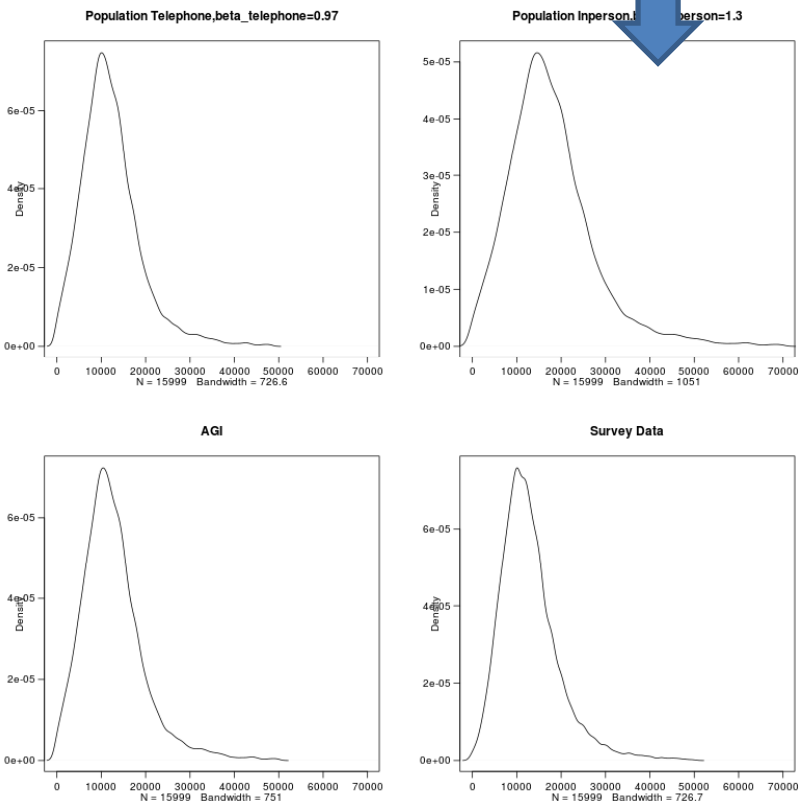
Simulation Study: Total Family Income

Hypothetical Populations - Varying mode effects

beta_inperson=0.7



beta_inperson=1.4



Simulation Results – Evaluation of Combination Methods

- Including item missing in imputation yields
  - Larger absolute relative bias on the average
  - Larger variation

- Combination method 3 outperforms the competing method using deterministic regression model, but not in stochastic regression model simulations

Imputation Model: Ignorable Mode Effects - Continuous Variables

Normal Linear Regression Model:

$$Y_{jT} \sim N(X_j \beta, \sigma^2)$$

Assuming the standard noninformative prior distribution

$$\Pr(\beta, \sigma \mid X) \propto \frac{1}{\sigma^2} \rightarrow \qquad (\beta \mid \sigma^2, y) \sim MVN(\hat{\beta}, V(\hat{\beta})\sigma^2)$$

where, $\hat{\beta} = (X^T X)^{-1} X^T Y$,and $V(\hat{\beta}) = (X^T X)^{-1}$

$$\Pr(\sigma^2 \mid y) \sim Inv - \chi^2(n-k, s^2)$$,and

$$s^2 = \frac{1}{n-k}(y - X\hat{\beta})^T (y - X\hat{\beta})$$

where n is sample size and k number of parameters

Imputation Model: Nonignorable - Selection Models – Continuous Variables

A model for the mode choice mechanism:

