An Evaluation of An Estimation Procedure From A DSRDD Telephone Sample Design, or How Well Do Sample Weights Work.

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KEYWORDS: Random Digit Dialing, Weighting, Weighting Class, Non-response, Telephone Sampling, Imputation, Design Weights.

Introduction:

Two of the important tools used for adjustments to compensate for non-response in sample survey data have been the use of weighting class estimators and the technique of post-stratification.

The weighting class estimator is formed by substituting the mean of the respondents in each class for the responses to the non-respondents for that class in the sample. Post-stratification refers to the technique of stratifying the sample after the data has been collected and using auxiliary data from sources outside of the sample to produce estimates from the sample. Since the adjustments produced by the weighting class adjustments are derived completely from the sample design and implementation we call these weights "design weights" more or less following the lead of Platek.

Operationally there is no difference between the weighting class technique and missing at random procedure for adjusting for non-respondents. However it does seem that the assumptions underlying the two notions may be different. The missing at random approach treats the effect of non-response as affecting the selection probability of the responding elements in the sample, while the weighting class estimator sees no change in the selection probability but only an absence of values for some units which is partially rectified by simply replacing the missing values with the mean of those values belonging to the responding sample elements.

The implication of the difference in assumptions, if any will not be discussed in this paper, nor will it discuss the role of post-stratification. Except to say that in the absence of non-response, post-stratification appropriately executed reduces the variance of estimates based on the sample data. In the presence of a non-response bias it also plays a role in bias reduction.

Combining weighting class and post-stratification estimators is not new to survey sampling in fact much has been written on the subject. The application of weighting class estimators is less well developed in the estimation procedures for RDD telephone sample designs.

This paper discusses and illustrates three ways in which weighting class techniques can be applied to RDD sample surveys, and provides an empirical comparison of their effectiveness and accuracy by comparing RDD sample based estimates with census counts. It also illustrates the importance of using the number of telephone numbers attached to a housing unit in the computation of design weights. The estimates are based on data collected in approximately equal quarterly installments during the year beginning in April 1990, and ending in March, 1991. The estimates are compared with the April 1, 1990 Census results. We realize that this discrepancy in the timing adds additional error possibilities to the comparison, however we believe that the results of the investigation will be of interest.

The first estimator treats the whole sample as the weighting class and adjusts all of the selection probabilities by the inverse of the overall response rate for the sample. The second estimator defines the weighting classes in terms of a geographical stratification scheme originally used to select the sample, so that the adjustment to the weights uses the response rate for the stratum and the selection probability of the element. The third procedure creates weighting classes based on the area code and prefix of the phone number attached to each sample element.

The Sample:
The sample used for this discussion is a Disproportionate Stratified Random Digit (DSRDD) sample, sometimes referred to as a list based sample. In this sampling scheme the universe of all possible telephone numbers for the area sampled is split into blocks of contiguous telephone numbers, and on the basis of directory listings these blocks were sorted into two groups:

> Blocks of phone numbers likely to be attached to residences, and
>
> Blocks of phone numbers not likely to be attached to residences.

A different sampling rate is then used to sample each group. For example if the selection probability for the group or stratum with phone numbers which are likely to be residential is p, then the selection probability for the other, i.e., the unlikely group or stratum is usually p/k where k is an integer greater than one. The resulting sample has a higher frequency of residential phone numbers than a simple RDD sample. In short the DSRDD sample has a higher hit rate than a simple RDD sample. In some commercial applications the stratum or group with phone numbers which are unlikely to be attached to residences is simply dropped from the sample.

For the survey which produced this data, both the likely and the unlikely groups of phone numbers were further split into five strata using area-code and exchange prefix combinations. A stratified random sample was then drawn from each of the 10 strata created. The sampling probabilities varied by strata.

Completed interviews were obtained from 2696 households. The respondent was a responsible adult living in the housing unit, and information was collected on all persons living in the housing unit. Data was collected on 7365 persons in Wisconsin.

Computing The Weights:
The raw weights for this design were the inverse of the sample selection probabilities. These raw weights were used to produce three other sets of weights which we will call the flat rate weight, the region rate weight and the prefix weight. The raw rate is,

$$w_i = 1/\pi_i$$

where π_i is the selection probability for the i^{th} sample element. This is usually the product of the probability of selecting the phone number used to reach the housing unit and the number of residential phone numbers attached to the housing unit. For this particular survey the number of residential phone numbers attached to each sample household was not available so that the value of π_i used for the weights did not contain a factor for the number of residential phone numbers attached to the i^{th} sample housing unit. Fortunately other surveys of the same area provide us with estimates of the number of housing units with multiple residential numbers for each region. We use these estimates to adjust the sample weights, and to provide an idea of the impact of the missing factor on the estimates.

