Considerations for the Use of Small Area Analysis in Survey Analysis for Health Policy: Example from the 2015 Ohio Medicaid Assessment Survey

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Abstract
State-based surveys are often required to produce reliable estimates at multiple levels of geography (e.g., state, sub-state region, and county). Often the optimal design varies depending on the level of geography used in analysis. Small area estimation (SAE) can assist in improving precision in sub-state areas that do not have enough interviews to produce reliable estimates directly. The 2015 Ohio Medicaid Assessment Survey (OMAS) allows for the measurement of health status, access to the healthcare system, and health determinant characteristics for Ohio's Medicaid, Medicaid eligible, and non-Medicaid populations. Understanding the variation in these outcomes at different levels of geography is important to both practitioners and legislators. This paper describes the approach taken to design the 2015 OMAS to optimize the number of direct estimates that can be produced while ensuring that a minimal number of interviews are available at all levels of geography to support SAE estimates. Our paper demonstrates how this process leveraged data from the previous iteration of OMAS to minimize the design effects in as many areas as possible.

Key Words: Dual Frame RDD, Small Area Estimation (SAE), Optimal Design, Design Effects, Unequal Weighting Effect (UWE)

1. Introduction

1.1 Background

The Ohio Medicaid Assessment Survey (OMAS) examines health status, access to the healthcare system, and health-determinant characteristics of Ohio's Medicaid, Medicaid eligible, and non-Medicaid populations. OMAS is an important tool to help the Ohio Department of Medicaid and other state agencies identify gaps in needed health services, develop strategies to increase service capacity, and monitor Ohioans' health status and health risk.

Understanding the needs of residents at as small a geographic level as possible is therefore a priority. The last OMAS (formerly called the Ohio Family Health Survey) to produce small area estimates at the county level was in 2008 (Ruhil et. al., 2008).

1.2 Motivation

In 2014, Ohio expanded Medicaid under the Affordable Care Act (ACA) to include all adults 19-64 years of age with family incomes less than or equal to 138% of the Federal Poverty Level (FPL). The 2015 OMAS is the first iteration of OMAS since the ACA was fully enacted and Medicaid was expanded

Both state legislators and researchers are interested in the effect of the ACA on insurance rates at the following levels of geography:

- State
- Region (7 Medicaid regions consisting of contiguous counties)
- County type (Metropolitan, Suburban, Rural Appalachian, and Rural non-Appalachian)
- Metropolitan county (7 counties)
- County (88 counties in Ohio)

2. Design Considerations

2.1 General Design Considerations

The 2015 OMAS had funding to achieve 42,876 interviews. OMAS is a telephone survey that utilizes a dual frame design – landline and cellphone – in order to maximize coverage of the target population (all noninstitutionalized individuals residing in the State of Ohio). Due to increases in the population of Ohioans that use cellphones primarily or exclusively – up to 52.9% for adults and 62.8% for children (Blumberg et. al., 2013) – the survey design allocated 55% of sample to the cellphone frame.

The survey design needed to account for multiple analytic objectives; the first of these was to make precise estimates for hard-to-reach populations. Namely,

- Minorities;
- Households with children;
- Households below 138% of poverty; and
- Rural residents

Secondly, the sample needed to support precise estimates at small areas of geography. ***Table 1*** presents the minimum precision targets (in terms of relative standard error) desired at key geographic levels for two key outcomes – percentage of uninsured persons and percentage of persons with Medicaid.

Table 1: Minimum Desired Relative Standard Errors for the 2015 OMAS by Outcome Type and Level of Geography

Level of geography	Percent insured	Percent with Medicaid
State	3%	5%
Medicaid region	5%	10%
Metropolitan county	5%	20%
County type	3%	3%
County	20%	20%

2.2 Small Area Estimation Design Considerations

Small Area Estimation (SAE; Rao, 2003) is a statistical technique that combines direct respondent data with population characteristics for a smaller area of geography (e.g., a county) to produce estimates that are more precise than the direct respondent data can produce on their own. For geographic areas that cannot support the maximum desired relative standard error, SAE is needed to produce reliable estimates. SAE methods considered for OMAS will weight direct survey data from a county with the population estimates such that counties with sufficient sample size will have estimates entirely based on survey response data while counties with minimal sample size will rely more on the model based estimate.

