Reducing Nontelephone Bias in RDD Surveys

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Introduction

Telephone surveys face the challenge of assessing, and compensating for, bias from noncoverage of nontelephone households. Work by Keeter (1995) suggested that some persons and households who do not have a telephone at a particular time are actually between spells of telephone service. This basic observation, coupled with an estimation strategy proposed in a different context by Politz and Simmons (1949), led to the potential for a statistical adjustment for nontelephone bias in random-digit-dialing (RDD) surveys. This adjustment uses data from sample persons in households that experienced spells of telephone interruption in the recent past. Brick, Waksberg and Keeter (1996) examined several bias-reducing estimates using data on interruptions in telephone service from the National Household Education Survey (1993) and the National Survey of Veterans (1993). Frankel, Ezzati-Rice, Wright and Srinath (1998) applied these and other adjustment methods to two RDD health surveys for the states of Iowa and Washington. Both of these investigations were limited by the inability to compare the adjusted estimates with corresponding estimates that included nontelephone respondents.

In the present paper we empirically evaluate a telephone-interruption estimate by a direct comparison to corresponding sample values from the 1997 National Health Interview Survey (NHIS), which includes both telephone and nontelephone persons. Conducted annually on behalf of the National Center for Health Statistics, the NHIS uses an area probability sample design with door-to-door CAPI-based interviewing. In 1997 questions about interruptions in telephone service were added to the questionnaire, which is administered to households both with and without current telephone service. Data for 103,477 sample persons in the 1997 NHIS allow us to obtain empirical evidence on the degree to which the telephone-interruption-based estimates applied to the "current telephone" portion of this national sample agree with the estimates from the full sample of both telephone and nontelephone households and persons.

Conceptual Framework for Noncoverage Adjustment

In order to quantify the ability of our proposed estimates to reduce bias associated with non-coverage of nontelephone households, we develop mathematical expressions for the bias associated with these estimates.

The target population of persons in households at the time of the telephone survey can be classified into four groups, as shown in Table 1. Group T/NI contains persons coming from households with telephone service at the time of the survey and no interruption in service of more than one week during the previous year. Group T/I contains persons coming from households with telephone service at the time of the survey but with interruption in telephone service of more than one week during the year. Group NT/I contains persons from households that had no telephone service at the time of the survey but had telephone service at some time during the year (for a certain period or periods); and, finally, Group NT/NI contains persons from households with no telephone service during the entire year. Let the number of households in each of these groups be as shown in Table 1.

The population numbers in the cells are generally unknown, though we may know or reliably estimate the numbers of telephone and nontelephone households and persons in the population. Let N be the size of the total population. Let N_t be the number of telephone households. When we select a sample of households through RDD, we have a sample only from the telephone households. Let the sample size be n_t. Assume that we are interested in estimating a certain population proportion (e.g., the proportion of persons who did not get medical care for cost reasons last year). Let this proportion in the population in the four cells be as shown in Table 2.

We are interested in estimating P, which can be written as

$$P = \frac{N_{t1} P_{t1} + N_{t2} P_{t2} + N_{o1} P_{o1} + N_{o2} P_{o2}}{N}.$$

P can also be written as

$$P = \frac{N_t P_t + N_o P_o}{N}$$

where P_t and P_o are

$$P_t = \frac{N_{t1} P_{t1} + N_{t2} P_{t2}}{N_t}$$

$$P_o = \frac{N_{o1} P_{o1} + N_{o2} P_{o2}}{N_o}.$$

Bias in Poststratification

If we obtain a sample from the elements of the population that have a telephone at the time of the survey and if we adjust the base sampling weights to the full known population totals, we obtain the usual telephone-sample estimate. That is, the sample estimate is based on a telephone sample projected to the total (telephone and nontelephone) population. Let the sample estimate of the proportion of interest based on the sample of telephone households be p_t. We have

$$E(p_t) = P_t.$$

The bias in using p_t as an estimate of P is

$$B(p_t) = P_t - P.$$

This can be written as

$$B(p_t) = \frac{N_o}{N} (P_t - P_o). \qquad (1)$$

Thus, the bias of the telephone-sample estimate is a function of the proportion of nontelephone households in the population at the time of the survey and the difference in the proportion of interest between telephone and nontelephone households.