Weights Ignoring The Number of Residential Phone Numbers Per Housing Unit:
The flat rate weight (γ) is obtained by dividing the raw weight by the response rate expressed as a proportion, i.e.

$$\gamma_i = w_i\,(100/R),$$

where R is the overall response rate for the survey.

The region rate weight (λ) is the product of the raw weight and the response rate for the sampling stratum in which it occurred,

$$\lambda_{ij} = w_{ij}\ \ (100/r_j)$$

where r_j is the response rate for the j^{th} geographic stratum, and w_{ij} is the raw weight for the i^{th} observation from the j^{th} sampling stratum, j=1,.., 5.

The prefix rate weight (τ) is the product of the raw weight for the observation and the response rate for the prefix area in which it occurs, i.e.,

$$\tau_{ik} = w_{ik}\,(100/r_k)$$

where w_{ik} is the raw weight for the observation from the k^{th} prefix area and r_k is the response rate from the k^{th} prefix area, k=1,..., K.

Weights Adjusted For Housing Units With Multiple Residential Phone Numbers:
Data from another survey of the same area was used to produce estimates of the proportion of each regions' households which contain multiple residential phone numbers. These proportions varied from a low of .009 to a high of .034, i.e., from less than 1% to about 3.4%. The adjusted weights are the products of the weights from the previous section and ($1-g_j$), i.e.,

$$\Gamma_{ij} = \gamma_{ij}(1-g_j)$$
$$\Lambda_{ij} = \lambda_{ij}(1-g_j)$$
$$T_{ij} = \tau_{ij}(1-g_j)$$

where g_j is the estimated proportion of the regions' housing units with more than one residential phone number.

(Note that there are five geographic strat with 2 sub-strata each, so that j=1,..., 10, and that sub-strata in the same geographic stratum have the same value for g_j).

Estimating The Response Rate
A recurrent problem with RDD samples is the determination of the actual response rate. Even though the response rate is clearly defined, e.g.

$$\frac{\text{completed} \times 100}{\text{Total eligible sample points}},$$

the mechanics of an RDD sample are such that the exact value of the response rate can not be calculated.

The problem is caused by the existence of phone numbers in the sample whose status could not be resolved during the course of the survey. The solution chosen is to estimate the proportion of "eligibility undetermined " phone numbers in the sample which are attached to residences and to add the estimate to the number of known eligibles in the sample. This producing in effect an estimate of the number of eligibles in the sample, and hence an estimate of the sample's true response rate. The estimate of the response rate used here corresponds to the CASRO procedure for reporting response rates.

The response rate formula and categories are shown in Table 1.

Table 1
Definition of Response Rate Formula Categories

Category	Description of Category
Completed	Interview completed from an eligible respondent
Non-response	An eligible respondent exists, but no interview obtained.
Ineligible	The telephone number is not attached to a residence with an eligible respondent.
Eligibility Undetermined	No determination could be made as to whether or not the telephone number is attached to a residence containing an eligible respondent

The response rate is estimated with the formula:

$$\text{CASRO RR} = \frac{\text{Completed}}{\text{Completed + Non-Response + (a x Eligibility Undetermined)}} \times 100$$

$$\text{where } a = \frac{\text{Completed + Non-response}}{\text{Completed + Non-response + Ineligible}}$$

Response Results:
Response rates differed by area code prefix combinations About 800 of the exchange prefix groups had no eligible phone numbers. Most of these , 644, were in fact part of the sample from the "unlikely" strata. The remainder of the area code prefix groups from the "unlikely" strata, 12 in all, had 100% response rates. In fact these 12 area code prefix combinations had only one eligible each.

For the most part the lowest response rate for any area-code exchange prefix combination in the "likely" strata is 20 percent. About 63 of the "likely" sample area code exchange prefix combinations show a response rate of between 20 and 50%, and about 229 of the area-code exchange prefix combinations show a response rate greater than 50% but less than 100%. A total of 258 area-code prefix combinations had a response rate of 100%

The relative weight adjustment imposed on the sample weights will in general be less than or equal to 5, with most of them being less than 2. This is for those who are worried about the impact of these weight adjustments if they are applied to unusual or extreme observations.

