

An Analysis of Nonresponse Bias Resulting from Non-Resolution of Telephone Numbers, Eligibility Screener Nonresponse, and Interview Nonresponse for the National Immunization Survey

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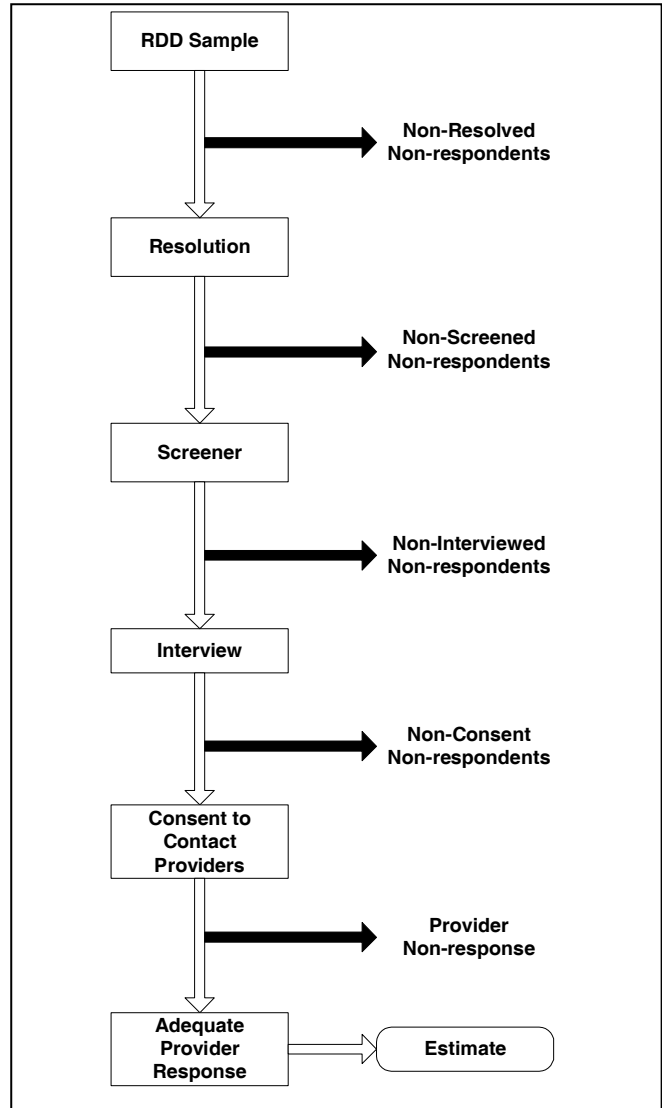
Abstract

The National Immunization Survey (NIS) is an annual nationwide, list-assisted RDD survey conducted by NORC on behalf of the Centers of Disease Control and Prevention. It consists of two phases: a telephone component that seeks to identify households with children aged 19 to 35 months, collect socio-demographic information, and obtain consent to contact the immunization providers for those children; and a provider component wherein questionnaires are mailed to each child’s providers seeking immunization data about the child, which are used to estimate vaccination coverage rates. To contribute to the estimates a case must pass through five stages: resolution, eligibility screening, the household interview, consent to contact providers, and provider response. This paper explores the effect of non-response at the first three stages on estimates of vaccination coverage.

1. NIS Nonresponse

The stages of the NIS and the types of NIS nonrespondent are shown in Figure 1. A sample of telephone numbers is drawn in each estimation area—either a whole state, a metropolitan area within a state, or a “rest of state” area—and an attempt is made to identify and interview households containing children aged 19 to 35 months. A telephone number that is part of the initial sample must first be “resolved”; that is, it must be determined whether or not the telephone number belongs to a household. If a household is identified, it must then be screened for the presence of 19 to 35 month old children, and, if the household contains such children, the household must be interviewed. At the end of the interview, consent to contact the child’s immunization providers is sought, and, if granted, an Immunization History Questionnaire (IHQ) is mailed to each of the child’s providers. The information recorded on the IHQs form the basis for constructing indicators of whether or not the child is up-to-date (UTD) with respect to his or her vaccinations. These indicators are then used to estimate the vaccination coverage rates in each estimation area and for the nation as a whole.

