THE SURVEY OF INCOME AND
PROGRAM PARTICIPATION

NONRESPONSE ADJUSTMENT METHODS FOR DEMOGRAPHIC SURVEYS AT THE U.S. BUREAU OF THE CENSUS

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I. INTRODUCTION

A sound sampling plan for a survey includes extensive effort to obtain useable data for each unit selected into the sample. Resources are allocated to develop a good sampling frame, design a good questionnaire, good interviewer's training and other data collection procedures such as how to gain cooperation of respondents. However, in spite of such efforts, all surveys encounter missing data which could occur either due to noncoverage or nonresponse. In this paper, we will discuss missing data due to nonresponse and methods to adjust for it. It occurs when some or all responses to the questions on a questionnaire are not obtained. This may be due to the respondents inability or unwillingness to answer.

Researchers have been striving to reduce nonresponse. For example, they have done this by better designing and testing questionnaires thoroughly for complete and accurate answers before fielding the survey, providing respondents aids to keep better records, giving respondents gifts (cash or kind) to gain their cooperation and finding ways to improve training given to the data collection staff. Researchers are also heavily involved in improving the methods to account for missing data. Two approaches commonly used are imputation and weighting adjustment.

In imputation, missing information is replaced with useable data from other sources. Regression imputation (Kalton and Kasprzyk, 1982) and cold-deck and hot-deck methods have been used by the U.S. Bureau of the Census. The demographic surveys primarily use the cold-deck and hot-deck procedures. The cold-deck procedure uses values from some prior distribution (same survey or other source), while the hot-deck uses current responses from the same source (survey) to substitute for missing values. Imputation is carried out by cross-classifying survey units into categories (cells) by a few variables in an attempt to group responses that are relatively homogeneous within the cells and heterogeneous between cells. Within a cell, values obtained for survey units are inserted as responses for missing items. To accomplish this, there must be at least one response available in each category to be a donor for imputation.

Imputation is commonly used for partial response, that is, when a questionnaire is partially answered. It has also been used to compensate for complete nonresponse. One such example is the 1960 U.S. Census (Pritzker et al., 1965) adjustment for missing data. In this adjustment, a nonresponding household was imputed by a responding household (donor) in the same cross-category. This approach of imputing a complete questionnaire amounts to doubling the weight of those respondents whose records are duplicated. Such a procedure can increase the variance as compared to weighting adjustment. Hansen, Hurwitz and Madow (1953) show that the maximum increase in variance is about 12 percent for the method of duplicating records. If a donor is used more than once, the variance increase could be even larger.

Weight adjustment within cells (Oh and Scheuren, 1983) to compensate for complete nonresponse (unit nonresponse) is the predominant technique used in the demographic surveys of the Bureau of the Census. The general approach is basically the same for all its major surveys. It is simple and less expensive to implement, as compared to imputation, and seems to work well (Jones, 1984) for some labor force characteristics in the Current Population Survey (CPS) such as number of persons in the labor force, employed and unemployed. These estimates were not seriously affected by noninterview bias. The only labor force categories with substantial bias were those which included vacationers and persons on layoff.

In this paper we will primarily discuss nonresponse weighting adjustment for demographic surveys used at the Bureau of the Census. Sections II and III discuss various types of nonresponse and adjustment approaches to deal with these different types of nonresponse, respectively. The effect of nonresponse on survey estimates is discussed in Section IV, and the criteria to define noninterview cells are presented in Section V. As an example, the noninterview adjustment methods used for the Survey of Income and Program Participation (SIPP) are presented in Section VI. Section VII presents a discussion on noninterview adjustment research.

II. TYPES OF NONRESPONSE

Nonresponse can be divided into the following categories:

TYPE A NONINTERVIEW: A Type A noninterview occurs when every member of the household is a noninterview. Also called a household nonresponse, it occurs when no one is home, household members are temporarily absent (for example, they could be away on vacation), household members refuse to participate in the survey, or the household cannot be located.

Type B Noninterview: This type of noninterview occurs when a housing unit is vacant, occupied by persons with their usual residence elsewhere, unfit or set to be demolished, under construction and not ready for occupancy, or converted to temporary business or storage. It also occurs when a site for a mobile home, trailer or tent is unoccupied or when a permit has been granted, but construction is not started.

Type C Noninterview: It occurs when a housing unit is demolished, or house or trailer is moved, converted to permanent business or storage, or merged or condemned.

Type Z Noninterview: Type Z noninterview occurs when a member of an interviewed household is not interviewed and a proxy interview is not obtained. It is also called person nonresponse.

Item Nonresponse: Item Nonresponse occurs when a response to one or more questions is not provided, though most of the questionnaire is completed.