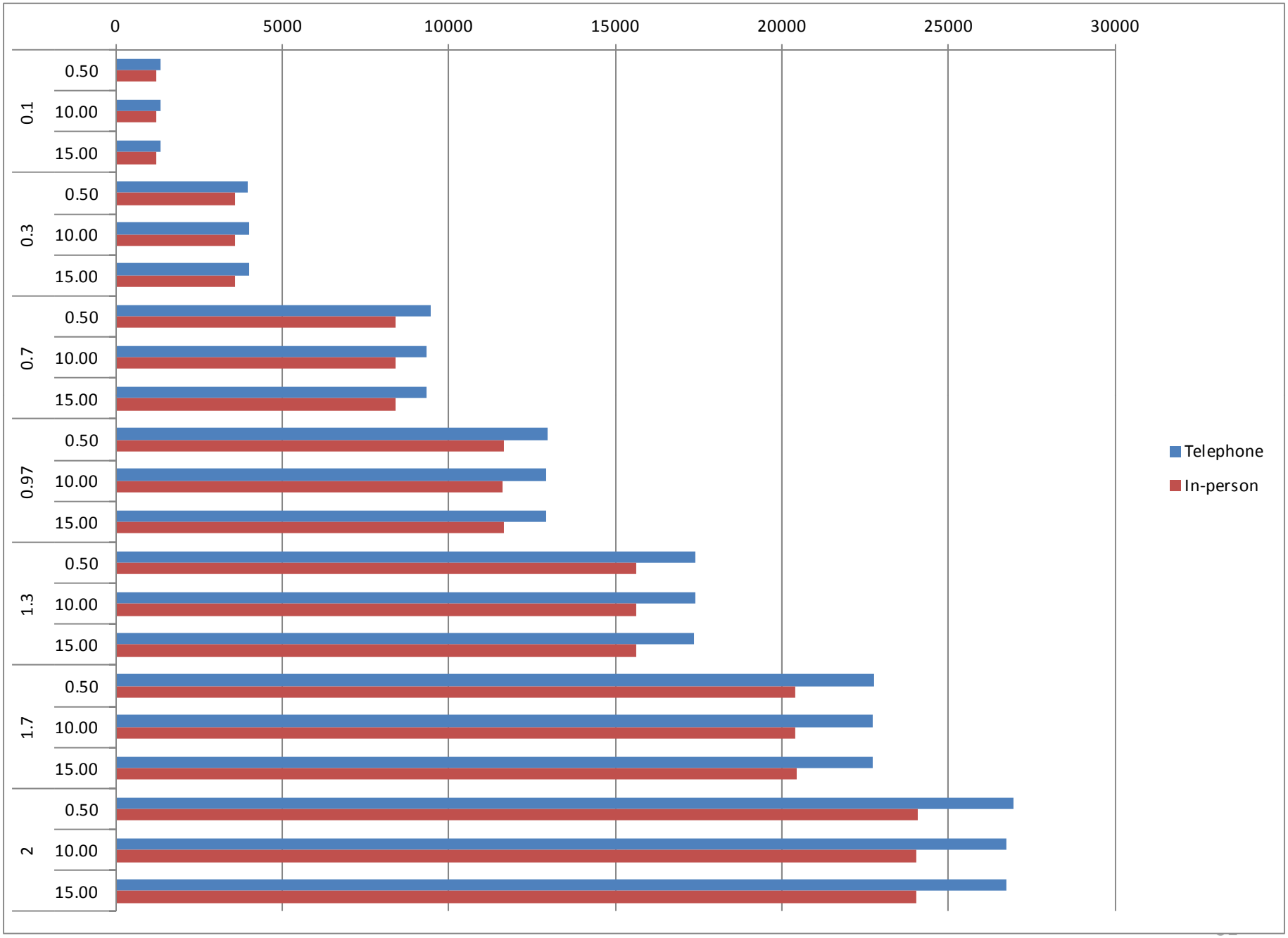
$$\Pr(R_{jT} = 0 \mid X_j^R, Y_{jT}; \psi) = \left[1 + \exp(-X_j^{(R)}\beta^{(R)} - \gamma Y_j)\right]^{-1}$$

A complete data model:

$$(Y_{jT} \mid X_j^{(Y)}; \theta) \sim N(X_j^{(Y)}\beta^{(Y)}, \sigma^2)$$

$$L_{full}(\theta, \psi \mid Y_T, RjT) = \prod_{j \in U_T} \frac{1}{\left[1 + \exp(-X_j^{(R)}\beta^{(R)} - \gamma Y_j)\right]} \frac{1}{\sigma} \Phi\left(\frac{Y_j - X_j^{(Y)}\beta^{(Y)}}{\sigma}\right) \times$$

$$\prod_{j \in U_R} \int_{-\infty}^{\infty} \left(1 - \frac{1}{\left[1 + \exp(-X_j^{(R)}\beta^{(R)} - \gamma Y_j)\right]}\right) \frac{1}{\sigma} \Phi\left(\frac{Y_j - X_j^{(Y)}\beta^{(Y)}}{\sigma}\right) dy_j$$


0
5000
10000
15000
20000
25000
30000
0.1
0.3
0.7
0.97
1.3
1.7
2
0.50
10.00
15.00
Telephone
In-person

Subset of Current Population Survey (CPS), 1973, and Social Security Records: Exact Match Data

The mode distribution shifts across the month in sample as expected (n=15,999)