Based on prior OMAS surveys and conversations with stakeholders at least 10 estimates are needed at the county level, including:

- Insurance type
- Insurance purchased from the Health Care Exchange (healthcare.gov)
- Special health care needs
- Self-rated health status
- Chronic disease
- Medicaid enrollment/eligibility
- Poverty status
- Income support in household
- Pregnant within the past year
- Employment status

These outcomes will be produced for adults. When applicable, estimates for children will also be produced at the county level.

2.3 Design Goals

In order to determine the optimal design for the 2015 OMAS, two design goals were formed.

1. Want to develop a design allocation that maximizes the use of direct estimation
2. Must ensure a minimum number of cases in each county in order to assist in the SAE

This paper describes how we developed a set of design options and evaluated them to determine which was optimal.

3. Methods

3.1 Allocation Methods

For each frame, six allocation options were considered: two general allocation types with three methods each for assigning a targeted sample size. The general allocation types include: (1) a single-step allocation to counties, and (2) a two-step allocation in which a balanced (equal) number of respondents are allocated to each of the seven Medicaid regions and then proportionally to the counties within each Medicaid region. Within each of these allocation schemes are three alternatives for county allocation: (1) a proportional allocation, (2) a quasi-proportional allocation with a minimum of at least 30 respondents per county, and (3) a quasi-proportional allocation with a minimum of at least 45 respondents per county.

The single-step method provides the smallest design effects, but may not yield adequate precision in smaller Medicaid regions (i.e., regions consisting of less populated counties). The two-step method results in larger design effects at the state level due to the disproportionally nature of its allocation, but improves precision at lower levels of geography because of the increased allocation to smaller regions. Similarly, a targeted sample size within each county helps to ensure a minimum level of precision at the county level, but may increase the design effects at higher levels of geography.

For the landline frame, county-level stratification was based on the actual county to which the listed telephone number was assigned. For some metro counties further stratification was conducted in order to oversample African Americans. Furthermore, counties with a high proportion of listed telephone numbers associated with an Asian or Hispanic surname were stratified to increase the selection probabilities of those telephone numbers. The sample size allocation for each stratum was based on the population in that stratum according to the American Community Survey.

For the cellphone frame, county-level stratification was based on the county in with the cellphone was activated and/or the county containing the billing address – this is known as the *rate center county*. While these rate centers are correlated to the county of residence for a person they are subject to classification error (Berzofsky, et. al, in press). Berzofsky et. al, (in press) developed an approach for allocation to strata that accounts for this classification error. This approach was implemented for the 2015 OMAS.

3.2 Determining the Optimal Design

Given the six landline options and six cellphone options, there are 36 possible combined design options to consider. In order to determine which of these best meets the evaluation criteria, a two-step process was used:

1. Reduce the number of options under consideration based on the UWEs for each option.
2. Determine the optimal option based on the precision of estimates for the percent of persons insured and the percent of persons with Medicaid across key domains and geographic areas.

3.2.1 Determining the Design Effects Due to Unequal Weighting

In order to accurately assess the precision, a design effect for a given sample design must be calculated. In the case of a telephone survey where there is no clustering, the source for the design effect comes solely from the unequal weighting effect (UWE). The UWE is a measure of the amount of weight variation across strata. The UWE in domain g, when all respondents in a stratum have the same design based weight, is defined as:

$$UWE_g = \frac{n_g \sum w_i^2}{(\sum w_i)^2} = \frac{n_g \sum_{h=1}^{H}(n_h w_h^2)}{\left[\sum_{h=1}^{H}(n_h w_h)\right]^2},$$

where n_g is the sample size in a particular geographic area or demographic domain g, n_h is the number of expected respondents in stratum h, and w_h is the design-based weight for stratum *h* in the sample. The design-based weight for a stratum is calculated as the expected eligible number of telephone numbers in the stratum divided by the desired number of respondents. In other words,

$$w_h = \frac{N_h \times e_h}{n_h},$$

where N_h is the total of telephone numbers in stratum *h* that can be selected and e_h is the eligibility rate for a telephone number in stratum *h* based on the 2012 OMAS data.

