COMPENSATION FOR UNIT NONRESPONSE IN RECURRING SURVEYS

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1. Nonresponse in Recurring Surveys

1.1 Introduction

Weighting appears to be the predominant technique employed to compensate for survey errors due to unit nonresponse in recurring sample surveys. However, within this class of compensation procedures there is considerable variation relative to (1) the determination of subpopulations within which weighting occurs, and (2) the selection or derivation of the attending weights. Other techniques prescribed for unit nonresponse include various forms of item imputation, employing estimators based on double sampling schemes, and modelbased inference.

The principal considerations associated with the selection of an appropriate unit nonresponse compensation procedure should include (1) conduciveness to error reduction (2) cost, cost, (3) computing convenience, and (4) general applicability. No additional explanation of criteria (1) and (3) will be offered at this point. However, criterion (4), general applicability, is intended to convey the need of adjustment techniques which are not only applicable to a variety of surveys and the production of their principal estimates, but also adaptable to potential changes in the general survey conditions, including changes in ancillary data upon which nonresponse adjustment may be contingent.

This paper will provide preliminary observations relating to a continuing assessment of the weighting procedure currently used to compensate for unit nonresponse errors in the Current Population Survey a recurring demographic survey which is conducted by the U.S. Bureau of the Census. The investigation entails an assessment of this procedure relative to the criteria cited earlier. This presentation will also explore the potential efficacy of some of the alternative nonresponse adjustment methods in enhancing the quality of estimates from recurring surveys.

1.2 The Current Population Survey

The Current Population Survey (CPS) is designed signed to provide monthly estimates of employment, unemployment, and other general labor force characteristics for the population aggregate as well as for various subpopulations.

It is a national sample comprised of about 60,000 households (eligible for interview) which are randomly divided into eight rotation groups. Within a period of about ten years each sample household is expected to be interviewed for four consecutive months, excluded from the sample for the next eight months, and interviewed again for four consecutive months.

As a result of refusals and "noncontacts", little or no survey data are obtained from about four to five percent of the CPS households each month. Table 1 provides the CPS sample sizes and distributions of the unit nonresponse (noninterview) rates for 1982. A nonresponse weighting technique is employed for the survey; it can be briefly described as follows:

(1) Noninterview adjustment clusters are formed within each of the fifty states and the District of Columbia by grouping sample PSU's which are similar with regard to certain characteristics thought to be at least "moderately correlated" with the principal survey variables.

(2) PSU's within noninterview clusters are classified as SMSA (belonging to or comprising a standard metropolitan statistical area) or non-SMSA.

(3) After the eight rotation groups are paired noninterview (nonresponse) weighting classes are defined by partitioning the housing units within the subpopulations defined by steps (1) and (2) into several race - residence categories (see Tables 2 and 3). The weighting classes are essentially fixed for about ten years.

(4) For weighting cell j, weighted tallies of respondent households (V_j) and nonrespondent household (Z_j) are made.

(5) The weight (nonresponse adjustment factor) usually applied to each of the responding households in a weighting class is computed in the following manner:

$$F_j = \frac{V_j + Z_j}{V_j} \qquad (1.2.1)$$

However, if this computation exceeds 2.00, or if there are less than 30 unweighted nonrespondent households for a given weighting class, some of the classes are required to be collapsed prior to a final determination of the nonresponse adjustment.

Table 1. Current Population Survey Sample Sizes and Noninterview Rates - 1982

		Average	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
Total Sample Size (Eligible for Interview)		60,111	59,989	59,756	62,043	59,768	59,991	60,044	60,241	59,992	60,002	59,942	59,818	59,714
Noninterviews	Total	2,337	2,394	2,434	2,834	2,416	2,321	2,392	2,441	2,371	2,222	2,129	1,970	2,119
	Rate	3.9	4.0	4.1	4.6	4.0	3.9	4.0	4.1	4.0	3.7	3.6	3.3	3.5
	No One at Home	0.6	0.7	0.6	0.7	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6
	Temporarily Absent	0.7	0.5	0.6	0.8	0.6	0.6	0.8	1.1	1.0	0.7	0.6	0.5	0.6
	Refusal	2.5	2.6	2.7	2.9	2.8	2.6	2.5	2.3	2.3	2.2	2.2	2.1	2.3
	Other	0.1	0.2	0.2	0.2	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1

