A COMPARISON OF TWO METHODS OF ADJUSTING FOR NONCOVERAGE OF NONTELEPHONE HOUSEHOLDS IN A TELEPHONE SURVEY

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1. Introduction

In order to measure progress toward a number of childhood-immunization goals and to assist the Centers for Disease Control and Prevention (CDC) in directing resources, the National Immunization Survey (NIS) has, since April 1994, monitored vaccination coverage levels among children 19 to 35 months of age. The survey uses list-assisted random-digit dialing (RDD) and a screening interview to identify households that contain one or more age-eligible children. In common with other RDD surveys, the NIS faces the problem of being unable to contact households that do not have telephones. Worse, data from the National Health Interview Survey (NHIS) show that children in nontelephone households have lower rates of immunization than children in telephone households. Fortunately, however, those same data furnish a basis for adjusting the weights of children in the NIS to compensate for the noncoverage of the nontelephone households. The present paper describes two approaches to this adjustment -- modified poststratification and model-based weighting -- and compares them with simple poststratification, which uses only the population control totals for a set of cells.

The NIS covers all 78 of the Immunization Action Plan (IAP) areas that make up the United States. These are the 50 states, the District of Columbia, and 27 other metropolitan areas (where a state contains metropolitan IAP areas, the rest of the state forms a separate IAP area). For each IAP area the target sample size is 110 completed household interviews for age-eligible children in each calendar quarter. Ezzati-Rice et al. (1995) describe the design in greater detail.

The NIS estimates several rates of vaccination coverage. One of the most important is the 4:3:1 up-to-date rate, the percentage of children who have received 4 or more DTP shots, 3 or more Polio shots, 1 or more MMR shots.

2. Nonresponse-Adjusted Base Sampling Weights

To provide population-based estimates, the weighting methodology first assigns a basic sampling weight to each sample telephone number in an IAP area. This weight equals the reciprocal of the probability of selecting the telephone number. Then a number of adjustment factors are applied to take into account multiple telephone lines, cross-overs between IAP areas, and unit nonresponse.

In the NIS unit nonresponse may occur at several stages, each yielding a different amount of information about the nonresponding telephone number or household. The nonresponse adjustment consolidates these stages into three categories, corresponding to knowledge that the household contains an eligible child, knowledge that the telephone number belongs to a household (but not whether the household contains any eligible children), and no knowledge of whether the unit is a household. Each category yields a noninterview adjustment factor within a modest number of cells (e.g., the cross-classification of telephone area code and whether the telephone number is directory-listed).

The product of the noninterview adjustment factors and the basic sampling weight (adjusted for multiple telephone lines and for cross-overs between IAP areas) yields the nonresponse-adjusted base sampling weight.

3. Simple Poststratification

Although one can use an RDD sample to generalize to the population of age-eligible children in telephone households in a straightforward manner, the objective of the NIS is to generalize to the entire population of age-eligible children residing in households in each IAP area. The difference between these two populations can be substantial. In the U.S. as a whole around 12% of age-eligible children reside in nontelephone households; and the noncoverage rate varies among IAP areas, from a low of about 2% to a high of around 25%. Also, vaccination rates can differ between age-eligible telephone and nontelephone children. At a national level the 1992 NHIS Immunization Supplement indicates that, for example, 61% of telephone children (19 to 35 months of age) had received four or more doses of DTP vaccine, and were therefore considered up-to-date, whereas only 44% of nontelephone children were up-to-date on DTP. Thus the vaccination rates of telephone children would generally overestimate the vaccination rates of the entire population. The present section and the next two briefly sketch three approaches to reducing this noncoverage bias: simple poststratification, modified poststratification, and model-based estimation. Battaglia et al. (1995) describe them more fully.

Certain demographic and socioeconomic characteristics may account for both a household's telephone ownership and the children's being up-to-date on vaccination coverage. Simple poststratification divides the RDD sample into a set of cells by using variables that are related to unit nonresponse and/or noncoverage and are associated with the key subject-matter variables. It then brings the total nonresponse-adjusted base sampling weight into agreement with a population control total in each cell.

The NIS questionnaire and the National Center for Health Statistics' natality data file have in common several variables from which reasonably detailed population control totals can be constructed: state and county of residence, race of child, Hispanic origin of child, age of child in months, race of mother, Hispanic origin of mother, and education of mother. For each of 12 poststratification cells (based on race/ethnicity, mother's education, and age of child), we formed a population control total by adjusting the number of live births for infant mortality, immigration, and migration.

An analysis of the 1992 NHIS, however, indicated that, even when one controls for the available demographic and socioeconomic factors, the percentage of 19- to 35-month-old children who are 4:3:1 up-to-date is lower for nontelephone children than for telephone children. Even so, the simple-poststratification estimates can serve as a useful baseline in assessing the impact of other approaches to estimation.