Mode	M1	M2	M3	M4	M5	M6	M7	M8
Telephone	2%	34%	60%	66%	6%	53%	63%	65%
In-person	98%	66%	40%	34%	94%	47%	37%	35%

Overall: 56% in-person, 44% telephone

Hypothetical Populations Income Means- Varying mode effects

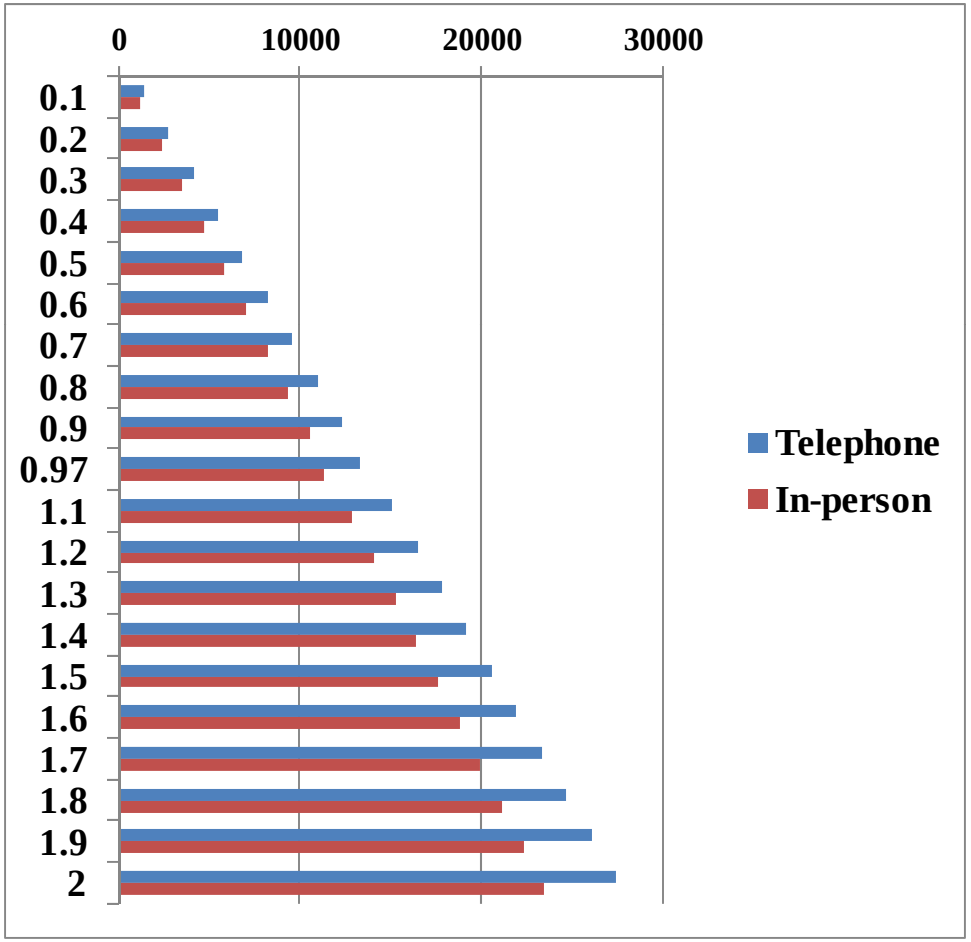
$$Y_{Ij} = \beta^{(AGI)} Y_j^{(AGI)}$$

$$Y_{Tj} = \beta^{(AGI)} Y_j^{(AGI)}$$

Beta constant for in-person varies between 0.1-2.0 based on AGI

Corresponds to Relative Bias of (-0.9 to 1)

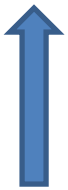
The higher mean for telephone respondents is preserved



Simulation study 1: Household Income

Varying goodness of model fit

$$\hat{Y}_j = X_j^{(Y)} \hat{\beta}^{(Y)} + e_j \qquad e_j \overset{iid}{\sim} N\left(0, \sigma^2 / c\right)$$



c(0.5,10,15)

where *i* represents a respondent

Alternatively, Multiple Imputation Method

Phase 1	Phase 2
Y_1 (Telephone)	Y_2 (In-person)
R_T	NR_I
NR_T	R_I

- A special case of a missing data problem
- Impute data for each phase through a series of multiple imputation models as if all units had reported in that particular mode
- Impute nonrespondent data for Telephone and In-person phases via multiple imputation models
- *X* covariates in the models are combination of personal and residential data (such as age, gender, etc.)
- Continuous variable: Normal linear regression model, noninformative prior distribution.