Table 2. CPS Noninterview Adjustment Cells for SMSA's

Residence / Race	Central City of SMSA	Balance of SMSA	
		Urban	Rural
White			
Not White			

Table 3. CPS Noninterview Adjustment Cells for Non-SMSA's

Residence / Race	Urban	Rural	
		Nonfarm	Farm
White			
Not White			

2. Preliminary Assessment of Compensation Procedures

2.1 <u>Basic Assumptions and Model for Sample Weighting Adjustment</u>

Let's assume that for a given recurring survey we have a sample of size n from a population os size N. Associated with each of the N units in the population there is a selection probability Π_i, i=1, 2,...N. Furthermore we will assume that among the n sample units m are nonrespondents and n_R = n-m are respondents. Thus, the CPS estimator for the population total after adjusting for unit nonresponse takes the following form.

$$\hat{Y}_{CPS} = \sum_{j=1}^{M} \frac{1}{z_j} \sum_{\ell=1}^{n_{Rj}} \frac{y_{Rj\ell}}{\pi_{j\ell}} \qquad (2.1.1)$$

where

$y_{Rj\ell}$ = value of the ℓth sample respondent in the jth weighting class.

n_{Rj} = number of sample respondents in the jth weighting class.

n_j = number of sample cases from the jth weighting class.

$z_{j\ell}$ = z_j = the estimated response rate for the jth weighting class.

$\pi_{j\ell}$ = selection probability for the ℓth sample respondent in the jth nonresponse weighting class.

M = total number of nonresponse weighting classes to which the housing units of the paired rotation group are assigned.

The random variable z^{-1}_j is the inverse of the estimated mean response rate for those population units which are or would have been assigned to the jth weighting class had they been included in the sample.

Implicit in the formation of the CPS nonresponse weighting classes are the following assumptions:

1. There is "significant" correlation between the principal survey variables and the variables used to define noninterveiw clusters.

2. Within each weighting class $E\ y_{Rj} = E\ y_{\bar{R}j}$, where $y_{\bar{R}j}$ is the mean for the sample nonrespondents in the jth weighting class.

3. The weighting class means differ, that is, $E\ y_{Rj} \neq E\ y_{Rj'}$, $j \neq j'$.

2.2 Preliminary Assessment of CPS

Kalton (1981) refers to the adjustments resulting from the unit nonresponse weighting procedure used for the CPS as sample weighting adjustments. They have the effect of distributing the sample respondents among the weighting classes in the same manner that the total sample has been distributed.

Unfortunately, the selection of weighting classes for this procedure is constrained by the requirement that measurements for the weighting class variables must be available for both the respondents and the nonrespondents. This essentially restricts the characteristics by which they are defined to those associated with geography, color, urbanicity, housing unit characteristics, and design levels. Although an examination of the extent to which the CPS nonresponse weighting classes satisfy the three assumptions given in section 2.1 have been deferred, the possibility of making the adjustment for each primary sampling unit within a noninterview cluster and specified color group has been partially explored.

The issue of the appropriateness of the size of the nonresponse weighting classes in limiting excessive variance increases is one which warrants some attention. In the CPS the consequence of restricting the subdivision of the noninterview clusters to that based on the two color groups could be a significant reduction in the nonresponse-related variance of a survey estimate. Of course, this must be weighed against the potential increases in nonresponse bias. In practice, significant increases in the bias are usually associated with considerable reductions in differences (relative to Ey_j) between the weighting classes, and in the homogeneity within classes.