Full Weight Adjustment for Noncoverage and Bias Reduction

Let the number of persons coming from households in the sample with no interruption in telephone service during the year be n_{t1}. Let p_{t1} be the proportion of interest for this group. Let n_{t2} be the number of persons from households with interruption in telephone service and p_{t2} be the corresponding estimate. Let N_t be the number of persons in telephone households and N_o be the number of persons in nontelephone households at the time of the survey. As indicated earlier, these population sizes either are known or can be estimated, either from the survey or from alternative sources.

Let $\hat{N}_{t2}$ be the weighted estimate of N_{t2}, the number of persons coming from households with telephones and interruption in telephone service.

Form the two totals $N_t - \hat{N}_{t2}$ and $N_o + \hat{N}_{t2}$. We compute an overall estimate of the proportion of interest in the population $\hat{P}$ as follows. First, we multiply the proportion of interest obtained from the sample of persons in telephone households and the estimated number of persons in telephone households without interruption. This gives an estimate of the number of persons in telephone households without interruption with the characteristic of interest. Then we multiply the proportion of interest for persons in telephone households with interruption and the estimated number of persons in nontelephone households and telephone households with interruption. This gives an estimate of the number of persons in nontelephone households and telephone households with interruption with the characteristic of interest. The sum of the two estimates divided by the estimated number of persons in the population gives an estimate of the overall proportion of interest in the population. We refer to this estimate as the *full-weight-adjustment estimate* (FWAE). That is,

$$\hat{P} = \frac{(N_t - \hat{N}_{t2})\, p_{t1} + (N_o + \hat{N}_{t2})\, p_{t2}}{N}.$$

The bias in $\hat{P}$ is

$$B(\hat{P}) = E(\hat{P}) - P = E_1 E_2(\hat{P}) - P$$

where $E_2(\hat{P})$ is the conditional expectation over samples in which the two subsample sizes (number of persons with and without interruption) are fixed. Substituting for $E_2(\hat{P})$ and taking the expectation, we get

$$B(\hat{P}) = \frac{N_o}{N} (P_{t2} - P_0). \quad (2)$$

Compare (2) with (1). Now the bias is the proportion of nontelephone households multiplied by the difference between the proportion of interest for telephone households with interruption and the corresponding proportion for nontelephone households. There is a reduction in the bias if this difference is smaller than the difference in rates between telephone and nontelephone households.

Further, we can express the difference in (2) as the sum of two differences. That is, (2) can be written as follows by substituting for P_o using its definition:

$$B(\hat{P}) = \frac{N_o}{N} \frac{[N_{o1}(P_{t2} - P_{o1}) + N_{o2}(P_{t2} - P_{o2})]}{N_o}. \quad (3)$$

If we assume that the two interruption groups (one with telephone service at the time of the survey and the other without telephone service) are similar, that is $P_{t2} = P_{o2}$, then the expression for the bias reduces to

$$B(\hat{P}) = \frac{N_{o1}}{N} (P_{t2} - P_{o1}). \quad (4)$$

This bias is smaller as it involves only the proportion of permanent nontelephone households and the difference between the proportion of interest for persons in telephone households with interruption and persons in nontelephone households without interruption. Of course, the assumption that the two interruption groups have the same mean implies that the characteristics of interest are independent of the length of interruption, which may not be true. But if we use a Politz-Simmons-type approach (Politz and Simmons, 1949) in which the weights are based on the length of interruption, then the expected value of such a weighted mean could be closer to the mean for those without telephones and with interruption, in which case the bias will be closer to expression (4).

Examination and Evaluation of the Full-Weight-Adjustment Estimate

In order to understand how and why the proposed weighting adjustments will lead to reduced bias, we seek a data set that allows us to examine the following subpopulations with respect to various characteristics that might be subjects of a survey. These subpopulations, which are aggregations of the four groups defined earlier, are

1. Persons in telephone households with or without interruption.
2. Persons in nontelephone households with or without interruption.
3. Persons in telephone households with interruption
4. Persons in nontelephone households without interruption
5. Persons in nontelephone households with interruption.

