GEOGRAPHICAL VARIATION IN WITHIN-HOUSEHOLD COVERAGE OF HOUSEHOLDS WITH TELEPHONES IN AN RDD SURVEY

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1. Introduction

This paper examines within-household undercoverage in the National Immunization Survey (NIS). The objective of the NIS is to monitor vaccination levels on an ongoing basis in each of 78 Immunization Action Plan (IAP) areas, each of which consists of a substate area or an entire state. The survey uses a two-phase sample design. In the first phase, a quarterly random sample of telephone numbers for each IAP area is called, and households with one or more children aged 19-35 months are identified through a series of screening questions. Vaccination information is collected for all age-eligible children living in these households. About 250,000 households are screened for eligible children each quarter. In the second phase, health-care providers of children in surveyed households are contacted to obtain vaccination information. This paper focuses exclusively on the first phase.

One measure of the effectiveness of a random-digit-dialed (RDD) survey is its coverage of the target population. The NIS yields estimates of the total number of children 19 to 35 months of age in each of the 78 IAP areas. In this paper, we assess coverage as a ratio by comparing these numbers to more-accurate totals derived from vital-statistics data, adjusted for the percentage of young children living in households without telephones. We identify the demographic and socioeconomic characteristics of IAP areas with the lowest coverage rates, and we discuss the implications of these findings for other surveys.

2. Defining Undercoverage

Usage in the statistics profession does not consistently distinguish the terms "response rate" and "coverage rate." At one extreme, undercoverage is defined as occurring only if units that should be in the sampling frame are not in the frame, and nonresponse occurs when weighted estimates of units are too low for any other reason. In a well-designed list-assisted RDD survey, the only obstacles to achieving a coverage rate (in this narrow sense) of 1.0 are the absence of telephones from some households and failure to sample numbers in some banks of telephone numbers, such as those containing no or few directory-listed numbers. Telephone surveys usually take this approach to estimate response rates. Massey (1995) discusses the computation of response rates according to this approach and applies it to the National Immunization Survey.

Madow et al. (1983, Vol. 1, p. 16) give a broader definition of undercoverage: "Undercoverage occurs if units that should be on the frames or lists from which a sample is selected are not on the lists, if units in the frame or sample are incorrectly classified as ineligible for the survey, or if units are omitted from the sample or skipped by the interviewer."

Madow et al. (1983, Vol. 1, p. 18) then define nonresponse: "Unit nonresponse occurs if a unit is selected for the sample and is eligible for the survey, but no response is obtained for the unit or the obtained response is unusable. There are four primary reasons for unit nonresponse in housing unit surveys:

1) No one is at the unit when the efforts are made to interview.
2) The interviewer cannot communicate with the persons in the unit, e.g., because of illness or a language problem.
3) Total refusal occurs or the interview is broken off by the respondent and the partial response prior to break off is classified a refusal.
4) The responses given by the unit are later classified as unusable."

These definitions shift some enumerator errors from nonresponse to undercoverage. For example, an enumerator's misclassifying a telephone number in an RDD survey as non-residential when it is actually residential would contribute to undercoverage.

In some situations the distinction between undercoverage and nonresponse error is not clear according to these definitions (Office of Management and Budget, 1990). Of particular concern are cases in which a household respondent does not provide a full roster of persons in the household, either intentionally or because the person doesn't consider some persons to be household members. For non-telephone household surveys, some authors have considered it nonresponse, and some have

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considered this as within-household undercoverage.

When response rates or coverage rates are computed using independent controls, the full set of reasons for rates lower than 1.0 may be unknown. Some unknown reasons may result in major reductions in rates. This occurs in the NIS. Table 1 shows several nonresponse rates and a coverage rate for the fourth quarter of 1994 (Abt Associates, 1995, Chapter V). The definition of nonresponse for households known to contain an eligible child is unambiguous. The "household screener response rate" under a broad definition of nonresponse is only 76.1%. This compares to the rate of 92.0% under a narrow definition. Under a broad definition, the overall response rate is simply the product of .965 and .761. Similarly, the overall response rate under a narrow definition is the product of .965 and .92. The last line of the table shows a coverage rate of 81.0%, under a narrow definition of nonresponse and assuming all unexplained shortfall from the control total (derived from Vital Statistics) is due to undercoverage.[2]

In part, the coverage rate is under 100% because not all young children are reported, but underreporting does not account for the entire difference. For example, among nonresponding telephone numbers the incidence of young children is much higher among those for which an appointment or callback was established. We estimate that compensating for this effect would increase the coverage rates given in this paper by about 5 percentage points.