One effect of using the area code prefix combination response rate in the design weight is to use small local area averages to compensate for the observations missing because of non-response. Improvements in accuracy as a result of this strategy will vary depending on how strongly the variables being measured are related to geographical area.

Results:
The scoreboard for the accuracy of the various estimators was constructed from the 1990 census population counts for the household population. These counts were adjusted downward to reflect the telephone household coverage in each county. The counties were then grouped into four regions. Census counts for these regions were then computed and used as the scoreboard for evaluating the sample estimates. Note that unlike the sample designs strata which are defined in terms of exchange area boundaries, these regions are defined in terms of county boundaries.

The adjusted census counts shown in the tables below were obtained by multiplying each county's household population by the percent telephone households in that county. These adjusted counts were then summed to give the region and state totals for persons living in households.

The stratum boundaries for the 10 strata used in the sample design were defined in terms of exchange areas which are usually not co-terminous with county boundaries. The regions used for the census counts were defined in terms of census boundaries. The stratum boundaries were therefore not co-terminous with the boundaries of the county based regions.

Estimates for the county based regions were made from the sample using the respondents' response to a question asking for the name of the county in which the housing unit was located. The resulting unadjusted estimates[1] and the adjusted census counts for the four regions are shown in Table 2. Raw weight estimates for the regions are also shown in Table 2.

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[1]Estimates produced using weights unadjusted for the number of residential phone numbers in the housing units

Table 2.
Table Showing Unadjusted Sample Estimates And Population Counts for Geographic Regions

	Region 1	Region 2	Region 3	Region 4	All Regions
Raw Weight (w_i)	712344	1220596	727594	784843	3445377
Flat Rate Weight (γ_i)	995547	1705861	1016860	1096869	4815137
Region Rate Weight (λ_i)	954141	1771761	971903	1046508	4744313
Prefix Rate Weight (τ_i)	926462	1818657	982496	1032019	4759634
1990 Census of Persons in Telephone Households	896741	1719117	987500	1023079	4626437

Table 3
Table Showing Adjusted Sample Estimates And Population Counts for Geographic Regions

	Region 1	Region 2	Region 3	Region 4	All Regions
Raw Weight	697502	1179401	707221	771344	3355468
Flat Rate Weight (Γ_i)	974805	1648288	988388	1078003	4689484
Region Rate Weight (Λ_i)	934262	1711964	944690	1028508	4619423
Prefix Rate Weight (T_i)	907159	1757277	954986	1014268	4633691
1990 Census of Persons in Telephone Households	896741	1719117	987500	1023079	4626437

Table 3. shows the estimates for the same regions adjusted for the percent of housing units in the region with 2 or more residential telephone numbers.

Discussion:

Table 4 provides a summary of the performance for the different estimates. For estimates based on the unadjusted weights , the region rate weights and the prefix rate weights out-perform the flat rate estimate. The unadjusted 'region rate weight' estimate out-performs the unadjusted 'prefix rate weight' estimate.

However when the adjustment for the housing units with multiple residential phone numbers is added to the 'region rate weight' estimate the sum of the squared differences between the estimates and the corresponding census counts drops by more than 50%. This is an indication of the high value of the correction for multiple phone-numbers in the sample housing units.

The result is even more dramatic for the estimates based on the prefix rate weights. When the weights are adjusted for multiple phone number housing units, the sum of the squared differences moves from 1.09E+10 to 2.7E+09, an even more dramatic improvement.

So dramatic, in fact, that the adjusted prefix rate weight estimate out-performs the adjusted region rate weight estimate with a sum of squared differences of 2.7E+09 versus 3.32E+09 for the adjusted region rate weight estimate.

While these results are based on a DSRDD sample and only one survey, it is reasonable to expect that they will apply to simple RDD sample as well, and that the use of prefix rate weights, and the incorporation of the number of residential phone numbers attached to the sample housing units into the housing unit weight will lead to improvements in the sample estimates.

Table 4
The Squared Difference Between The Regional Estimates And The Regional Census Counts Summed Over The Four Regions

Weighting scheme	Unadjusted	Adjusted
Raw Weight	4.07 E+11	4.73 E+11
Flat Rate Weight	1.62 E+10	1.41 E+10
Region Rate Weight	6.86 E+09	3.32 E+09
Prefix Rate Weight	1.09 E+10	2.7 E+09

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