Figure 1: NIS Stages and Types of Nonrespondent



Nonresponse occurs at each stage. For some telephone numbers, it is never determined whether the number belongs to a household or not; i.e., some numbers remain unresolved; some households that have been identified do not complete the screener; some households that are screened eligible for the interview do not complete the interview; some households that

complete the interview do not give consent to contact the child's immunization providers; and for some children with consent, providers do not respond adequately to determine the child's UTD status. This paper uses data from the 2005 NIS to explore the effect of the first three types of nonrespondent—non-resolved nonrespondents, non-screened nonrespondents, and non-interviewed nonrespondents—on the national vaccination coverage estimates.

We focus our analysis on the UTD rate for the 4:3:1:3:3:1 vaccination series. Children are considered to be UTD for this series if they have received: 4+ doses of diphtheria, tetanus, and acellular pertussis vaccine; 3+ doses of polio vaccine; 1+ dose of measles, mumps, and rubella vaccine; 3+ doses of hepatitis B vaccine; 3+ doses of *Haemophilus Influenzae* type B (Hib) vaccine; and 1+ doses of varicella vaccine. Because there is interest in monitoring the vaccination coverage rates among various subgroups of the population, we also focused on the 4:3:1:3:3:1 UTD rate for the following: males, females, children in households above the poverty line, children in households below the poverty line, Hispanics, non-Hispanics, and children in different racial groups: White; Black/African American; American Indian or Alaska Native; Asian, Native Hawaiian, or Pacific Islander; and Multiracial.

2. Possible Approaches to Analyzing Nonresponse Bias

Nonresponse bias in a survey estimator \bar{y}_r can be expressed in two forms (Groves, 2006). The first formulation assumes each unit in the target population is, *a priori*, either a respondent or a nonrespondent:

$$(1) \quad Bias(\bar{y}_r) = \frac{M}{N}(\bar{Y}_r - \bar{Y}_m)$$

where M is the number of nonrespondents in the population, N is the total number of units in the target population, \bar{Y}_r is the respondent mean in the target population, and \bar{Y}_m is the nonrespondent mean in the target population.

The second formulation assumes that each unit in the target population has a propensity ρ_i to respond:

$$(2) \quad Bias(\bar{y}_r) \approx \frac{\sigma_{yp}}{\bar{\rho}}$$

where σ_{yp} is the correlation between the survey variable and the response propensity, and $\bar{\rho}$ is the mean response propensity in the population.

In either formulation the bias is related to both the response rate and the degree to which the respondents differ from the nonrespondents with respect to the survey variable.

The response rate is known, or at least estimated, from the results of the survey data collection operation. In the 2005 NIS, the resolution rate was 83%, the screener completion rate was 93%, and the interview completion rate was 84%, for an overall response rate to the RDD portion of the survey of 65% (AAPOR RR3). The consent-to-contact-providers rate given interview completion was 79%, and the provider adequacy rate given consent was 81%, for a total survey response rate through all stages of 41% (AAPOR RR3).

The degree to which respondents differ from nonrespondents is generally unknown, and nonresponse bias analyses must measure this difference either in a direct or indirect way. Groves (2006) summarizes the typical approaches. If the nonresponse bias is to be measured directly, either the survey estimate must be compared to a similar estimate from a more accurate, external source or the "true" value of the survey variable for nonrespondents must be obtained, e.g., through a follow-up study of the nonrespondents. Neither of these approaches is viable for the 2005 NIS; data from a more accurate external source are not available and the "true" UTD status for nonrespondents is not known. Therefore we must satisfy ourselves with an indirect approach. These approaches take two forms: a "level of effort" analysis and a comparison of respondents to the entire sample using information available on the sampling frame for both respondents and nonrespondents. We discuss these approaches in the next sections.

3. Level of Effort Analysis

In a "level of effort" analysis, those respondents who respond only after a great deal of interviewing effort has been applied are assumed to resemble nonrespondents. Given this assumption, a difference in the survey variable between "high effort" respondents and "low effort" respondents would indicate that a difference exists between the respondents and nonrespondents, and therefore nonresponse bias exists in the survey estimate.

We defined “interviewing effort” in two ways: number of calls and refusal conversion status. First, we plotted the 4:3:1:3:3:1 UTD rate estimate against the number of calls needed to complete the RDD interview, initially using the base weights (Figure 2)—i.e., not adjusted for nonresponse and not raked to population control totals—and then using the final weights which reflect adjustments for nonresponse and raking (Figure 3). Neither plot shows a significant, consistent change in the UTD rate estimate as the number of calls necessary to complete the interview increases. We also created similar plots (not shown here) for the gender, poverty status, and race/ethnicity subgroups and again found no significant difference between low-effort and high-effort respondents. If the assumption that high-effort respondents resemble nonrespondents is correct, this suggests there is little nonresponse bias in the estimate due to nonresponse to the RDD portion of the survey, either overall or for any of the subgroups.