4. Modified Poststratification

Although, within the poststratification cells developed from the natality data file, the up-to-date vaccination rates differ between telephone and nontelephone children, the poststratification framework still offers a way to achieve additional bias reduction. At a national level, the NHIS Immunization Supplement can provide estimates of vaccination rates for telephone and nontelephone children for the various poststratification cells. This information can in turn be used to split each poststratification cell into two subcells: one representing up-to-date children, and the other representing children who are not up-to-date. Poststratification can then be used to adjust the weights of the NIS children within these subcells. The resulting weights should reduce noncoverage bias.

5. Model-Based Estimation

The NHIS sample is too sparsely spread over the IAP areas to allow for direct estimates of the relationships of the vaccination rates for nontelephone to telephone children at that level. Instead, we use a statistical model to take into account the characteristics of the individual children in the NHIS and also to allow for geographic variation not accounted for by those characteristics. We then apply the model to the data from the individual children in the NIS. In this way the model-based approach works with the NIS data at a finer level of detail than is possible with simple or modified poststratification.

The model-based approach takes vaccinated and unvaccinated children separately. We illustrate for vaccinated children. From the child-level and county-level variables that are available in the data from both the NHIS and the NIS, we use the NHIS data to select a logit model for $\tau(x)$, the probability that a vaccinated child with characteristics x (the variables in the model) resides in a telephone household. For child i with nonresponse-adjusted base sampling weight W_i, the model-based approach adjusts W_i to reflect the overall probability that a vaccinated child is selected into and participates in the NIS. A vaccinated child in the NIS with characteristics x_i has (estimated) probability $\hat{\tau}(x_i)$ of residing in a telephone household. The probability that child i is selected into and responds to the NIS, given that he or she resides in a telephone household, is $1/W_i$. Thus the overall probability is $\hat{\tau}(x_i)/W_i$, and taking the reciprocal yields the weight $W_i/\hat{\tau}(x_i)$.

For unvaccinated children a parallel development produces an augmented weight in the same form. Then, by applying a common multiplicative factor to the augmented weight for each RDD child in poststratification cell g (vaccinated and unvaccinated), we bring the weighted sample total into agreement with the population control total for cell g.

In developing estimates from the NIS data for April through December 1994, the modeling was based on one vaccination measure, 4:3:1 up-to-date, and on three demographic groups that combined the age of the child and the education of the mother: (1) mother's education is less than 12 years; (2) mother's education is 12 years or more and child is 19 to 25 months old; and (3) mother's education is 12 years or more and child is 26 to 35 months old. Cross-classification of the data (around 3200 observations) from the National Health Interview Survey and its Immunization Supplement for 1992 and 1993 according to the 4:3:1 up-to-date measure and the three demographic groups produced six modeling cells. For the modeling we assembled an extensive list of variables that might affect the likelihood that a household would have a telephone. After developing a separate logit model within each of these cells, we merged the six lists of explanatory variables and included main-effect and interaction variables for the cell structure and interactions between the cell structure and the other explanatory variables. We then considered logit models for the combined data from the six modeling cells. Fortunately, a single model (containing some indicator variables and interactions) emerged as adequate for the full data set, combining vaccinated and unvaccinated children in all three demographic groups. Because of space limitations we do not list the variables in the final model. Generally speaking, the variables involved family income, mother's education, whether the child was up-to-date on 4:3:1, whether the child's main racial background is black, whether the child is a black male, whether the child is of Hispanic origin, whether the child's main racial background is other, and three county-level variables: the logit of the proportion of households with telephones, the proportion of the population that was white, and the percent of the population that was of Mexican origin.

6. Comparing the Methods

Because they implement different approaches, one expects simple poststratification (SP), modified poststratification (MP), and model-based estimation (MB) to yield different estimates of immunization coverage in some IAP areas. We examined the extent of these differences and identified the IAP areas in which they seemed substantial. For model-based estimation we asked whether particular components of the model are primarily responsible for the observed differences.

On the whole each set of weights yields estimates that differ from the other two in a number of IAP areas. As one might expect, MP and MB differ more from SP than from each other. MP and MB are both lower than SP in each IAP area, sometimes by several percent. The differences between MP and MB go in both directions.

Modified Poststratification vs. Simple Poststratification

To display the IAP-level differences between two sets of estimates in a way that shows the overall pattern and readily reveals the largest differences, it is useful to plot the difference against one of the estimates. Figure 1 plots the percentage difference (MP − SP)/SP against SP. At the lower center of the plot seven IAP areas show a noticeably greater percentage decrease. Apart from these the decreases range from 0.5% to 4.1%.