We have not, however, made such an adjustment. Thus we use "within-household undercoverage" to include cases where a respondent does not provide a full roster and also to include unexplained shortfalls from independent control totals. This follows the approach taken by Maklan and Waksberg (1988) for RDD surveys and by the Office of Management and Budget (1990) in a definitive report on survey coverage.

3. Weighting Methodology

The NIS uses separate samples in each of 78 geographic areas, known as Immunization Action Plan areas, that make up the United States. An IAP area may be an entire state (e.g., Missouri), an individual city (e.g., Detroit), a single county (e.g., Milwaukee county), several counties (e.g., Fulton and DeKalb counties), or the remainder of a state (e.g., remainder of Michigan, remainder of Wisconsin, and remainder of Georgia). For each IAP area, a random-digit-dialing sample is drawn on a quarterly basis, and the telephone survey is administered each quarter. List-assisted RDD is used (Lepkowski, 1988). Banks of 100 contiguous telephone numbers with zero residential directory-listed numbers are removed from the sampling frame. The sample of telephone number is then drawn from the banks with one or more directory-listed numbers (i.e., the 1+ working banks). An automated procedure is also used to remove a portion of the business and nonworking numbers from the sample before it is dialed by the interviewers (Battaglia et al., 1995). The target population for the NIS is children age 19 to 35 months. If a household contains more than one age-eligible child, vaccination information is collected on each child. Approximately 110 RDD interviews are conducted each quarter. Four consecutive NIS quarters, from July 1994 to June 1995, provide the data for this analysis of coverage.

The NIS weighting methodology entails several steps. The children in the RDD sample constitute only a small fraction of an IAP area's total population of children 19 to 35 months of age. By assigning a weight to each child in the sample it is possible to derive vaccination coverage estimates for the population as a whole. A standard procedure for RDD samples (Massey and Botman, 1988) yields the weights within each IAP area. First, a base sampling weight is assigned to each child according to the probability of selection of the telephone number and adjusted for the presence of multiple telephone lines in the household. Second, each child's base sampling weight is adjusted to account for nonresponse in the RDD survey. Nonresponse or failure to interview households with age-eligible children occurs for three main reasons: a) the interviewer cannot determine the status of a telephone number (i.e., residential, business, or not assigned); b) the sample telephone number is residential, but the interviewer cannot determine whether the household contains any children 19 to 35 months of age; and c) the household contains at least one age-eligible child, but the interview cannot be completed. Third, the nonresponse-adjusted weight is further adjusted to a set of known population totals (Vital Statistics births adjusted for migration, foreign births, and infant mortality). Finally, an adjustment for noncoverage of households without telephones is made to account for the fact that children in nontelephone households, excluded from the first-phase telephone sample, are less likely to be up-to-date on their vaccinations than children in telephone households.

The weight calculations listed in the first two steps yield a nonresponse-adjusted base sampling weight for each child for whom vaccination data are collected. The nonresponse-adjusted base sampling weight reflects only the population of age-eligible children in telephone households in the 1+ working banks in a given IAP area.

[2]The figures presented in the table come from the survey interview process. The coverage rates in the rest of this paper by state and substate area arise from the weighting for the survey. Thus, the two sets of coverage rates are not entirely comparable.

For a given IAP area, the ratio of the sum of the nonresponse-adjusted base sampling weight to the product of the Vital Statistics population count of births and an estimate of the proportion of children age 19 to 35 months in telephone households in the 1+ working banks yields a measure of the level of coverage of the telephone population in the 1+ working banks of children age 19 to 35 months. Current Population Survey data for 24 months (February 1994 to January 1996) were used to provide state estimates of the proportion of children aged three years and under who are in telephone households and the proportion of telephone children in the 1+ working banks (Giesbrecht et al., 1996). Using 1990 Census estimates of the number of two-year-old children in telephone households at the IAP area level, the CPS estimates were adjusted to better reflect the individual IAP areas in those states with two or more IAP areas. A coverage rate less than 1 indicates that a portion of the telephone population in the 1+ working banks is not being covered by the telephone survey.