Because the sample split between the landline and cellphone frames is approximately equal, the UWE for a given design was approximated as the arithmetic average of the UWE from the landline allocation and the UWE from the cellphone allocation (i.e., UWE = [UWE_LL + UWE_CELL]/2). Although this is not the exact UWE from the combined frames, it is a close approximation that can be easily computed (Berzofsky, Lu, & Sahr, in progress).

For each design option by telephone type, UWEs were calculated for all levels at which estimates will be produced (i.e., state, Medicaid region, county type, and county). Given that state-level estimates require combining across all counties, and therefore have the greatest amount of weight variation, the UWEs are highest at the state level. ***Table 2*** presents the combined UWEs at the state level for all 36 possible design options.

Table 2: Estimated Unequal Weighting Effects for 36 Design Options

Cellphone designs		Landline designs					
		Single-step			Two-step		
		No target	**Target 30**	**Target 45**	**No target**	**Target 30**	**Target 45**
Single-step	No target	1.27	1.27	1.26	1.59	1.58	1.57
	Target 30	1.27	1.27	1.26	1.59	1.58	1.57
	Target 45	1.27	1.27	1.26	1.59	1.58	1.57
Two-step	No target	1.43	1.43	1.42	1.75	1.74	1.73
	Target 30	1.43	1.43	1.42	1.75	1.74	1.73
	Target 45	1.42	1.42	1.41	1.74	1.73	1.72

Based on the UWEs in ***Table 2*** as well as the UWEs at the Medicaid region, county type, and county level, ***Table 3*** presents the 12 design options that were further considered. The designs selected did not necessarily have the lowest UWE at the state level, but if they were not low at the state level, they offered a benefit at a different geographic level. For example, design numbers 4, 5, and 6 offered better unequal weighting effects at the Medicaid region level. Furthermore, if two options provided nearly identical UWEs across all geographic areas only one was included for further consideration.

Table 3: Designs Considered for Further Evaluation

Design Number	Landline design	Cellphone design
1	Single-step; no county target	Single-step; no county target
2	Single-step; county target 30	Single-step; county target 30
3	Single-step; county target 45	Single-step; county target 45
4	Two-step; no county target	Two-step; no county target
5	Two-step; county target 30	Two-step; county target 30
6	Two-step; county target 45	Two-step; county target 45
7	Single-step; county target 30	Two-step; county target 30
8	Single-step; county target 30	Two-step; county target 45
9	Two-step; no county target	Single-step; county target 45
10	Two-step; county target 45	Single-step; county target 45
11	Two-step; no county target	Single-step; county target 30
12	Two-step; county target 30	Single-step; county target 30

3.2.2 Determine the Expected Precision of Key Estimates

For the design numbers that were selected for further consideration, precision estimates were computed for two key outcomes in OMAS: (1) the percentage of persons with insurance and (2) the percentage of persons with Medicaid. For each of these outcomes, ***Table 4*** lists the domains by geographic level for which estimates were produced.

Table 4: Estimates Considered for Precision Evaluation by Geographic Level and Domain

	Geographic level				
Domain	**State**	**Medicaid region**	**County type**	**Metropolitan counties**	**All counties**
All adults	X	X	X	X	X
African American Adults	X	X	X	X	
Hispanic Adults	X				
Asian Adults	X				
19–44 year olds	X	X			
45–64 year olds	X	X			
65 years old or older	X	X			
Children	X	X			X

In order to make standard errors more easily comparable, the percent relative standard error (RSE) was computed for each estimate. The RSE is defined as

$$RSE = \frac{SE}{p} \times 100,$$

where SE is the standard error for the estimate and p is the estimate (for a dichotomous outcome like percent insured and percent with Medicaid). In order to estimate the SE for the 2015 OMAS, the following formula was used:

$$SE = \sqrt{\frac{p_{2012}(1-p_{2012})}{n_{2015}} \times UWE_{2015}},$$

where p_{2012} is the estimated prevalence in the domain in the 2012 OMAS, n_{2015} is the estimated 2015 OMAS sample size in the domain and geographic level, and UWE_{2015} is the design effect for the domain and geographic level. The 2015 OMAS sample size for a domain and geographic level was computed on two factors:

1. The estimated number of adult completes in a county, and
2. The expected proportion of adult respondents in the county that is in the domain based on the 2012 OMAS proportion of respondents in that domain

The estimated sample size in a domain and county were computed for each frame (landline and cellphone) separately and then summed together to estimate the total sample size in the county. This was done to take into account the known demographic differences in respondents from each frame (e.g., in the 2012 OMAS, 18%–20% of adult landline respondents were in a household with a child, whereas 33%–36% of adult cellphone respondents were in a household with a child). Geographic area sample sizes were determined by combining the appropriate county-level sample sizes. For the precision of an estimate to meet the evaluation criteria, the RSE needed to be smaller than both of the following:

1. The 2012 OMAS RSE (except for nonmetropolitan counties)
2. A predetermined minimum RSE defined in ***Table 1***

4. Results

In general, all 12 design options performed similarly. Furthermore, designs that did not meet the criteria were often not very far from the desired RSE. Options that did not have a two-step allocation for the landline sample often performed better in the metropolitan counties for estimates in the African American domain. This is because the balanced design at the Medicaid region level allocated more sample to rural counties than would have been based on population distribution. Therefore, the metropolitan counties did not have as much sample allocated to them reducing the impact of the oversample of African Americans.

To illustrate the similarity across designs, ***Table 5*** presents the percentage of counties that meet the evaluation criteria. This table illustrates that all designs will require some level of SAE. For example, for Option 3, 10.2% and 29.5% of counties will require SAE for adult insured and kids insured.

Table 5. Estimated Percentage of Counties that Meet Precision Criteria by Key Outcome and Design Option

	Percentage of Counties Achieving Criteria			
	Percentage Insured		Percentage with Medicaid	
Design Option	Adults	Children	Adults	Children
1	84.1	69.3	44.3	61.4
2	85.2	71.6	44.3	64.8
3	89.8	70.5	51.1	65.9
4	85.2	72.7	52.3	73.9
5	87.5	72.7	52.3	73.9
6	92.0	75.0	59.1	73.9
7	89.8	75.0	50.0	72.7
8	92.0	76.1	48.9	73.9
9	89.8	76.1	47.7	68.2
10	93.2	77.3	52.3	68.2
11	88.6	75.0	48.9	68.2
12	88.6	75.0	48.9	68.2

At the county level, designs that targeted 45 respondents under each frame (90 total) performed best (e.g., Option 3, Option 6). Furthermore, two-step designs performed better because they allocated more sample to smaller counties. However, the two-step designs did not perform as well at the state level.

Based on the evaluation criteria, Option 3 was selected as the design for the 2015 OMAS. While Option 6 performs better from an SAE perspective, due to the other precision targets at the state level, Option 3 was determined to be optimal.

Figure 1 and ***Figure 2*** present the expected sample size in each county and whether that county will require SAE to produce reliable estimates for percentage adults and children with insurance and with Medicaid, respectively, by design number. For adults, nine counties are expected to require the use of SAE to produce reliable estimates of the percentage insured. For children, twenty-five counties are projected to require SAE for reliable estimates of the percentage insured. The counties that are projected to require SAE tend to be the more rural counties in Ohio.