We want to examine whether the absolute difference (with respect to these characteristics) between subpopulations 1 and 2 is greater than the absolute difference between subpopulations
3 and 2. We will also look at the differences between subpopulations 3 and 5 and subpopulations 3 and 4.

We compute the proposed full-weight-adjustment estimate and compare that estimate to the traditional telephone-only estimate, which does not involve weight adjustment, for noncoverage of nontelephone households. We also examine an estimate that uses a sample from subpopulation 3 as a proxy for persons in subpopulation 5 only (not subpopulations 4 and 5 together). We call this latter estimate as the *partial-weight-adjustment estimate* (PWAE). It does not adjust for persons in subpopulation 4 who come from nontelephone households without interruption (i.e., households with no telephone service during the entire year).

Empirical Evidence and Evaluation of Interruption Estimates

The initial data files for the 1997 National Health Interview Survey include the demographic characteristics of the sample persons, as well as some information on medical care and work activity. As in Tables 1 and 2, the sample can be divided into four cells based on the presence of a working telephone in the household at the time of the interview and whether the household experienced an interruption in telephone service greater than one week but less than one year. Table 3 gives weighted (using the preliminary NHIS weights) estimates for five person-level characteristics for each of the four cells. The weighted sample is distributed as follows:

Telephone/No Interruption = 93.27%,
Telephone/Interruption = 2.19%,
No Telephone/ Interruption =1.81% and
No Telephone/No Interruption = 2.73%.

Note that 40% of households without a telephone at the time of the NHIS interview had phone service at some point during the prior 12 months. Only 2.73% of the entire population was without telephone service for the entire 12-month period prior to the NHIS interview. Alternatively, we may split the population at the time of the survey into three groups. The first group consists of persons who had telephone service during the entire 12-month period (93.27%). The second group consists of persons who had phone service for only part of the prior 12 months (4.00%). The third group consists of persons who had no telephone service during the past 12 months (2.73%). In the 1997 NHIS the third group is the smallest of the three. In an RDD survey, we have samples from the first two groups and no sample from the third group.

The table indicates that persons residing in telephone households with an interruption in telephone service are much more similar to those without a telephone than to persons in telephone households with no interruption.

Table 4 shows weighted estimates for telephone persons (at the time of the survey), nontelephone persons (at the time of the survey), and all persons, and our proposed partial-weight-adjustment estimate and full-weight-adjustment estimate, both based on data from households with interruption in telephone service. The estimate for all persons (from the full 1997 NHIS sample) provides a standard for assessing bias in other estimates.

Table 5 compares the noncoverage bias in the usual telephone estimate, the partial-weight-adjustment estimate and the full-weight-adjustment estimate. For example, for the characteristic "Did not get medical care for cost reasons in the past 12 months," the sample estimate for all persons (telephone and nontelephone) is 4.49%. For the telephone portion of the sample, the corresponding estimate is 4.14%. This is a bias of 4.14-4.49 = -0.35%. The corresponding partial-weight- and full-weight-adjustment estimates are 4.26% and 4.43%, respectively. Thus, the partial-weight-adjustment estimate has a bias of 4.26-4.49 = -0.23%, and the full-weight-adjustment estimate has a bias of 4.43-4.49 = - 0.06%. As shown in Table 5, the partial-weight-adjustment estimate reduces the bias somewhat, but the full-weight-adjustment estimate reduces bias even further.

Table 6 also shows the percentage of bias from noncoverage of nontelephone households that is eliminated with the partial-weight- and full-weight-adjustment estimates. The full-weight-adjustment estimate is clearly superior to the partial-weight-adjustment estimate. For the characteristics examined, the average reduction in bias associated with nontelephone coverage is approximately 83%, and the minimum reduction is 65%. Though more variables and surveys should be examined, this is a clear indication that using interruption in telephone service in estimation provides a powerful tool for the substantial reduction of bias from noncoverage of nontelephone households.

In practice, most telephone surveys utilize complex weighting adjustments involving poststratification (often implemented by raking) to a number of population characteristics. To assess the impact of poststratification on bias reduction, we poststratified the telephone estimate and the two weight-adjustment estimates, using the 88 age by sex by race/ethnicity poststratification cells from the 1997 NHIS. Even with poststratification, the telephone estimate tends to have the largest bias, and the full-weight-adjustment estimate tends to have the lowest bias.