In step 3 of the weight calculations the IAP area Vital Statistics population control totals are adjusted to reflect: 1) infant mortality, 2) immigration (i.e., foreign births), and 3) mobility between IAP areas. The adjustments are made using information from NCHS on infant deaths and on residence at time of birth versus location of the birth and from the 1990 Census on residence in 1990 versus residence at time of birth. The coverage analysis presented below uses the adjusted Vital Statistics control totals. Because the adjustments could have an impact on the IAP area coverage rates, a sensitivity analysis was conducted. The IAP area coverage rates were computed using the unadjusted Vital Statistics control totals. The impact of the adjustments was to raise or lower the coverage level by a maximum of 4 percentage points, with most IAP areas changing by only 1 to 2 percentage points. The adjustments were therefore deemed not to have more than a small impact on the IAP area coverage rates.

4. Coverage for IAP Areas

In order to examine variation in the coverage rate among IAP areas in more detail, we split each of eight IAP areas (in four states) into two pseudo-IAP areas. This choice capitalized on the fact that the IAP areas for four cities -- Cleveland, Atlanta, Phoenix, and Seattle -- are defined at the county level and that the rest-of-state IAP area in each case contains substantial populations both in and outside MSAs. For the four metropolitan IAP areas, the center city became a pseudo-IAP area. For example, Cuyahoga County, Ohio, was divided into a Cleveland pseudo-IAP area and a rest-of-county pseudo-IAP area. The rest-of-Ohio IAP area was similarly divided into two pseudo-IAP areas: MSA counties and nonMSA counties. (Franklin County, Ohio [Columbus] is a separate IAP area.) Besides providing additional areas that differ in their characteristics, this strategy offers some opportunity for comparisons among center cities, their nearer (and usually older) suburbs, and the nonMSA counties of the state. Comparisons with the MSA part of the rest-of-state IAP area may be less clear-cut, because that part may include both the outer suburbs of the particular city and entire MSAs elsewhere in the state.

The coverage rate for the U.S. (a weighted average), 71.8%, indicates a substantial degree of within-household undercoverage. Around this overall figure the 86 IAP and pseudo-IAP areas exhibit wide variation, ranging from 42.3% in the Arizona nonMSA pseudo-IAP area to 94.8% in the Georgia MSA pseudo-IAP area with a median (unweighted) at 71.3% and lower and upper fourths (approximate quartiles) at 63.9% and 79.0%, respectively. Among the 22 areas at or below the lower fourth, 19 come from among the 36 metropolitan areas. Thus it appears that large urban areas tend to produce higher levels of undercoverage. Compared to their corresponding rest-of-state IAP areas, the 27 metropolitan IAP areas (not including the District of Columbia) often have coverage rates that are more than 20 percentage points lower. Indeed, only two are higher, and the median difference is -17%.

For the four pairs of metropolitan IAP area and rest-of-state IAP area that were split to produce the 16 pseudo-IAP areas, Table 2 shows the coverage rates for the four pieces: the center city, the rest of the county (or counties, for Atlanta), the MSA counties in the rest-of-state area, and the nonMSA counties in the rest-of-state area. In each instance, the center-city pseudo-IAP area has a lower coverage rate than the "older suburb" pseudo-IAP area. Except in Seattle, these differences are significant at the .05 level. Also, in all four states the MSA rest-of-state pseudo-IAP area has significantly higher coverage than the nonMSA rest-of-state pseudo-IAP area.

To investigate the relation of the coverage rate to characteristics of the 86 areas, we considered ten potential explanatory variables from 1990 Census data:

WHITE	Percent of population white
BLACK	Percent of population black
AMIND	Percent of population American Indian, Eskimo, or Aleut
HISP	Percent of population of Hispanic origin
URBAN	Percent of population urban
POVERTY	Percent of population below poverty level
FEMHEAD	Percent of families with a female head
NOHSED	Percent of persons age 25+ with less than a high-school education
INCOME	Per capita personal income
LPOPDEN	Logarithm (base 10) of the population density (per square mile) .

We also included indicator variables for three of the four Census regions:

MIDWEST
SOUTH
WEST

(the East region is handled by the intercept term). Scatterplots of the coverage rate against these variables suggested some moderate slopes, accompanied by substantial variation. The Arizona nonMSA pseudo-IAP area stood out in several of these plots because of its low coverage rate and, especially, its high value of AMIND. Thus we tentatively set aside that pseudo-IAP area. Also, because AMIND has a different interpretation in Alaska, we eliminated that variable from further consideration. In addition, we considered dropping two further IAP areas: Alaska (because of its very low population density) and Hawaii (because of its distinctive racial composition).

