COVERAGE IN A SAMPLE DESIGNED FOR INTERVIEWING ONLY NONTELEPHONE HOUSEHOLDS

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1. Introduction

The National Survey of America's Families (NSAF) is part of a multi-year study to assess the New Federalism by tracking ongoing social policy reforms and relating policy changes to the status and well-being of children and adults. The major objective of the study is to assess the effects of the devolution of responsibility for major social programs such as Aid to Families with Dependent Children from the federal to the state level. The NSAF is collecting information on the economic, health, and social dimensions of well being of children, non-aged adults, and their families in 13 states that will be intensively studied as part of the project, and in the balance of the nation to permit national estimates. The 13 states were selected to vary in terms of their size and geographic location, the dominant political party, and key baseline indicators of well being and fiscal capacity. A sample of the balance of the nation is included so that national estimates can also be produced. Low-income families are oversampled because the policy changes of interest are anticipated to affect them most. The initial round of the NSAF took place in 1997, and a follow-up round is planned for 1999. Two rounds of case studies are occurring in parallel with the survey to provide a detailed understanding of the policy changes occurring in each of the 13 states. This study is being directed by the Urban Institute and Child Trends and is funded by a consortium of foundations, led by the Annie E. Casey Foundation. Westat is responsible for data collection and related activities.

A major design feature of NSAF is the use of a random digit dialing (RDD) sampling frame to cover households with telephones in combination with an area sample to cover households without telephones. The RDD telephone sample was designed to cover approximately 95 percent of the U. S. households. Households were selected for the area frame via a stratified, multi-stage design from only those block groups with relatively high rates of nontelephone households (over 2 % for most study areas). Nontelephone households were interviewed by calling the central RDD facility on a cellular phone. Restricting the sampling frame to such block groups was intended to decrease the cost per completed interview. This paper focuses on the area sample and its coverage of the nontelephone households.

Excluding some block groups was, of course, expected to result in undercoverage of nontelephone households. The 1990 Census estimated that only between 6 percent and 10 percent of the nontelephone households per study area were in the excluded block groups, while 50 percent of the overall population was excluded. However, the sample yield of nontelephone households was much lower in the survey than expected based on the 1990 Census data (54% of the expected). This paper examines why the yield of nontelephone households was so low.

There are a number of possible explanations for the low yield. Two reasons are believed to be primary: (1) The block groups with low percentages of nontelephones households that were excluded from the frame now have much higher rates of nontelephone households; and (2) Measurement error has a different effect on NSAF than on the Census.

The paper estimates the magnitude of the effect of the first explanation, based on some special tabulations provided by the Census Bureau from the Current Population Survey (CPS).[1] (CPS is the monthly labor force survey conducted by the Census Bureau for the Bureau of Labor Statistics.) The paper also provides a speculative estimate of the effect of the second explanation, based on 1970 Census reinterview results. The combined effect of the two explanations can be estimated in two different ways, but in both ways all or nearly all of the difference is accounted for.

2. Frame Truncation

This section examines why the percent of nontelephone households may have increased in block groups excluded from the sampling frame. In Section 4, we estimate the magnitude of this using CPS data. There are 2 reasons why block groups with high percentages of nontelephone households in 1990 may have lower percentages in 1997, while block groups with low percentages in 1990 may have higher percentages in 1997. First, there may be real socio-economic changes between 1990 and 1997 in some block groups so that poverty and associated

[1] The CPS and Census estimates of the percentage of nontelephone households differ substantially. In the analysis that follows, we adjust CPS estimates to be consistent with Census level estimates.

characteristics such as not having a telephone changed over the 7 years. A second and probably more important reason is that there is random fluctuation over time in the percentage without telephones in a geographic area such as a block group. By sampling only from block groups with high percentages of nontelephone households at one instant of time, we tend to include those block groups that are at the high end of their normal range of the percentage and exclude many block groups that are at the low end of their normal range.