In order from the lowest the seven IAP areas are Arizona-Rest of State, Arkansas, New Mexico, Kentucky, Mississippi, West Virginia, and Oklahoma. In each of these IAP areas a very substantial percentage of the households that contain a two-year-old child do not have a telephone. From the 1990 Census this figure ranges from 18.4% in Oklahoma to 25.4% in Arizona-Rest of State. A high prevalence of such nontelephone households is a necessary ingredient in a substantial difference between SP and MP. The other main ingredient is a lower rate of immunization coverage among nontelephone households than among telephone households (in the NHIS) within each of the poststrata used in the IAP area. These ingredients combine to yield a substantially greater upward adjustment for the weights of children in many of the not-up-to-date subcells than for the weights of children in the corresponding up-to-date subcells. By contrast, simple poststratification applies the same adjustment (generally upward) to all children in a poststratification cell. The result, for these IAP areas, is the more-negative values of (MP − SP)/SP.

Model-Based Estimation vs. Simple Poststratification

Figure 2 plots the percentage difference (MB − SP)/SP against SP. Again all the differences are negative. Three IAP areas at the bottom (Kentucky, Mississippi, and West Virginia) stand out from the others. Further, a discernible gap in the overall distribution of (MB − SP)/SP just above −4% suggests that six additional IAP areas should receive closer scrutiny: Chicago, Newark, and Baltimore at the left and New York City, Georgia-Rest of State, and South Carolina to the right of the center. Each of these nine IAP areas contains a substantial percentage of households with a 2-year-old child that do not have a telephone (from 13.9% in New York City to 23.6% in West Virginia).

In model-based estimation the adjustment to the weight reflects a number of characteristics of the individual child, as described in Section 5. Thus further exploration of the impact of the model-based approach focused on the weights within IAP areas. In order to produce a lower estimate of the 4:3:1-up-to-date rate in an IAP area, model-based estimation must give relatively more weight to children who are not up-to-date. Thus we plotted the difference in a child's weights against the child's simple-poststratification weight, MB − SP versus SP, with separate plots (not shown) for up-to-date and not-up-to-date children. The difference in weights generally is more often positive for not-up-to-date children than for up-to-date children. More importantly, the plot for the not-up-to-date children shows a number of children (typically 5 to 15) whose MB weight is substantially greater than their SP weight. With a few exceptions, scattered over the nine IAP areas, the up-to-date children do not have such large differences between their MB and SP weights. Thus a sizable portion of the decrease in estimated 4:3:1-up-to-date rate seems to come from a modest number of not-up-to-date children whose weights receive a large upward adjustment in the model-based estimation process.

For comparison, in the four IAP areas with the smallest percentage decrease in 4:3:1-up-to-date rate (.05% to .49%) the plots for up-to-date children and not-up-to-date children are quite similar. Not-up-to-date children with sharply greater MB weight are absent.

Where children's MB weights were substantially greater than their SP weights, we asked which variables in the model were responsible. For the nine IAP areas we identified the children (either not-up-to-date or up-to-date) whose MB weight was substantially greater than their SP weight and then listed those weights for each child, along with the values of all variables in the random-effects logit model. These children's combinations of characteristics showed considerable diversity among the IAP areas. As a rough summary over the IAP areas, the following variables made the largest and most frequent contributions: main racial background = black, Hispanic origin, family income, and mother's education. In some instances the county effect or the logit of the proportion of households with telephones played a role. Often the children with the largest values of MB − SP combined contributions from several variables. Thus it appears that the model-based approach takes the characteristics of NIS children into account in some detail.

Model-Based Estimation vs. Modified Poststratification

To compare MP and MB, we plotted the percentage difference in 4:3:1-up-to-date rate, (MB − MP)/MP, against MP. These differences were generally not large, and they went in both directions; only six IAP areas lay outside the interval from −2% to +2%. In order of decreasing magnitude these IAP areas are New Mexico, Arizona-Rest of State, Arkansas, Texas-Rest of State, Georgia-Fulton/Dekalb, and Illinois-Chicago; for all except Illinois-Chicago the MB estimate is greater than the MP estimate.

As before, we examined data for individual children, plotting the difference in their weights (MB − MP) and listing their values of the variables in the model. The plots showed a number of children, both up-to-date and not up-to-date, with substantial differences in either direction. Otherwise, the differences were reasonably well centered around zero, both for up-to-date children and not-up-to-date children. On balance, for five of the six IAP areas, two groups of children combined to make the MB estimates higher than the MP estimates: up-to-date children with sizable positive differences in their weights and not-up-to-date children with moderate to sizable negative differences in their weights. The same general pattern applies in Illinois-Chicago with the roles of up-to-date and not-up-to-date children reversed.