Next we divided respondents into two groups: those that never refused to be interviewed and those that completed the interview only after a refusal conversion. The 4:3:1:3:3:1 UTD rate estimate was then compared for these two groups, both overall and for each subgroup, first using the unadjusted base weights and then using the final, nonresponse adjusted and raked weights. The results appear in Table 1. No significant differences were found between the refusal and non-refusal respondents, again suggesting that little nonresponse bias in the estimate exists, given the assumption that high-effort respondents (i.e., converted refusals) resemble nonrespondents.

4. Comparing Respondents to the Entire Sample Using Sampling Frame Information

The NIS sampling frame contains three pieces of case-specific information—indicators of whether the telephone number is residential-listed, whether an advance letter was sent, and whether the telephone number is inside a metropolitan statistical area (MSA)—and information specific to the telephone number’s exchange (i.e., area code plus first three digits of the telephone number); for example, the median household income in the exchange, the median years of education in the exchange, etc. Since this information is available for both respondents and nonrespondents at each stage of the survey, it can be used to directly measure nonresponse bias at each stage with respect to these variables.

Table 2 shows, for each stage of the RDD portion of the survey, a comparison of the frame information for

the entire sample eligible for the stage and the respondents to the stage, first using the base weights only and then using the weights that have been sequentially adjusted for nonresponse at each stage.

An example will be useful. Looking at the “Residential-Listed” variable, using the base weights we see that 40.13% of the entire sample of telephone numbers is residential-listed, and among the resolved cases (i.e., the respondents to the resolution stage), 37.49% are residential-listed. That is, using the unadjusted base weights, the resolved cases are 6.58% less residential-listed than they would be under full response to the resolution stage of the survey—meaning that after the resolution stage, without any adjustment for non-resolution, the sample is biased downward 6.58% in terms of residential-listed status. However, using the weights that have been adjusted for non-resolution, 40.13% of the resolved cases are residential-listed; that is, all of the bias in residential-listed status due to non-resolution has been removed by the nonresponse adjustment. (This is no accident; residential-listed status was one of the variables used to form the nonresponse adjustment cells.)

Moving to the screener stage and using only the unadjusted base weights, among all resolved households 82.32% are residential-listed, and among screener respondents, 82.81% are residential-listed; i.e., an upward bias of 0.60% was introduced in residential-listed status at the screener stage. However, using the non-resolution adjusted weights, 83.73% of resolved households are listed, and, using the weights that were adjusted for nonresponse to the screener, 83.74% of screened households are listed—the weighting adjustment for non-screening removed nearly all of the bias introduced by nonresponse to the screener stage.

Finally, moving to the RDD interview stage and using only the base weights, among screened eligible households, 79.02% are residential-listed, and 79.75% of the completed RDD interviews are residential-listed, indicating an upward bias of 0.93% at the interview stage. Using the weights adjusted for non-screening, 80.10% of the screened eligible households are listed, and, using the weights that were adjusted for nonresponse to the interview, 80.54% of interviewed households are listed. Thus, the interview nonresponse adjustment lowered, but did not completely eliminate, the residential-listed bias introduced due to interview nonresponse.

Multiplying together the biases at each stage calculated using only the base weights, we estimate that the eligible population identified and interviewed is 5.15%

less residential-listed than the eligible population as a whole. (In making this multiplication, we are assuming that the proportion residential-listed among unresolved cases that are really households is equal to the proportion residential-listed among the resolved households, and that the proportion residential-listed among the unscreened households that are really eligible is equal to the proportion residential-listed among the screened eligible households.) Doing the same calculation but using the weights that were sequentially adjusted for nonresponse to each stage, we estimate that the eligible population identified and interviewed is 0.55% more residential-listed than the eligible population as a whole. That is, while we estimate that a bias of about 5% in residential-listed status was introduced due to nonresponse at the resolution, screener, and interview stages, the nonresponse-adjusted weights eliminate nearly all of that bias.