3. Measurement Error

Another hypothesis we believe may be an important reason for the lower than expected yield of nontelephone households in the NSAF is measurement error. In any survey, there are many sources of nonsampling error that affect the estimates. For some types of estimates, small nonsampling errors have little or no effect on the estimates. However, for rare characteristics, even small nonsampling errors may result in substantially overestimating the prevalence of the characteristics. Decennial Census reinterview results show that the net effect of measurement error in the Census is to overestimate the number of households without telephones. NSAF, however, should have many fewer errors of reports of no telephone when there is one, because household respondents should usually correct reporting errors at the point where a cellular phone interview is about to be done. Below, we discuss how measurement errors might differentially affect estimates of the percentage of nontelephone from the Census and the NSAF.

Suppose a survey or census is conducted, and data are collected on a characteristic. Despite the best quality control measures, some errors will occur (respondents will answer incorrectly, interviewers will record the responses incorrectly, keyers will enter the data incorrectly, data prep staff will mistakenly change a value, etc). At least conceptually, we can imagine comparing the value reported in the survey to the true characteristic of the respondent. The truth-interview table (Table 1) summarizes this comparison for an item that takes on only two values (*no* and *yes*). For example, the outcome might be either yes, the household has a telephone, or no, the household does not have a telephone.

Table 1. Truth-interview table

	Interview	
Truth	No	Yes
No	a	b
Yes	C	d

The off-diagonal elements (b and c) in the table are the counts of the number of errors. A low level of error for a characteristic might be less than 5 percent of all the observations falling into the off-diagonal cells. The percentage of cases in the off-diagonal cells [$(b+c)/n$, where n is the sum of the sample size across all the cells of the table] is called the gross difference rate. The gross difference rate is sometimes estimated in surveys by using reinterviews to measure the same characteristic twice for a subset of the respondents.

The number of cases that fall into cells b and c depends on the probability of making an error. Let φ be the probability that the interview response is *yes* when the truth is *no* (a false positive) and let θ be the probability that the interview response is *no* when the truth is *yes* (a false negative). If the true proportion of the population with the characteristic is P, then we can express the error in the survey estimate as a function of these three parameters. The bias in the survey estimate of the proportion of households answering *yes* (where bias is the expected difference between the estimate and the true value due to measurement error) is $(1\text{-}P)\ \varphi\text{-}P\theta$.

Now to apply this conceptual framework to the telephone status question, we need estimates of the error rates. The only data we were able to find on this comes from a report from the 1970 Census content analysis (U.S. Bureau of the Census, 1975)[2]. That report contains a table (Table 9 in the report) showing the following numbers for telephone availability.

Table 2. Reinterview-interview table from 1970 on telephone availability

	Interview	
Reinterview	No-telephone	Yes-telephone
No-telephone	545	112
Yes-telephone	185	6,376

If we assume that the reinterview is the truth, as they did in this report (a tenuous assumption but one that is conservative in estimating the bias from the census), we estimate φ=.170 (the false positive rate of the household saying they have a telephone when they actually do not) and θ=.028 (the false negative rate of saying they do not have a telephone when they do). Further assume that the percentage of the population with a telephone is 95 percent (P=.95). Now we have the parameters needed to estimate the bias using the expression given above. The estimated bias in the estimate of the percent of households with telephones is -.018. In other words, the census underestimates the percentage of telephone households by 1.8 percentage

[2] The 1980 and 1990 reinterview reports did not contain any estimates on telephone status.

points, and overestimates the percentage of nontelephone households by 1.8 percentage points. In relative terms, this is a 36.6 overestimate of the 5 percent of the population without telephones.

It is worth noticing that the large bias is mainly a function of the statistic being rare in the population rather than poor quality in the survey. The gross difference rate estimated from the data in Table 2 is 4.1 percent. For most characteristics, this would not be considered to be a serious data quality problem, but because nontelephone households are rare, even this error rate can have a large effect on the estimate. The other factor that affects the size of the bias is the ratio of the probabilities of making the two types of errors. For this case, the estimated probability of a false positive is about 6 times the probability of a false negative.