Very little is included in the literature on the determination of sample sizes for nonresponse weighting classes. However the following discussion can facilitate the evaluation of the adequacy of the sample sizes for the CPS nonresponse weighting classes and those associated with similar adjustment procedures. Assuming independence between weighting classes, we have

$$\mathrm{Var}\,(\hat{Y}_{CPS}) = \sum_{j=1}^{M} \mathrm{Var}\left[\frac{1}{z_j}\sum_{\ell=1}^{n_{Rj}} \frac{y_{Rj\ell}}{\pi_{j\ell}}\right]$$

$$= \sum_{j=1}^{M} \mathrm{Var}\left(\frac{1}{z_j}\, y_{\hat{R}}\right)$$

where

$$y_{\hat{R}} = \sum_{\ell=1}^{n_{Rj}} \frac{y_{Rj\ell}}{\pi_{j\ell}}$$

now

$$\mathrm{Var}\,(z^{-1}{}_j y_{\hat{R}}) = E\,[\mathrm{Var}\ (z^{-1}{}_j y_{\hat{R}}\ | y_{\hat{R}}, n_j)]$$

$$+ \mathrm{Var}\,[E\ (z^{-1} y_{\hat{R}} | y_{\hat{R}}, n_j)]$$

$$= E[(y_{\hat{R}})^2\ \mathrm{Var}\ (\frac{n_j}{n_{Rj}}\, | y_{\hat{R}}, n_j)]$$

$$+ \mathrm{Var}\ [y_{\hat{R}}\ E\ \frac{n_j}{n_{Rj}}\ | y_{\hat{R}}, n_j)]$$

$$\doteq \frac{1-Z_j}{n_j Z^3{}_j}\ E\ (y_{\hat{R}})^2$$

$$+ \left[\frac{1}{Z_j} + \frac{1-Z_j}{n_j Z^2{}_j}\right]^2 \mathrm{Var}\ (y_{\hat{R}}) \qquad (2.1.4)$$

(for fixed n_j)

$$= \left\{\left[\frac{1}{Z_j} + \frac{1-Z_j}{n_j Z^2{}_j}\right]^2 + \frac{1-Z_j}{n_j Z^3{}_j}\right\} \mathrm{Var}\ (y_{\hat{R}})$$

$$+ \frac{1-Z_j}{n_j Z^3{}_j}\ (E\ y_{\hat{R}})^2,$$

using the approximations

$$E\left(\frac{1}{z_j}\right) \doteq \frac{1}{Z_j} + \frac{1-Z_j}{n_j Z^2{}_j}$$

and

$$\mathrm{Var}\left(\frac{1}{z_j}\right) \doteq \frac{1-Z_j}{n_j Z^3{}_j} \qquad \text{(See Cochran p. 70)}$$

If we denote (2.1.4) by T_j

$$\text{Var}\ (Y_{CPS}) \doteq \sum_{1}^{M} T_j \tag{2.1.5}$$

For recurring surveys, estimates of the mean and variance of y_R' and of Z_j are either available or can be obtained. Thus (2.1.4) and (2.1.5) could be used to determine sample sizes for weighting classes consistent with desired levels of precision.

From the above results, we have, for fixed n_j,

$$E\ (z^{-1}_j\ \acute{y}_R) = E\ [E\ \acute{z}^{-1}_j\ \acute{y}_R \mid \acute{y}_R)]$$
$$\doteq \frac{1}{Z_j} + \frac{1-Z_j}{n_j Z^2_j}\ E\ (\acute{y}_R)$$

This impiles that

$$\text{Bias}\ (\hat{Y}_{CPS}) = B\ (\hat{Y}_{CPS})$$
$$\doteq \sum_{j=1}^{M} \left\{ \left[\frac{1}{Z_j} + \frac{1}{n_j Z^2_j} \right] E(\acute{y}_R) - Y_j \right\}$$

where, under a general set of assumptions, Y_j may be represented as follows:

$$Y_j = Z_j\ E(y_R) + (1-Z_j)\ E(\tilde{y}_R), \tag{2.1.6}$$

where y'_R is the relevant estimate associated with the sample nonrespondents.

Therefore

$$B(Y_{CPS}) \doteq \sum_{j=1}^{M} \left\{ \left[\frac{1}{Z_j} + \frac{1-Z_j}{n_j Z^2_j} - Z_j \right] E(\acute{y}_R) - (1-Z_j)\ E\ (\tilde{y}_R) \right\}. \tag{2. 1.7}$$

Previous survey data, including that from a CPS nonresponse follow-up study (see Jones and Palmer, 1967) and the 1980 Census Telephone Follow-up Experiment suggest that for some of the key CPS variables (including unemployment) $E(y_{Rj\ell})$ is larger than $E\ (\tilde{y}_{Rj\ell})$. Under this assumption $B(\hat{Y}_{CPS}) > o$, and increases in the size of n_j would lead to a reduction in this bias. Thus, for these variables, larger weighting classes such as those based on the subdivision suggested earlier could lead to reductions in both the variance and bias of the corresponding estimates.