Straightforward multiple regression, with all the above variables except AMIND in the model, produced a reasonably good fit, but no one variable made a strong contribution to the coverage rate. Model selection by stepwise regression led to three somewhat different subsets of variables, according to whether the data set contained all 86 areas, omitted Arizona nonMSA, or omitted both Arizona nonMSA and Alaska and Hawaii. The variables that appeared in at least one of the three subsets were WHITE, BLACK, HISP, POVERTY, FEMHEAD, LPOPDEN, and WEST. Thus it is reasonable to conclude that the variables not selected (URBAN, NOHSED, INCOME, and the other region indicators) are less useful in accounting for variation in coverage rate. Beyond noting that only LPOPDEN was selected into all three models, we are not prepared at present to rank the contributions of the variables or to report regression coefficients in any model.

5. Discussion

There has been considerable research on coverage problems in the Canadian and U. S. Censuses, but relatively little on surveys. Office of Management and Budget (1990) contains a good overall discussion of survey coverage. Most of the research on survey coverage has involved address- and area-based sample surveys conducted by the U. S. Census Bureau. (See, for example, Hainer et al., 1988.)

Very little work has been done for telephone surveys. Thornberry and Massey (1988) extensively discussed the health characteristics of persons in households without telephones. Maklan and Waksberg (1988) investigated within-household coverage in RDD surveys as compared to address-based surveys such as the Current Population Survey (CPS). O'Rourke and Lakner (1989) investigated male undercoverage when using the last-birthday method of respondent selection.

Shapiro et al. (1993), among others, have examined coverage by age, race, and sex for the CPS. They have shown that coverage is generally poorest for Black males.

Hogan (1993) reported results for the 1990 Census. Groups with particularly poor coverage are Black non-homeowners in large urban areas, Hispanic non-homeowners in large urban areas, Hispanic non-homeowners in non-urban areas, and non-urban non-homeowners generally. States with poor coverage include California, Delaware, New Mexico, and Texas. States with good coverage include Connecticut, Indiana, Iowa, Massachusetts, Minnesota, Missouri, Nebraska, Pennsylvania, Rhode Island, and Wisconsin.

Chakrabarty (1995) is the only author who has investigated differential coverage by demographic characteristics and geography for a survey. He compared undercoverage in the CPS relative to the 1990 Census. Population density was one of the characteristics that we found to be correlated with coverage rates, with low-density areas tending to have high coverage. Consistent with these results, Chakrabarty found that overall coverage in rural areas was better than coverage in urban areas, concluding "Rural areas outside MSAs show as good as or better coverage than Urban areas for total population ...." However, Chakrabarty did not find differences in coverage rates between MSAs and non-MSAs, nor did he find differences between central cities and the balance urban within MSAs.

Chakrabarty did not generally find differences among the four regions, although he found that Blacks have lower coverage in the West Census Region than in other regions. This is consistent with our finding that WEST is correlated with coverage and has lower coverage rates than average. Chakrabarty did not examine any other characteristics that we did.

The variables that we found related to coverage and the direction of the correlations (positive or negative) are not surprising in light of earlier coverage studies. Our evidence for lower coverage in the West Census Region was perhaps unexpected, but it is consistent with Hogan's conclusions on states with good and poor coverage in the Census. One might have expected percent with less than a high school education, per capita income, and percent urban also to show a relationship with coverage rates. The urban/suburban/rural differences found among a handful of opportunistically selected areas (Table 2) are also not surprising, but they may indicate that the relationship of coverage rates to population density is not necessarily an indication of high coverage in rural areas.

The substantial degree of within-household under-coverage of children 19 to 35 months of age in the NIS has implications for any RDD survey that screens for the presence of young children. Such surveys are very likely to encounter a similar degree of undercoverage.

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Table 1: Alternative Response Rates and Coverage Rate, 4th Quarter 1994		
	Definition of Nonresponse Rate	
Type of Response Rate	**Narrow**	**Broad**
Eligible Household	96.5%	96.5%
Household Screener	92.0%	76.1%
Overall	88.8%	73.4%
Coverage	81.0%	---

Table 2. Coverage rate in the 16 pseudo-IAP areas formed by splitting four metropolitan IAP areas (OH - Cuyahoga County, GA - Fulton/Dekalb Counties, AZ - Maricopa County, and WA - King County) and the corresponding rest-of-state IAP areas.

	Metropolitan		**Rest-of-State**	
	City	**Rest of IAP area**	**MSA**	**nonMSA**
Cleveland & OH	58.8	80.3	87.1	66.5
Atlanta & GA	55.6	85.3	94.8	74.1
Phoenix & AZ	61.5	71.2	90.8	42.3
Seattle & WA	68.6	70.0	83.0	75.4