By changing some of these quantities, we can assess how sensitive the estimated bias is to these values. To be conservative, assume that the gross difference rate is only 2 percent (half of that reported in the 1970 census), P=97%, and the ratio of the false positive to the false negative probability is 10 (rather than the 6 as estimated from the 1970 reinterview data). These assumptions tend to reduce the estimated bias from the census. Under these conditions, the bias due to measurement error in the census estimate of the percentage of telephone households is -.011 percentage points. Since the true percentage of households without telephones under these assumptions is only 3 percent, the result is still a 36.6 percent overestimate even though the absolute overestimate is smaller. This shows that the measurement error is very likely to result in a large overestimate in the Census estimated percentage of households without telephone if the estimates from the 1970 census reinterview are at all reliable.

Now, we examine how measurement error might affect the NSAF estimate of the percentage of nontelephone households. In the NSAF, we might expect the false positive probability (φ) to be approximately the same as estimated from the census since there is no follow-up if the household reports having a telephone when there is not one. However, it is likely that the false negative probability (θ) is much smaller in the NSAF because there is a very important follow-up (the interviewer asks the respondent to participate in an interview on a cellular telephone because the respondent reports not having a telephone in the household). If we assume the 1970 Census reinterview false positive rate of 0.170 and assume one-fifth the 1970 reinterview false negative rate (0.028/5), then the NSAF estimated bias in the percentage of telephone households is .003, a very slight overestimate of only 6 percent in the number of telephone households. The maximum overestimate from the NSAF estimate, if φ=.170, is when θ=0. The bias in the NSAF estimate in this case is .008.

In summary, the effect of measurement errors in the census and the NSAF are of different magnitudes and probably in different directions. Measurement error may result in an overestimate the percentage of nontelephone households in the census of approximately 1.8 percent. While in the NSAF, it may result in an underestimate of about 0.3 percent.

4. Interaction of Frame Truncation and Measurement Errors

We consider two approaches to estimating the difference in yield explained by frame truncation and measurement error. In the first approach, the difference in yield that is explained by truncation is estimated. Then, of the residual, the amount explained by measurement error is estimated.

Based on the 1990 Census, the expected yield was 100%-8.2%=91.8% of the nontelephone households, where 8.2% is the percent of nontelephone households in the truncated areas in the 1990 Census. The loss due to truncation is 27.7 percent based on CPS estimates of the percentage of nontelephone households excluded from the NSAF sampling frame. The loss due to measurement error is 36.6 percent. To compute the adjusted yield, we take the product of what is left in the frame after accounting for what is lost due to frame truncation and what is left in the frame after accounting for measurement error over the expected yield as follows:

$$\begin{aligned} \textit{Adjusted Yield} &= \frac{(100-27.7)*(100-36.6)}{100-8.2} \\ &= 50\% \text{ of expected} \end{aligned}$$

Now, the actual yield was 54 percent of the expected. This implies that there was no loss, and that we actually found slightly more nontelephone households than we should have expected.

In the second approach to estimate the effects of truncating and measurement error, the effect due to measurement error is first estimated. Then the amount explained by truncation is estimated.

The derivation of the loss due to truncation after accounting for measurement error is somewhat complex (see Westat (1998, in press) for more details). A key assumption is that measurement error is at the same rate both inside the frame and outside the frame. For example, if one assumes that measurement error for the Census is .366 and that the proportion of households without telephones is .05, then the false nontelephone rate for the Census is (.366)(.05) = .018. It is assumed that .018 of households both inside the frame and outside the frame are mistakenly classified as not having telephones.

The first input data is the distribution of telephone and nontelephone households by inside and outside the frame as given in Table 3, as estimated in March 1997 CPS. Unadjusted CPS estimates are used in this table, since we are looking at the distribution of nontelephone households and not examining the percentage of households that are without telephones. Note that the percentages for telephone and total households outside the frame are probably a little too low because the estimates are from CPS tabulations of housing units constructed before 1990.

