A Simulation-Based Approach to Refining Estimates of Sampling Variability for the Planning Database’s Low Response Score

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This presentation is released to inform interested parties of ongoing research and to encourage discussion of work in progress. The views expressed are those of the author and not necessarily those of the U.S. Census Bureau.
Presentation Agenda

• Introduction and context (PDB, LRS, and research questions)
• Method (simulation-based variance estimation)
• Data source and sample design
• Analysis
• Conclusion
What is the Planning Database?

• Publicly available collection of popular measures
  – **Ex:** # of HUs, % Pop under 5 yrs, Median Hhld Income, Pop Density

• Data comes from Census 2010 and ACS 5-year Summary Files

• Aggregated counts and percents at tract & block group levels.

• Many uses – primary function is to aid in planning field operations for Census 2020 and other survey projects

• [https://www.census.gov/research/data/planning_database/](https://www.census.gov/research/data/planning_database/)
What is the Low Response Score?

• Metric created for PDB as predictor of self-response propensity

• Derived from multivariate linear regression (MLR) model with Census 2010 mail non-response rate as dependent variable

• Ranges from 0 to 100 (low LRS = higher predicted self-response rate); Example: when LRS = 25, we predict that 25% of households in that tract will not self-respond to the Census.

• Based on 25 main-effect inputs from ACS 5-year Summary Files

• Methodology: see Erdman and Bates (2017)
## Low Response Linear Regression Model (Block Group)

<table>
<thead>
<tr>
<th>Coef</th>
<th>Sig</th>
<th>(Intercept) 10.29 ***</th>
<th>Renter occupied units 1.08 ***</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ages 18-24</td>
<td>0.64 ***</td>
<td>Female head, no husband 0.58 ***</td>
<td></td>
</tr>
<tr>
<td>Non-Hispanic White</td>
<td>-0.77 ***</td>
<td>Ages 65+ -1.21 ***</td>
<td></td>
</tr>
<tr>
<td>Related child &lt;6</td>
<td>0.46 ***</td>
<td>Males 0.09 ***</td>
<td></td>
</tr>
<tr>
<td>Married family households</td>
<td>-0.12 ***</td>
<td>Ages 25-44 -0.06</td>
<td></td>
</tr>
<tr>
<td>Vacant units</td>
<td>1.08 ***</td>
<td>College graduates -0.32 ***</td>
<td></td>
</tr>
<tr>
<td>Median household income</td>
<td>0.24 ***</td>
<td>Ages 45-64 -0.08 *</td>
<td></td>
</tr>
<tr>
<td>Persons per household</td>
<td>3.44 ***</td>
<td>Moved in 2005-2009 0.09 ***</td>
<td></td>
</tr>
<tr>
<td>Hispanic Any Race</td>
<td>0.41 ***</td>
<td>Single unit structures -0.52 ***</td>
<td></td>
</tr>
<tr>
<td>Population Density</td>
<td>-0.40 ***</td>
<td>Below poverty 0.11 ***</td>
<td></td>
</tr>
<tr>
<td>Different HU 1 year ago</td>
<td>-0.12 ***</td>
<td>Ages 5-17 0.17 ***</td>
<td></td>
</tr>
<tr>
<td>Non-Hispanic Black</td>
<td>-0.04 **</td>
<td>Single person households -0.24 ***</td>
<td></td>
</tr>
<tr>
<td>Not high school grad</td>
<td>-0.06 ***</td>
<td>Median house value 0.71 ***</td>
<td></td>
</tr>
</tbody>
</table>

Sig: *** $p < .001$; ** $.001 \leq p < .01$; * $.01 \leq p < .05$  
R-squared: 56.10%, $n = 217,417$  
Main Effects only, no interaction terms

Why should we care about LRS variability?

• Need to be able to discern significant differences between LRS predictions for field planning purposes.

• Ex: Tract A has LRS = 15, Tract B has LRS = 22. Are these significantly different?
Statement of Purpose

• Ongoing research into variability of the Low Response Score.
• Last time (Larsen, 2017), I used ACS replicate weights to generate approximate MOEs for LRS predictions at tract level.
  – Did not account for sampling variability in regressor inputs.
  – Currently do not have method that addresses sampling error from both the coefficient estimates and the regressor inputs.
• Can we use simulation techniques to determine whether the MOEs would significantly change under a “full” strategy?
Research Question

Consider two strategies for estimating the variance of LRS predictions using a Monte Carlo simulation approach:

- **"Partial"**: LRS predictions are simulated by allowing only the coefficients to vary while fixing the inputs in place.
- **"Full"**: LRS predictions are simulated by allowing both the coefficients and the inputs to vary.