In Table 2, we see that this is the case for the other frame variables as well; nonresponse introduced small biases but the nonresponse adjustments substantially reduced those biases. The variables with the largest biases remaining after the nonresponse adjustments are advance letter status (-2.86%), the percent of the population that is Hispanic in the telephone exchange (-1.56%), and the percent of the population that is non-Hispanic Black in the telephone exchange (-1.23%).

Figure 4 shows the correlations between the frame variables and 4:3:1:3:3:1 UTD status. These correlations are all very small (less than 5%), and, in particular, the correlations with advance letter status (2.5%), percent Hispanic in the telephone exchange (-1.5%), and percent non-Hispanic Black in the telephone exchange (-0.7%) are even smaller. We also examined the correlations for each subgroup, and they too were small. Therefore, in relation to the frame variables, very little nonresponse bias was observed, and, moreover, these frame variables have very little correlation with the survey variable of interest.

5. Conclusions, Limitations, and Future Work

We find no evidence of nonresponse bias in the national 4:3:1:3:3:1 UTD rate estimate, either for the nation as a whole or for any gender, poverty status, or race/ethnicity subgroup. The level-of-effort analysis did not reveal any significant differences between low-effort and high-effort respondents, either when “effort” was defined in terms of the number of calls or in terms of refusal/non-refusal status. A comparison of respondents to the entire sample at each stage of the RDD survey showed small biases with respect to the variables available on the NIS sampling frame, and

these biases were mitigated by the nonresponse weighting adjustments. Moreover, these frame variables are not very correlated with 4:3:1:3:3:1 UTD status, implying that even relatively large biases with respect to the frame information would not necessarily indicate bias in the 4:3:1:3:3:1 UTD rate estimate itself.

This analysis has several limitations. First, the level-of-effort analysis relies on the assumption that high-effort respondents resemble nonrespondents, but some studies have shown that this assumption is not necessarily a valid one. (See Lin and Schaeffer, 1995; Fitzgerald and Fuller, 1982.) Second, while the comparison of respondents to the entire sample used all of the frame information available, only three of the variables were case-specific and the others were specific only to the telephone exchange of the telephone number. The conclusion that the analysis of frame variables revealed no bias in the UTD rate estimate would be stronger if variables more highly correlated with UTD status were available to us. Finally, the analysis was limited to the national 4:3:1:3:3:1 UTD rate estimate; estimates are also produced for smaller geographical regions (state, metropolitan area, “rest of state” area) and for different vaccines and vaccine series, and so the analysis could be repeated for these other estimates.

A more direct estimate of nonresponse bias in the NIS may be possible. Immunization registries exist in each state to record childrens’ vaccinations as they are reported by vaccination providers. An effort is underway to select a sample of children from the registries in two states that are thought to be particularly complete and to attempt to administer the NIS to those childrens’ households. In theory, we would then have the vaccination history for both respondents and nonrespondents, and direct estimates of nonresponse bias in the UTD rate estimate in those states can be made.

References

- Fitzgerald, Robert, and Linda Fuller. 1982. “I Hear You Knocking but You Can’t Come In: The Effects of Reluctant Respondents and Refusers on Sample Survey Estimates.” *Sociological Methods and Research* 11: 3-32.
- Groves, Robert M. 2006. “Nonresponse Rates and Nonresponse Bias in Household Surveys.” *Public Opinion Quarterly* 70: 646-675
- Lin, I-Fen, and Nora Cate Schaeffer. 1995. “Using Survey Participants to Estimate the Impact of Nonparticipation.” *Public Opinion Quarterly* 59: 236-258.

Figure 2: 4:3:1:3:3:1 Up-to-date Rate by Calls to RDD Interview Completion, Base Weight