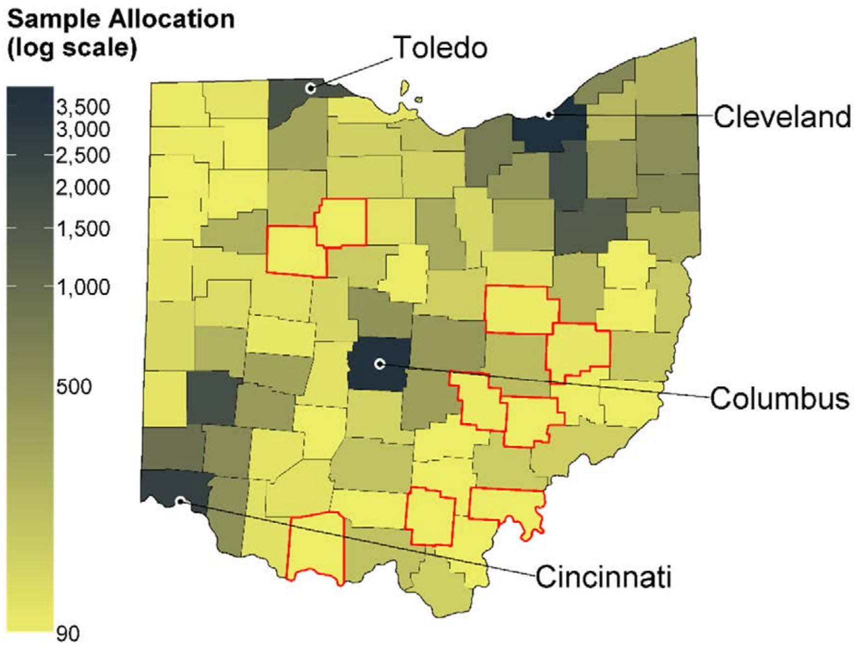

Figure 1: Expected Number of Adult Respondents (log scale[1]) by County and Counties that Will Require SAE for Percentage with Insurance Based on Precision Criterial (Outlined in Red)

[1] To display the full scale it is compressed to the log transform, but the values presented are the untransformed desired sample allocation.

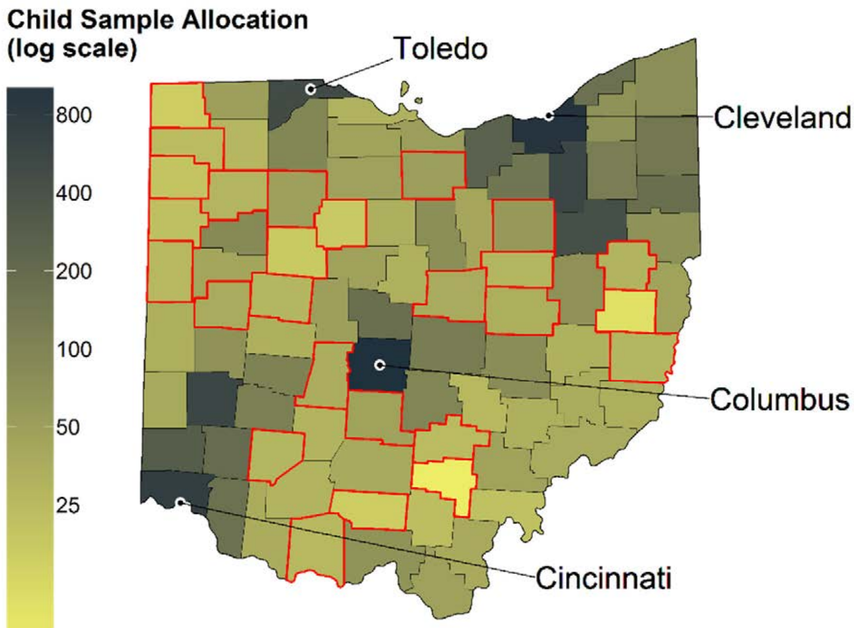

Figure 2: Expected Number of Child Respondents (log scale[1]) by County and Counties that Will Require SAE for Percentage with Insurance Based on Precision Criterial (Outlined in Red)

Figure 3 and ***Figure 4*** present the expected sample size in each county and whether that county will require SAE for percentage of adult and children with Medicaid, respectively. For adults, 42 counties are expected to need SAE to produce reliable estimates of the percentage with Medicaid. For children, twenty-nine counties are projected to require SAE. The counties identified as likely needing SAE to produce reliable estimates tend to be the more rural counties.