Conclusions, Recommendations and Further Research

This paper presents the first empirical evidence that using interruption in telephone service in estimation provides a powerful tool for the substantial reduction of bias from telephone noncoverage. More work is necessary to fully explore and examine the exact form of this adjustment and the behavior of the various estimates over a broad range of variables and surveys. We plan to pursue several areas using the NHIS data.

First, we will examine the bias reduction associated with the full-weight-adjustment estimate over a broader group of variables. We will also examine the mean squared error (variance added to squared bias) of our estimates. Because more weighting generally increases variance, we expect the more-complex interruption-based weighting procedures to present a range of trade-offs between bias and variance.

Following the basic ideas of Politz and Simmons, we plan to examine estimates that use weighting based on duration of interruption in telephone service. Finally,
we will also examine the behavior of the methods for certain domains of study (e.g., children 19-35 months) and subclasses of both the total sample and these domains. We also plan to examine use of the interruption-in-telephone-service estimators in the National Immunization Survey (NIS), a CDC-sponsored RDD survey that produces annual vaccination estimates for children age 19-35 months in 78 geographic areas consisting of the 50 states and 28 urban areas.

References

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Table 1: Target Population at the Time of the Telephone Survey

Interruption Status	Telephone Status at the Time of the Survey		Total
	Telephone	No Telephone	
No Interruption	*(T/NI)* N_{t1}	*(NT/NI)* N_{o1}	N_1
Interruption	*(T/I)* N_{t2}	*(NT/I)* N_{o2}	N_2
Total	N_t	N_o	N

Table 2: Population Proportion by Telephone Status and Interruption Status

Interruption Status	Telephone Status at the Time of the Survey		Total
	Telephone	No Telephone	
No Interruption	P_{t1}	P_{o1}	P_1
Interruption	P_{t2}	P_{o2}	P_2
Total	P_t	P_o	P

Table 3: Weighted Estimates for Five Characteristics by Interruption Group

Interruption Group	Did not get medical care for cost reasons in past 12 months (%)	Looking for work last week (%)	Race of person is black (%)	Age of person is less than 5 years (%)	Education of person is bachelor's degree (%)
Telephone/No Interruption	3.99	1.83	11.40	7.01	9.77
Telephone/Interruption	10.56	7.31	24.22	12.39	4.33
No Telephone/Interruption	10.36	9.81	29.04	15.43	1.40
No Telephone/No Interruption	12.73	5.36	26.32	11.42	1.52

Table 4: Weighted Estimates for Telephone Persons, Nontelephone Persons, All Persons, Partial-Weight-Adjustment Estimate and Full-Weight-Adjustment Estimate

Estimate for:	Did not get medical care for cost reasons in past 12 months (%)	Looking for work last week (%)	Race of person is black (%)	Age of person is less than 5 years (%)	Education of person is bachelor's degree (%)
Telephone persons	4.14	1.96	11.69	7.13	9.65
Nontelephone persons	11.79	7.05	27.40	13.01	1.47
All persons	4.49	2.19	12.41	7.40	9.27
PWAE	4.26	2.06	11.93	7.23	9.55
FWAE	4.43	2.20	12.26	7.37	9.40

Table 5: Comparison of Noncoverage Bias in the Estimates Obtained through the Partial-Weight and Full-Weight Adjustments with the Bias of the Estimate That Includes Only Telephone Persons, and Percent Bias Reduction

Bias of:	Did not get medical care for cost reasons in past 12 months (%)	Looking for work last week (%)	Race of person is black (%)	Age of person is less than 5 years (%)	Education of person is bachelor's degree (%)
Telephone estimate	-0.35	-0.24	-0.71	-0.27	0.37
PWAE	-0.23	-0.14	-0.48	-0.17	0.27
FWAE	-0.06	0.01	-0.14	-0.03	0.13

Table 6: Percentage Reduction in Bias

Estimate	Did not get medical care for cost reasons in past 12 months (%)	Looking for work last week (%)	Race of person is black (%)	Age of person is less than 5 years (%)	Education of person is bachelor's degree (%)
PWAE	34.4%	42.4%	32.7%	36.6%	26.7%
FWAE	84.0%	96.6%	79.7%	89.3%	65.0%