As was noted, the CPS noninterview clusters are fixed for a period of about ten years, and the sample mean for the respondents in the jth weighting class is assumed to be equal to the sample mean for the nonrespondents in the class. Thus, the sensitivity of the weighting classes relative to this assumption, as a result of change occasioned by time, should determine the appropriateness of a fixed set of weighting classes for a recurring survey. An informal review of the 1975 status of PSU's, in what was then the CPS noninterview clusters, indicated what appeared to be a number of substantial changes in their composition with regard to the extent to which they were homogeneous. This certainly suggests the need to periodically restructure the noninterview clusters or to develop an adjustment procedure with built-in adaptations to changes which violate the assumptions on which the clusters were formed.

As a result of the availability of relatively efficient computing facilities, the sample weighting adjustment procedure employed by the CPS presents no major problems with regard to cost and computing convenience.

However, extensive use of telephone interviewing and response error modeling (which will be discussed later) could reduce the data collection costs.

3. Applicable Alternatives to Sample Weighting

There are a number of alternatives to the sample weighting procedures discussed in the previous sections, which should be considered for the CPS and similar recurring surveys. Two of those alternatives will be reviewed, both of which are also weighting procedures with different approaches to the derivation of adjustment factors.

3.1 Weighting - Double Sampling Among Respondents

The weighting of a subsample of respondents within a weighting class is another plausible alternative to weighting by the inverse of the response rate for the class. This procedure has the effect of requiring a nonresponse weight of 2.0 to a random subgroup of responding units equal to the number of nonrespondents in the weighting class.

Platek and Gray (1978) remind us that the advantage of this procedure is the ability to ensure integral weights relative to nonresponse adjustment, which precludes various rounding errors in subclassified data. However, the increased variance (over that incurred by the sample balancing weighting technique) could be a matter of serious concern, depending on the size of the nonresponse rate.

The effects of a weighting-double sampling procedure on the the CPS, and other similar large scale surveys are not apparent. However, a research plan in this area is being developed, the implementation of which should provide greater insight into applicability and long-term effects of the adjustment technique.

3.2 Weighting With Response Probabilities

A variety of weighting techniques, which make use of the concept of response probabilities for specific subgroups of survey populations, has been advanced. Most of these techniques are based on a procedure introduced by Politz and Simmons (1949) which require that sample respondents be grouped according to estimates of their probabilities of responding to the survey. The weights with which the sample units in the resultant weighting groups are inflated are the inverses of the estimated response probabilities. The Politz - Simmons procedure obviously had some serious limitations, such as its inapplicability to refusals; however, there have been a number of recent useful extensions and applications of the procedure, included among which are those presented by Thomsen and Siring (1979), Drew and Fuller (1980) and Anderson (1978). Recurring surveys for which extensive callbacks are made are quite conducive to the modeling of response probabilities for various classes of the population.

Research is in progress regarding the development of regression models which may have utility in estimating CPS response probabilities for units with similar values of the "independent variables" of the models. The research will extend beyond the sometimes convenient linear additive models, which are often too constraining and not very robust.

The remainder of this section will be devoted to establishing a basis upon which an estimator which is is not only intended to compensate for nonresponse, but to also deal with the biasing effects of overcoverage, could evolve.

In a paper by Green (1979), a beta-negative binomial model is proposed which provides an estimate of the total number of eligibile units contained in a designated sample. This model assumes that the unit response probabilities remain constant over all calls or interview attempts. Also implicit in this model is the assumption that refusals would be followed-up, perhaps by more experienced interviewers or with a different data collection procedure.