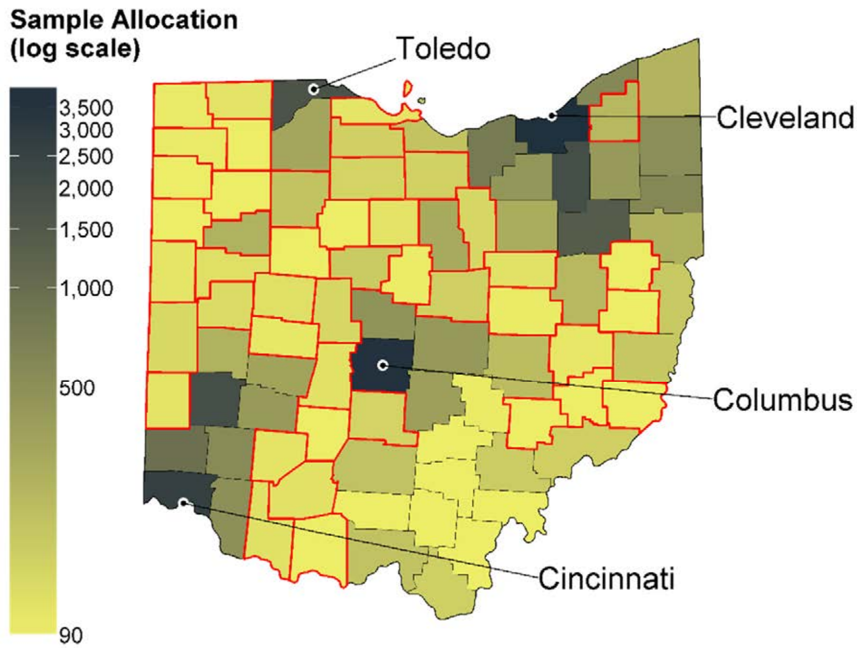

Figure 3: Expected Number of Adult Respondents (log scale[1]) by County and Counties that Will Require SAE for Percentage with Medicaid Based on Precision Criterial (Outlined in Red)

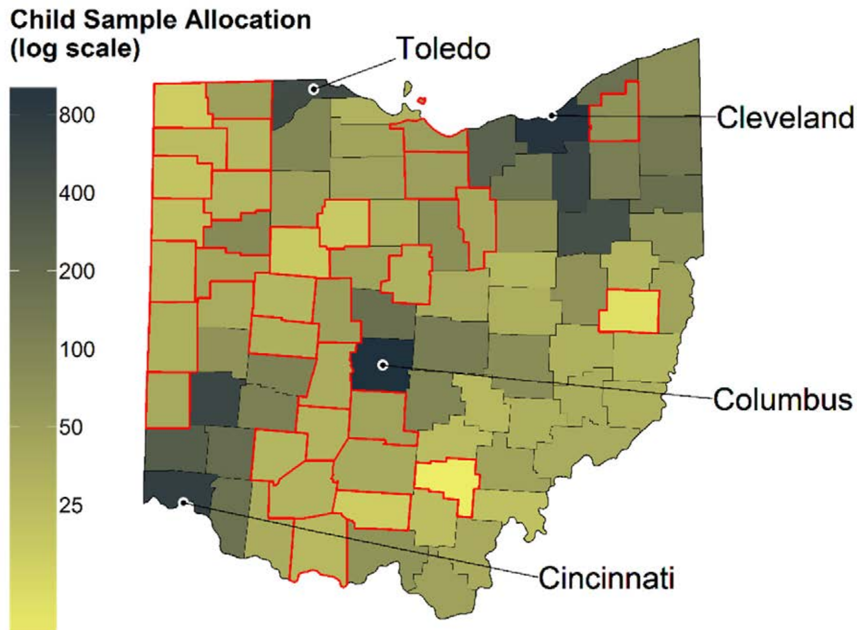

Figure 4: Expected Number of Child Respondents (log scale[1]) by County and Counties that Will Require SAE for Percentage with Medicaid Based on Precision Criterial (Outlined in Red)

5. Conclusions

Like many state-based surveys, the 2015 OMAS has many levels of geography at which it should support reliable estimates. In this paper, we demonstrate the approach we used to evaluate several different design options for a dual frame RDD survey that balances minimization of design effects at as many levels of geography as possible and ensuring enough completed interviews in less populated areas. The paper also illustrates that even with this optimization, SAE is needed to produce reliable estimates at the county level. This is especially true in smaller, more rural areas. Overall, the final design performed well at minimizing the number of areas for which direct estimates could not be computed reliably and ensuring that, when SAE was needed, each county contained a minimum number of respondents to contribute to the model-based estimate.

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