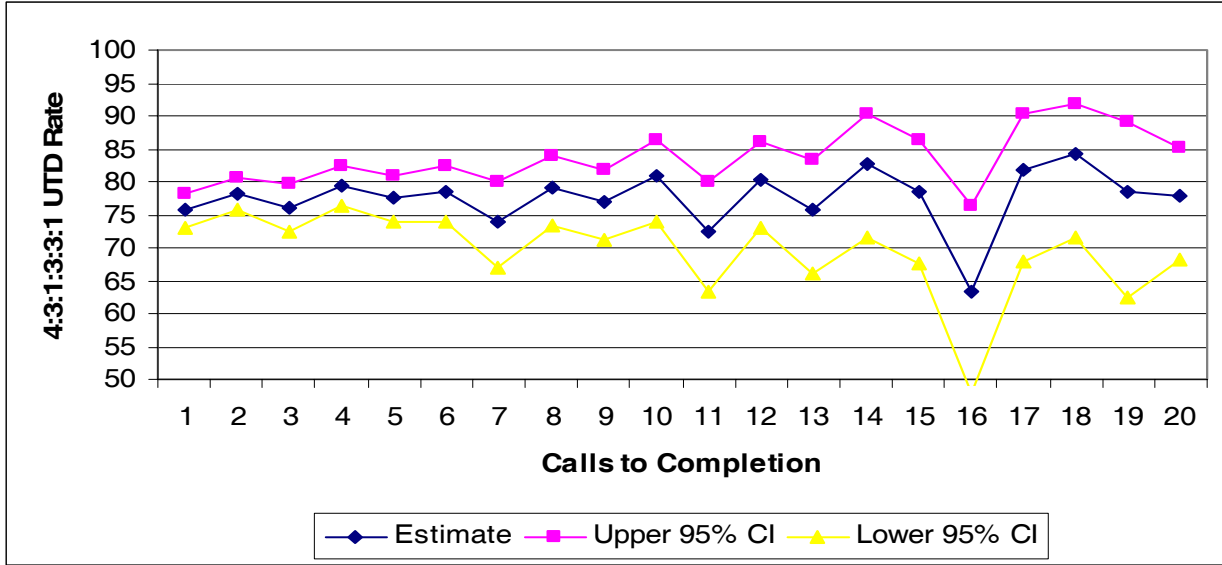


Figure 3: 4:3:1:3:3:1 Up-to-date Rate by Calls to RDD Interview Completion, Final Provider Phase Weight