**RQ**: Are the Full variance estimates significantly different than the Partial variance estimates for individual tracts?
Method: Monte Carlo variance estimate

2. For a given tract in the current PDB, generate 50 simulations of the LRS (either Full or Partial strategy)
3. Calculate the sample variance of the 50 simulations.
4. Repeat steps 2 and 3 over a large number (4000) of iterations.
5. The mean of these simulated variances is the Monte Carlo variance estimate.
6. Predicted LRS variance = MC variance of fitted LRS + MSE of model fit (27.8)
7. Repeat steps 2 through 6 for all tracts in the sample (n=1000)
LRS simulation example (1)

Miami-Dade County, Florida Tract 0083.05, 1\textsuperscript{st} iteration

\[ X = 50 \text{ LRS simulations} \]

\begin{align*}
\text{Mean } LRS_{Part} &= 23.34 \\
\text{Variance } LRS_{Part} &= 7.11 \\
\text{Mean } LRS_{Full} &= 22.75 \\
\text{Variance } LRS_{Full} &= 4.44
\end{align*}

Miami-Dade County, Florida Tract 0083.05, all iterations

\[ N = 4000 \text{ iterations} \]

\begin{align*}
\text{Mean } \text{Var}(LRS_{Part}) &= 5.95 \\
\text{Variance } \text{Var}(LRS_{Part}) &= 1.41 \\
\text{Mean } \text{Var}(LRS_{Full}) &= 5.76 \\
\text{Variance } \text{Var}(LRS_{Full}) &= 1.34
\end{align*}

Source: U.S. Census Bureau, 2012-2016 American Community Survey 5-year Summary Files
LRS simulation example (2)

Histogram of Var(partial)

Mean Var = 5.95
N = 4000 iterations

Histogram of Var(full)

Mean Var = 5.76
N = 4000 iterations

Source: U.S. Census Bureau, 2012-2016 American Community Survey 5-year Summary Files
Data sources

• As usual, the LRS model was fit with inputs from the 2010 Tract PDB (Census 2010 and 2006-2010 ACS 5-year aggregated data)
• For this study, simulated LRS predictions utilized estimates from the 2018 Tract PDB (Census 2010 and 2012-2016 ACS data)
  – Over 74,000 tracts in the 2018 PDB
  – Of these, about 71,000 tracts were eligible to receive an LRS
  – For simplicity, tracts with missing data on any regressor were excluded
Sample design

To ensure a reasonable degree of representativeness across the U.S., the sample pool of tracts was stratified by two variables:

<table>
<thead>
<tr>
<th>Census Region</th>
<th>Population Size*</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Northeast</td>
<td>• Less than 3000 people</td>
</tr>
<tr>
<td>• Midwest</td>
<td>• 3000 to 4999 people</td>
</tr>
<tr>
<td>• South</td>
<td>• 5000 people or more</td>
</tr>
<tr>
<td>• West</td>
<td></td>
</tr>
</tbody>
</table>

In total, the sample pool was split into 12 strata. Two samples of 1,000 cases were independently drawn using a proportionally allocated stratified sample design. **Two-sample approach is for research not presented today; the samples were combined for this RQ (n = 1990).**

* Based on total population estimates from the 2012-2016 ACS 5-year file.
# Composition of tract universe and samples by Census Region and estimated population

## Universe distribution

<table>
<thead>
<tr>
<th>Census Region</th>
<th>Less than 3000</th>
<th>3000-4999</th>
<th>5000 or more</th>
</tr>
</thead>
<tbody>
<tr>
<td>Northeast</td>
<td>3626</td>
<td>5516</td>
<td>3848</td>
</tr>
<tr>
<td>Midwest</td>
<td>5388</td>
<td>7176</td>
<td>4112</td>
</tr>
<tr>
<td>South</td>
<td>6358</td>
<td>9806</td>
<td>9344</td>
</tr>
<tr>
<td>West</td>
<td>2776</td>
<td>6647</td>
<td>6032</td>
</tr>
</tbody>
</table>

## Sample 1&2 distribution

<table>
<thead>
<tr>
<th>Census Region</th>
<th>Less than 3000</th>
<th>3000-4999</th>
<th>5000 or more</th>
</tr>
</thead>
<tbody>
<tr>
<td>Northeast</td>
<td>51</td>
<td>78</td>
<td>55</td>
</tr>
<tr>
<td>Midwest</td>
<td>76</td>
<td>102</td>
<td>58</td>
</tr>
<tr>
<td>South</td>
<td>90</td>
<td>139</td>
<td>132</td>
</tr>
<tr>
<td>West</td>
<td>39</td>
<td>94</td>
<td>86</td>
</tr>
</tbody>
</table>

## Shared tracts between 1&2

<table>
<thead>
<tr>
<th>Census Region</th>
<th>Less than 3000</th>
<th>3000-4999</th>
<th>5000 or more</th>
</tr>
</thead>
<tbody>
<tr>
<td>Northeast</td>
<td>1</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Midwest</td>
<td>1</td>
<td>0</td>
<td>2</td>
</tr>
<tr>
<td>South</td>
<td>1</td>
<td>2</td>
<td>0</td>
</tr>
<tr>
<td>West</td>
<td>1</td>
<td>0</td>
<td>2</td>
</tr>
</tbody>
</table>

Source: U.S. Census Bureau, 2012-2016 American Community Survey 5-year Summary Files
Process for tract-level assessment

• For each tract in the combined sample, find $V ar_{MC}(fit)$ under both Full and Partial strategies.