Table 3. Distribution of telephone and nontelephone households by inside or outside the NSAF frame

	March 1997 CPS	
	In frame	Outside frame
Nontelephone	.70	.30
Telephone	.47	.53
Total	.48	.52

Let r be the overall nontelephone rate prior to adjusting for measurement error. Then .366r is the false eligibility rate, both inside and outside the NSAF frame.

s_1 is the "true" nontelephone rate inside the frame and s_2 is the "true" nontelephone rate outside the frame. We form one equation for the number of nontelephone households inside the frame:

$$(s_1 + .366r)(.48N) = (.70)rN\ ;$$

where N is total households.

Then solving for s_1 ;

$$s_1 = 1.092r\ .$$

We form a similar equation for the number of nontelephone households outside the frame:

$$(s_2 + .366r)(.52N) = (.30)rN$$
$$s_2 = .211r$$

The number of nontelephone households inside the frame after accounting for measurement error is:

$$s_1(.48N) = .524rN\ .$$

The number of nontelephone households outside the frame, after accounting for measurement error, is:

$$s_2(.52N) = .110rN\ .$$

The proportion of nontelephone households inside the frame is:

$$\frac{.524rN}{.524rN + .110rN} = .824\ .$$

Thus, the estimate of the loss due to truncation is decreased from 27.7% to 17.6% when allowance is made for measurement error.

Again, the expected yield was 91.8 percent of the nontelephone households. The loss due to measurement error is still 36.6 percent. The loss due to truncation after accounting for measurement error is now only 17.6 percent. Then the adjusted yield, is the product of what is left in the frame after accounting for what is lost due to frame truncation and what is left in the frame after accounting for measurement error over the expected yield as follows:

$$Adjusted\ Yield = \frac{(100-36.6)*(100-17.6)}{100-8.2} = 57\%\ \text{of expected}\ .$$

Compared to the actual yield, this approach implies that there is 3 percent short fall that is still unexplained. The results of the two approaches are similar in that they both indicate measurement error and truncation account for all or most of the difference in yield.

5. Differences Between Nontelephone Households in Excluded and Included Block Groups

This section examines the bias from excluding block groups with low rates of nontelephone households from the sampling frame. If households without telephones in the NSAF frame have essentially the same characteristics as those excluded from the frame, there is no undercoverage bias in NSAF estimates because of frame truncation. This section compares nontelephone households inside and outside the frame. Using CPS data, Table 4 shows the estimated proportion of households and persons for different subgroups that are in excluded block groups. For example, it shows that 43 percent of persons that have income over twice the poverty threshold are in excluded block groups, whereas only 15 percent for poor persons (below 100% of the poverty level) are in excluded block groups. For a more complete set of tables, see Westat (1998, in press).

Table 4. Percentage excluded from the NSAF sampling frame

Households	
Families without children	33%
Families with children	21%
Nonfamilies	32%
Persons	
Above 200% poverty	43%
Between 100% and 200% of poverty	21%
Below 100% poverty	15%
In families with children	20%
Not in families with children	30%

Table 5 presents the data in Table 4 in a different format. For example, the third line of Table 5 indicates that only 30 percent of all excluded nontelephone households have children while 44 percent of all the nontelephone households included in the frame have children. (The numerator of 30 percent is excluded nontelephone households with children, and the denominator is all excluded nontelephone households.) Thus, a smaller percentage of excluded households have children, as compared to included households. Differences for persons and family groups above 200 percent of poverty are particularly dramatic: nearly half (49 percent) of the persons in excluded nontelephone households are above 200 percent of poverty, whereas only one-fifth of the persons in included nontelephone households are above 200 percent of poverty.

Table 5. Distribution of nontelephone households included and excluded from the NSAF sampling frame

Households	Included	excluded
Total	100%	100%
Families without children	23%	18%
Families with children	30%	44%
Nonfamilies	46%	38%
Persons		
Total	100%	100%
Above 200% poverty	49%	20%
Between 100% and 200% of poverty	23%	29%
Below 100% poverty	28%	51%
In families with children	50%	62%
Not in families with children	50%	38%

For all the characteristics examined, the differences in those included and excluded are substantial. This suggests that the frame truncation could result in important biases in the absence of an effective adjustment strategy. Exclusion rates tend to be higher for those who are less economically distressed, a group of lesser policy interest. These are not surprising results, as one would expect that block groups with high percentages of telephones are generally better off, and that any households in such block groups that report the lack of a telephone are more likely reflecting a transient difficulty. Thus, estimates of percentages of the poor that have various characteristics are likely to be less biased by truncation than estimates of percentages of the overall population that have various characteristics. Remember also that the large differences are for nontelephone households only, which are generally a small percentage of all households.