We will relax the first assumption and offer the following modification of Green's model:

Let

n' = the number of eligible units selected among the n sample cases, and

n_k = the number of sample units for which responses are obtained on the k-th contact

We will also let

$P(K=k)$ = the probability that a given sample unit, with varying response probabilities over different calls, will respond on the k=th call where

$$P(K=k) = \delta \qquad \text{if } k=1$$

$$(1-\delta)(1-a\delta)^{k-2}a\delta \qquad \text{if } \geqslant 2,$$

where $a < 1$, and both a and δ can be estimated from sample data. P_k will represent the proportion of all sample units whose response came on the k-th call, We have that

$$P_k = \int P(K=k)f(\delta)d\delta$$

f is assumed to have been generaged from a beta probability density function, with unknown parameters r and s.

Therefore $$P_1 = \int_0^1 \delta^r \frac{(1-\delta)^{\delta-1}}{\beta\ (r,s)} d\delta = \frac{r}{r+s} = \frac{n_1}{n'}$$

$$P_2 = \int_0^1 a\delta^r \frac{(1-\delta)^s d\delta}{\beta\ (r,s)} \qquad 3.3.1$$

$$= a\frac{\beta(r+1,s+1)}{\beta(r,s)} = aP_1\frac{s}{(r+s+1)}$$

$$= \frac{n_2}{n'} \qquad 3.3.2$$

$$P_3 = \int_0^1 a\delta^r \frac{(1-\delta)^s}{\beta\ (r,s)}(1-a\delta)d\delta$$

$$= aP_1\frac{s}{(r+s+1)} \qquad 3.3.3$$

$$- a^2 \frac{(r+1)rs}{(r+s+2)(r+s+1)(r+s)} = \frac{n_3}{n'}$$

$$P_4 = \int_0^1 \delta^r \frac{(1-\delta)^s}{\beta(r,s)} (1-2a\delta+a^2\delta^2)ad\delta \qquad 3.3.4$$

$$= P_3 - a \frac{(r+1)rs}{(r+s+2)(r+s+1)(r+s)} + \frac{a^3(r+2)(r+1)rs}{(R+s+2)(r+s+2)(r+s+1)(r+s)}$$

$$= \frac{n_4}{n'}$$

From the above set of equations an estimate of n' is possible, which in turn replaces n in the formulation of nonresponse adjustment factors. For example, for the subclass weighting technique, using M weighting classes, we would have the following estimation of the population total.

$$\hat{Y} = \sum \frac{1}{\pi_{jk}} \left(\frac{n_j'}{n_{Rj}'}\right) y_{jk} \qquad 3.3.5$$

where n', n_j, and n_j are all random variables.

Definitive statements regarding the relative impact of the probability model suggested here, as well as the atttending nonresponse adjustment are not available. However, the author is rather optimistic about the potential advantages of the procedure particularly those relating to its bias-reduction capacity.

4. Remarks

An all-purpose nonresponse data adjustment technique is highly inconceivable to this author. As pointed out by Lindstrom et. al., the choice of an adjustment procedure is limited by external factors which can vary considerably among surveys. However, the preliminary investigation of the Current Population Survey and the National Crime Survey suggest, that the following set of general rules are applicable to the selection of an appropriate nonresponse adjustment procedure for large recurring surveys.

(1) Avoid the common misconceptions. Even the quality of results from surveys with unusually low nonresponse rates can be diminished considerably by nonresponse, particularly estimates for subgroups with nonresponse rates which are much higher than the overall rate.

(2) Try to make an assessment of the relative importance or the degree of concern for the various costs and anticipated survey errors, and develop nonresponse models, strata, weighting classes, etc., which would lend themselves to an analysis of the behavior of those errors for which there is the most concern.

(3) Make extensive use of available ancillary data in conjunction with modeling procedures which identify the contribution of nonresponse to the measurement error components.

(4) Don't feel compelled or restricted to the use of a single procedure. Although it may necessitate additional complication, the collective effects of a combined procedure could possibly enhance the quality of the desired estimates.

Additional empirical and theoretical studies are still needed in order to provide more objective guidelines by which the effects of survey nonresponse are measured for a variety of survey conditions and the corresponding adjustments procedures are developed. More specifically, problems such as the impact of nonresponse weights on complex variance estimators, the effects of errors in assigning weighting class weights (including overcoverage problems), and the effectiveness of model-based procedures in handling nonresponse should be pursued further.

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