• Find $V ar_{MC}(pred) = V ar_{MC}(fit) + MSE$ under both strategies.

• Conduct F-tests for equality of variance at the tract level using full-to-partial variance estimate ratios.

### Examples of Tract-Level MC Variances and Ratios

<table>
<thead>
<tr>
<th>County, State Tract #</th>
<th>MC Var ($LRS_{Full}$)</th>
<th>MC Var ($LRS_{Full}$)</th>
<th>Full/Partial Ratio</th>
<th>P-value</th>
<th>F-test (fitted)</th>
<th>Full/Partial Ratio</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Miami-Dade Cty, FL Tract 0083.05</td>
<td>5.946</td>
<td>5.756</td>
<td>1.033</td>
<td>$p = 0.3003$</td>
<td>1.006</td>
<td>$p = 0.4644$</td>
<td></td>
</tr>
<tr>
<td>Los Angeles Cty, CA Tract 1352.02</td>
<td>6.353</td>
<td>5.879</td>
<td>1.081</td>
<td>$p = 0.1101$</td>
<td>1.014</td>
<td>$p = 0.4125$</td>
<td></td>
</tr>
<tr>
<td>Prince George’s Cty, MD Tract 8012.16</td>
<td>7.515</td>
<td>5.820</td>
<td>1.291</td>
<td>$p &lt; 0.0001$</td>
<td>1.050</td>
<td>$p = 0.2182$</td>
<td></td>
</tr>
<tr>
<td>Collier Cty, FL Tract 0102.15</td>
<td>8.867</td>
<td>5.814</td>
<td>1.525</td>
<td>$p &lt; 0.0001$</td>
<td>1.091</td>
<td>$p = 0.0845$</td>
<td></td>
</tr>
</tbody>
</table>

Source: U.S. Census Bureau, 2012-2016 American Community Survey 5-year Summary Files
## Tract-level assessment

<table>
<thead>
<tr>
<th>Combined Sample Sub-group</th>
<th>Number of Sampled Tracts</th>
<th>F-test Summary ( (\alpha = 0.1, ; df_1 = df_2 = 4000) )*</th>
<th>Fitted LRS</th>
<th>Predicted LRS</th>
</tr>
</thead>
</table>
|                           |                          | \( \begin{array}{ll}
\text{Number Sig} & \text{Percent Sig} \\
\text{Number Sig} & \text{Percent Sig} \\
\end{array} \) |            |              |
| All tracts                | 1989**                   | \( \begin{array}{ll}
177 & 8.9 \\
2 & 0.1 \\
\end{array} \) |            |              |
| **Region**                |                          |                                                        |            |              |
| Northeast                 | 367                      | \( \begin{array}{ll}
37 & 10.1 \\
2 & 0.5 \\
\end{array} \) |            |              |
| Midwest                   | 469                      | \( \begin{array}{ll}
30 & 6.4 \\
0 & 0.0 \\
\end{array} \) |            |              |
| South                     | 718                      | \( \begin{array}{ll}
62 & 8.6 \\
0 & 0.0 \\
\end{array} \) |            |              |
| West                      | 435                      | \( \begin{array}{ll}
50 & 11.5 \\
0 & 0.0 \\
\end{array} \) |            |              |
| **Pop. Size**             |                          |                                                        |            |              |
| < 3000                    | 507                      | \( \begin{array}{ll}
73 & 14.4 \\
1 & 0.2 \\
\end{array} \) |            |              |
| 3000 – 5000               | 824                      | \( \begin{array}{ll}
65 & 7.9 \\
0 & 0.0 \\
\end{array} \) |            |              |
| > 5000                    | 658                      | \( \begin{array}{ll}
41 & 6.2 \\
1 & 0.2 \\
\end{array} \) |            |              |

* Family-wise error rate; multiple comparisons controlled with Holm-Bonferroni.

** One tract in the sample was shown to present unusually large outlier characteristics, so it was omitted from this analysis.

Source: U.S. Census Bureau, 2012-2016 American Community Survey 5-year Summary Files
Tract-level assessment summary

• For most tracts, $\text{Var}(LRS_{Full})$ is not sig. different from $\text{Var}(LRS_{Part})$.
• This appears especially so for the predicted LRS values.
• It is reasonable to assume that variance estimates derived under the Partial strategy in a practical application will sufficiently account for the true sampling variability in the Low Response Score.

Source: U.S. Census Bureau, 2012-2016 American Community Survey 5-year Summary Files
Conclusion

• The evidence suggests that an actual (not simulation) variance estimation process using the Full strategy might not yield LRS MOEs that are significantly different from the current process (Larsen, 2017) that uses the Partial strategy.

• **Recommendation:** Continue investigation, but favor the Partial strategy over the Full strategy.
Next Steps

• Expand the simulation parameters
• Explore regional and population size differences
• Consider the block-group LRS
• Publication (Census Bureau Report Series)
• Approval to publish LRS MOEs in the Planning Database
Questions and Comments?

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Citations