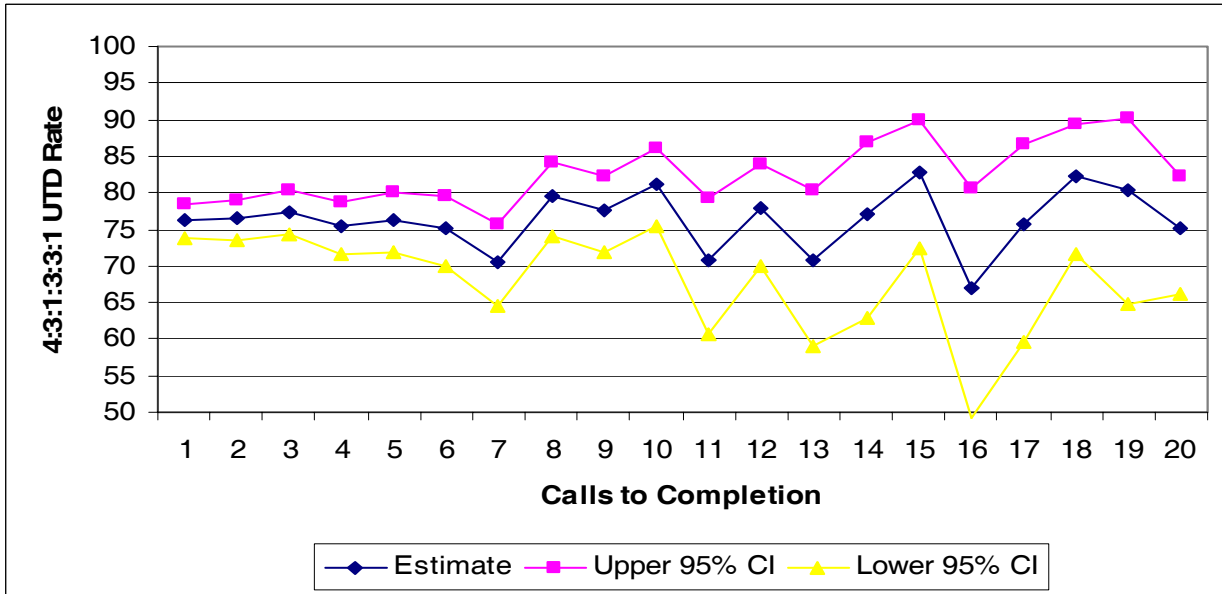


Figure 4: Correlations of 4:3:1:3:3:1 Up-to-date Status with Frame Information

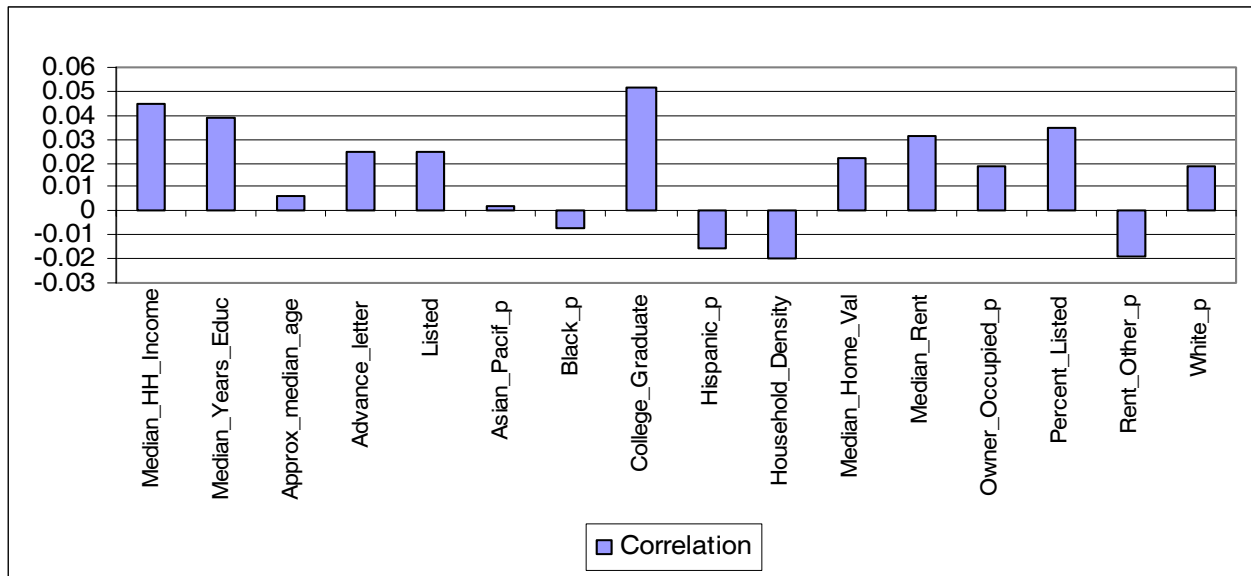


Table 1: 4:3:1:3:3:1 Up-to-date Rate: Refusal Conversion vs. No Refusal

| Type of Respondent | Using Base Weight | | | | Using Final Weight (PROVWT) | | | |
|---------------------|--------------------|------------|---------------------------|---------|-----------------------------|------------|---------------------------|---------|
| | Refusal Conversion | No Refusal | Refusal/No Refusal % Diff | P-Value | Refusal Conversion | No Refusal | Refusal/No Refusal % Diff | P-Value |
| All | 76.77 | 77.37 | -0.78% | 0.75 | 75.03 | 76.23 | -1.57% | 0.57 |
| Male | 74.98 | 77.98 | -3.85% | 0.32 | 75.73 | 76.82 | -1.41% | 0.72 |
| Female | 78.62 | 76.72 | 2.48% | 0.37 | 74.30 | 75.62 | -1.75% | 0.65 |
| Above Poverty | 78.66 | 78.34 | 0.40% | 0.89 | 77.36 | 77.20 | 0.21% | 0.95 |
| Below Poverty | 76.36 | 73.29 | 4.19% | 0.42 | 73.80 | 73.86 | -0.08% | 0.99 |
| Hispanic | 70.85 | 78.20 | -9.40% | 0.25 | 71.40 | 76.01 | -6.06% | 0.45 |
| Non-Hispanic | 78.16 | 77.13 | 1.33% | 0.55 | 76.08 | 76.32 | -0.31% | 0.91 |
| White Only | 77.63 | 77.46 | 0.22% | 0.94 | 73.90 | 76.20 | -3.02% | 0.38 |
| Black Only | 76.84 | 76.48 | 0.46% | 0.95 | 79.09 | 75.82 | 4.30% | 0.41 |
| AIAN Only | 63.93 | 73.14 | -12.58% | 0.42 | 76.29 | 75.05 | 1.66% | 0.89 |
| Asian or NHOPI Only | 74.48 | 76.22 | -2.28% | 0.80 | 76.35 | 75.66 | 0.91% | 0.93 |
| Multiracial | 69.80 | 79.46 | -12.17% | 0.28 | 80.73 | 78.47 | 2.87% | 0.71 |