6. Effectiveness of Household Undercoverage Adjustment

In the weighting procedure, the NSAF nontelephone household weights are adjusted for undercoverage using cells defined in terms of the Block Group-Level percentage of households below the poverty level as of 1990. (See Westat (1998, in press) for details and a complete set of tables.) If the percentages included and excluded from the frame were the same in each cell for all characteristics, then the undercoverage adjustment would be effective in removing nearly all of the undercoverage bias due to truncation. For example, consider persons above 200 percent of poverty in Table 5. If the percentages included and excluded from the frame were similar for the cells used in the adjustment, the undercoverage adjustment would effectively eliminate all or most of the bias resulting from the large overall difference (49% vs. 20%) for this statistic.

Table 6 shows an example of the effectiveness of the undercoverage adjustment looking only at family households without children. Table 6 gives the percentages in the types of cells used in the undercoverage adjustment. Across all adjustment cells, 49 percent of persons in excluded households are in family households without children, whereas only 20 percent of persons in included households are in family households without children. Consider the second row, Block Groups with "<10% poverty," which relates to the cell definitions used in the coverage adjustment. Here, the percent of persons in excluded households who are in family households without children is slightly higher (56% compared to 49%). However, the percent of persons in included households who are in family households without children is much higher (35% compared to 20%). The difference between the included and excluded percent is only 21 percent for the subgroup (56%-35%), compared to 29 percent for all persons (49%-20%). This indicates that the undercoverage adjustment is effective in reducing bias. Some, but not all characteristics studied show similar narrowing of differences, indicating that the household undercoverage adjustment should be effective in reducing bias. However, differences remain, so the adjustment will not eliminate all or nearly all of the bias. (Note that the undercoverage adjustment is done by much finer gradations of percentage poverty than shown in Table 6. The finer gradations are likely to reduce bias to a greater extent than Table 6 indicates.)

Table 6. Distribution of nontelephone households that are excluded and included from NSAF sampling frame, by percent of block group that is below poverty

Persons in family households without children		
	Excluded	Included
All poverty rates	49	20
<10%	56	35
10-20%	38	26

7. Conclusions

We have examined several issues regarding households without telephones in the NSAF. The NSAF estimate of such households, before application of undercoverage and poststratification factors, is only about half of what was expected. An analysis of CPS and Census data indicates that much of the difference is the result of truncating the sampling frame to block groups with higher nontelephone rates. Frame truncation had a larger effect than planned because excluded block groups with low percentages of households without telephones in 1990 tend to have higher percentages now. Measurement error is a second major reason for the lower NSAF yield. Measurement error leads to overestimates of the number of nontelephone households in the Census. However, measurement error has a different effect on NSAF and probably leads to a small underestimate. Thus, measurement error in the Census indicates that coverage is much closer to what should have been expected than direct estimates suggest.

The estimates for CPS also indicate that there are substantial differences between nontelephone households included and excluded from the NSAF frame for each of the characteristics we examined. The analysis shows that the poor and families with children are covered better than other types of persons and families. The household undercoverage adjustment procedure used in the weighting should significantly reduce but not eliminate the undercoverage bias from this source.

Undercoverage of households without telephones in NSAF is not as great as it appears since some of the apparent difference in yield is actually due to measurement error in the Census. Furthermore, the undercoverage is concentrated in households above 200 percent of the poverty level and without children. Thus, the undercoverage rate due to frame truncation is 15 percent for persons below 100 percent of poverty and 19 percent for children, compared to 30 percent for all households.

8. References

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