The identified children combined contributions from several variables in the model and in ways that varied among IAP areas. The variable contributing most frequently was household income. Children with sizable positive differences in their weights almost all had low values of household income, and many children with sizable negative differences had high values. The other two variables that frequently played a role were mother's education and Hispanic origin.

The poststratification cells for MP involve race/ethnicity, mother's education (though only by dichotomizing it at 12 years), and age of child and also (for the subcells) whether the child was 4:3:1 up-to-date. In several of the six IAP areas the small numbers of children with completed RDD interviews caused cells to be combined. Household income does not play a role in setting up the poststratification cells, because no such variable is available on the natality data file. This information suggests that, in some IAP areas, the model-based weights are able to take better account of key characteristics of children in the NIS. Overall, however, the modest differences between the MB and MP estimates in the bulk of the IAP areas indicate that this potential advantage does not have a large impact.

7. Conclusions

In summary we emphasize four key findings of this research:

1. The variables available for use in simple poststratification do not go far enough in reducing bias from noncoverage of nontelephone households.
2. By splitting each poststratification cell into up-to-date and not-up-to-date subcells, modified post-stratification makes substantial adjustments in several IAP areas.
3. Model-based estimation takes characteristics of NIS children into account in more detail, and it also produces sizable adjustments.
4. In the bulk of the IAP areas, the difference between the model-based estimate and the modified-poststratification estimate is modest.

At present, estimation in the NIS uses modified-poststratification weights that incorporate data from the 1994 NHIS. Further research may develop model-based weights from 1994 NHIS data and re-examine the comparisons among simple poststratification, modified poststratification, and model-based estimation that we have discussed in this paper.

References

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Figure 1. Modified Poststratification vs. Simple Poststratification:

Plot of 100(MB-SP)/SP vs. SP for the 78 IAP Areas

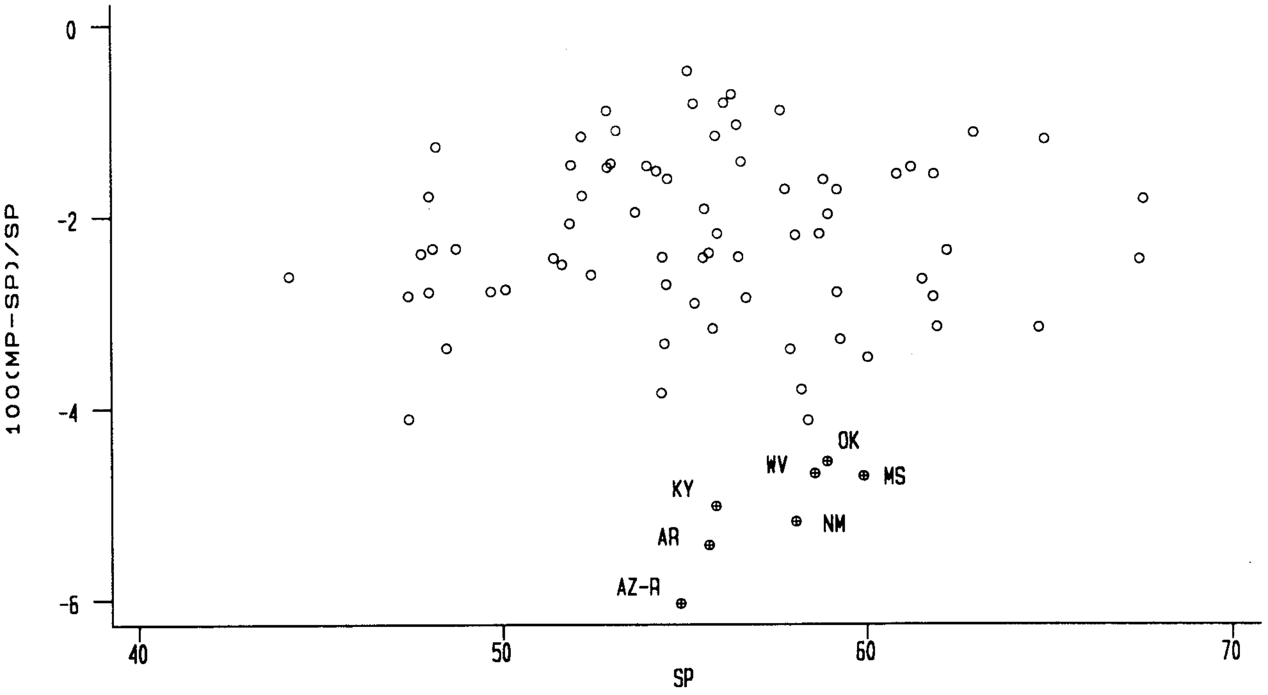

Figure 2. Model-Based Estimates vs. Simple Poststratification:

Plot of 100(MB-SP)/SP vs. SP for the 78 IAP Areas