Table 2: Comparing Respondents and Nonrespondents at Each Stage Using Frame Information

| Frame Variable | Stage | Using Base Weight | | | Using (Nonresponse Adjusted) Weight from Previous Stage | Using Nonresponse Adjusted Weight | |
|---------------------------|----------------------|----------------------------------|--------------------------|-----------------------------|---|-----------------------------------|-----------------------------|
| | | All Cases Eligible for the Stage | Respondents at the Stage | Respondent/All % Difference | All Cases Eligible for the Stage | Respondents at the Stage | Respondent/All % Difference |
| Residential-Listed | Resolution | 40.13% | 37.49% | -6.58% | 40.13% | 40.13% | 0.00% |
| | Screener | 82.32% | 82.81% | 0.60% | 83.73% | 83.74% | 0.01% |
| | Interview | 79.02% | 79.75% | 0.93% | 80.10% | 80.54% | 0.55% |
| | Overall ¹ | | | -5.15% | | | 0.55% |
| Advance Letter Sent | Resolution | 33.67% | 30.59% | -9.15% | 33.67% | 32.21% | -4.33% |
| | Screener | 74.65% | 75.01% | 0.48% | 74.84% | 75.07% | 0.31% |
| | Interview | 71.71% | 72.89% | 1.66% | 71.82% | 72.70% | 1.23% |
| | Overall | | | -7.20% | | | -2.86% |
| In MSA | Resolution | 81.50% | 80.92% | -0.71% | 81.50% | 81.50% | 0.00% |
| | Screener | 81.75% | 81.50% | -0.30% | 81.89% | 81.89% | 0.00% |
| | Interview | 83.73% | 83.46% | -0.32% | 84.15% | 84.10% | -0.05% |
| | Overall | | | -1.33% | | | -0.05% |
| Median HH Income | Resolution | \$51,488 | \$51,186 | -0.59% | \$51,488 | \$51,393 | -0.18% |
| | Screener | \$51,786 | \$51,742 | -0.09% | \$51,905 | \$51,884 | -0.04% |
| | Interview | \$52,670 | \$52,793 | 0.23% | \$52,803 | \$52,901 | 0.18% |
| | Overall | | | -0.44% | | | -0.04% |
| Median Home Value | Resolution | \$174,744 | \$172,233 | -1.44% | \$174,744 | \$174,186 | -0.32% |
| | Screener | \$169,366 | \$168,851 | -0.30% | \$170,866 | \$170,856 | -0.01% |
| | Interview | \$170,061 | \$169,555 | -0.30% | \$171,812 | \$172,460 | 0.38% |
| | Overall | | | -2.03% | | | 0.05% |
| Median Rent | Resolution | \$573 | \$567 | -1.01% | \$573 | \$571 | -0.27% |
| | Screener | \$565 | \$564 | -0.25% | \$568 | \$567 | -0.04% |
| | Interview | \$574 | \$573 | -0.22% | \$577 | \$578 | 0.05% |
| | Overall | | | -1.48% | | | -0.27% |
| Median Years Education | Resolution | 13.18 | 13.18 | -0.07% | 13.18 | 13.18 | -0.04% |
| | Screener | 13.15 | 13.15 | 0.01% | 13.15 | 13.15 | 0.01% |
| | Interview | 13.12 | 13.13 | 0.13% | 13.12 | 13.13 | 0.08% |
| | Overall | | | 0.07% | | | 0.05% |
| Percent College Graduates | Resolution | 26.28 | 26.12 | -0.60% | 26.28 | 26.22 | -0.23% |
| | Screener | 25.69 | 25.69 | 0.00% | 25.75 | 25.76 | 0.04% |
| | Interview | 25.55 | 25.72 | 0.66% | 25.59 | 25.72 | 0.48% |
| | Overall | | | 0.06% | | | 0.28% |
| Approximate Median Age | Resolution | 36.80 | 36.79 | -0.05% | 36.80 | 36.79 | -0.03% |
| | Screener | 36.78 | 36.81 | 0.08% | 36.80 | 36.82 | 0.04% |
| | Interview | 35.85 | 35.90 | 0.15% | 35.84 | 35.86 | 0.06% |
| | Overall | | | 0.18% | | | 0.07% |

¹ The "Overall" percentage is equal to the product of the "Respondent/All % Difference" across the three stages. This provides an estimate of the percentage difference in the frame variable between the interview respondents and the nonrespondents (at any stage) who are eligible for the interview; that is, it is an estimate of the over- or under-representativeness of the interviewed households compared to the eligible population as a whole. This technique assumes that the mean of the frame variable for the eligible nonrespondents is equal to the observed mean of the frame variable for the respondents. Using "Residential-Listed" as an example, it assumes that, among the non-resolved numbers that are actually households, the proportion that are listed is equal to proportion that are listed among the resolved households; and it assumes that, among the unscreened households that are actually eligible for the interview, the proportion that are listed is equal to the proportion that are listed among the screened eligible households.

Table 2 (cont.): Comparing Respondents and Nonrespondents at Each Stage Using Frame Information

| Frame Variable | Stage | Using Base Weight | | | Using (Nonresponse Adjusted) Weight from Previous Stage | Using Nonresponse Adjusted Weight | Respondent/All % Difference |
|--|------------|----------------------------------|--------------------------|-----------------------------|---|-----------------------------------|-----------------------------|
| | | All Cases Eligible for the Stage | Respondents at the Stage | Respondent/All % Difference | All Cases Eligible for the Stage | Respondents at the Stage | |
| Percent Hispanic | Resolution | 12.19 | 12.01 | -1.45% | 12.19 | 12.20 | 0.06% |
| | Screener | 11.93 | 11.77 | -1.34% | 12.04 | 12.01 | -0.22% |
| | Interview | 14.30 | 13.79 | -3.56% | 14.62 | 14.42 | -1.41% |
| | Overall | | | -6.23% | | | -1.56% |
| Percent Non-Hispanic White | Resolution | 69.02 | 69.24 | 0.32% | 69.02 | 68.98 | -0.05% |
| | Screener | 70.50 | 70.81 | 0.43% | 70.41 | 70.46 | 0.08% |
| | Interview | 68.44 | 69.33 | 1.30% | 68.00 | 68.38 | 0.55% |
| | Overall | | | 2.07% | | | 0.58% |
| Percent Non-Hispanic Black | Resolution | 12.00 | 12.04 | 0.36% | 12.00 | 12.05 | 0.43% |
| | Screener | 11.23 | 11.13 | -0.90% | 11.19 | 11.17 | -0.20% |
| | Interview | 10.67 | 10.38 | -2.72% | 10.72 | 10.56 | -1.46% |
| | Overall | | | -3.25% | | | -1.23% |
| Percent Non-Hispanic Asian or Pacific Islander | Resolution | 4.14 | 4.05 | -2.27% | 4.14 | 4.11 | -0.62% |
| | Screener | 3.80 | 3.76 | -1.02% | 3.84 | 3.83 | -0.18% |
| | Interview | 3.95 | 3.89 | -1.66% | 4.02 | 4.03 | 0.16% |
| | Overall | | | -4.88% | | | -0.64% |
| Household Density | Resolution | 2.53 | 2.53 | -0.02% | 2.53 | 2.53 | 0.08% |
| | Screener | 2.56 | 2.56 | -0.14% | 2.56 | 2.56 | -0.06% |
| | Interview | 2.66 | 2.65 | -0.36% | 2.66 | 2.66 | -0.14% |
| | Overall | | | -0.53% | | | -0.12% |
| Percent Residential-Listed | Resolution | 69.02 | 68.78 | -0.35% | 69.02 | 68.88 | -0.21% |
| | Screener | 73.22 | 73.32 | 0.13% | 73.23 | 73.25 | 0.02% |
| | Interview | 72.30 | 72.43 | 0.18% | 72.22 | 72.24 | 0.03% |
| | Overall | | | -0.05% | | | -0.15% |
| Percent Owner-Occupied Homes | Resolution | 65.32 | 65.41 | 0.14% | 65.32 | 65.32 | 0.01% |
| | Screener | 67.67 | 67.75 | 0.12% | 67.65 | 67.65 | 0.00% |
| | Interview | 67.55 | 67.79 | 0.35% | 67.44 | 67.52 | 0.12% |
| | Overall | | | 0.61% | | | 0.13% |
| Percent Rented/Other Homes | Resolution | 34.68 | 34.59 | -0.27% | 34.68 | 34.68 | -0.02% |
| | Screener | 32.33 | 32.25 | -0.24% | 32.35 | 32.35 | 0.00% |
| | Interview | 32.45 | 32.21 | -0.74% | 32.56 | 32.48 | -0.24% |
| | Overall | | | -1.24% | | | -0.26% |