III. ADJUSTMENT FOR VARIOUS TYPES OF NONRESPONSE

Of these five types of noninterview, no adjustment needs to be made for type B and type C noninterviews. This is because type C noninterviews are no longer housing units at the original address. For type B noninterviews, only households with usual residence elsewhere occupy housing units covered by these types of noninterview. Such households have a chance of being in a sample at their usual residence.

Imputation techniques are used to deal with item nonresponse and type Z nonresponse in most of the demographic surveys at the Bureau of the Census. Weighting adjustment is used for type A nonresponse and in certain cases for type Zs. The procedures used for type As and type Zs are similar and based on the same general principals.

IV. EFFECT OF NONRESPONSE ON SURVEY ESTIMATES

It is a common belief that respondents have different characteristics from nonrespondents. This theory is supported by recent studies completed by Petroni (1987), and Short and McArthur

(1986). Thus, nonresponse introduces bias in survey estimates We believe that the bias is small when the nonresponse rate is about 5% or less, but it increases as the nonresponse rate in survey increases. Increase in bias with increase in nonresponse can be shown mathematically as follows:

Let P_i $(i = 1,2,...K)$ be the proportion and R_i be the response rate of population members falling in i^{th} group or cell. Thus the overall response rate, R, is given by:

$$R = \sum_{i=1}^{K} P_i R_i \quad ; \quad 0 < R < 1 \text{ and } 0 < R_i < 1 \quad \forall i$$

where $\sum_{i=1}^{K} P_i = 1$

Furthermore, assume that

$\bar{Y}_i$ = Mean of a characteristic of interest of the population units falling in cell i.

$\bar{Y}_{i(\dot{\nu})}$ = Mean of a characteristic of interest of the population in the i^{th} class which would not respond if selected in a sample.

$\bar{Y}_{i(\nu)}$ = Mean of a characteristic of interest of the population in the i^{th} class which would respond if selected in a sample.

$$\bar{y} = \sum_{i=1}^{K} p_i \bar{y}_i$$

$\bar{y}_{i(\dot{\nu})}$ = Sample estimate of $\bar{Y}_{i(\dot{\nu})}$.

$\bar{y}_{i(\nu)}$ = Sample estimate of $\bar{Y}_{i(\nu)}$.

$$\bar{Y}_i = R_i \bar{Y}_{i(\nu)} + (1-R_i) \bar{Y}_{i(\dot{\nu})}$$

$$\bar{y}_i = \sum_{j=1}^{n_i} y_{ij} / n_i$$

$\Pi_{ij} = \Pi$ = Selection probability of j^{th} unit in i^{th} cell.

y_{ij} = Value of the characteristic of interest for the j^{th} unit in the i^{th} cell.

n_i = Number of sample units in i^{th} cell.

$n_{i\nu}$ = Number of sample units responding in i^{th} cell.

p_i = Proportion of sample units falling in the i^{th} group or cell.

Then $$\bar{y}_{(\nu)} = \frac{\sum_{i=1}^{K} \sum_{j=1}^{n_{i\nu}} \left[\pi_{ij}\right]^{-1} \left[\frac{n_i}{n_{i\nu}}\right] y_{ij}}{\sum_{i=1}^{K} \sum_{j=1}^{n_{i\nu}} \left[\pi_{ij}\right]^{-1} \left[\frac{n_i}{n_{i\nu}}\right]} \tag{2.1}$$

$$= \left[\sum_{i=1}^{K} \frac{n_i}{n_{i\nu}} \sum_{j=1}^{n_{i\nu}} y_{ij} \right] \Big/ \sum_{i=1}^{K} n_{i\nu} \left[n_i / n_{i\nu}\right]$$

$$= \sum_{i=1}^{K} \frac{n_i \bar{y}_{i(\nu)}}{\sum_i n_i}$$

$$= \sum_{i=1}^{K} p_i \bar{y}_{i(\nu)}$$

The expected value of $\bar{y}_{(\nu)}$ is

$$E\left[\bar{y}_{(\upsilon)}\right] = E\left[E\left(\bar{y}_{(\upsilon)} \mid n_1, n_{1\upsilon}, n_2, n_{2\upsilon} \ldots n_K, n_{K\upsilon}\right)\right]$$

$$= E \sum_{i=1}^{K} p_i \bar{y}_{i(\upsilon)}$$

$$= \sum_{i=1}^{K} P_i \bar{Y}_{i(\upsilon)} \qquad (2.2)$$

Therefore, the bias of the adjusted estimate is:

$$\text{Bias}\left[\bar{y}_{(\upsilon)}\right] = E\left[\bar{y}_{(\upsilon)}\right] - \bar{Y}$$

$$= \sum_{i=1}^{K} P_i \left[1-R_i\right] \left[\bar{Y}_{i(\upsilon)} - \bar{Y}_{i(\dot{\upsilon})}\right] \qquad (2.3)$$

Equation (2.3) suggests that the amount of bias depends on the response rate and the difference in the mean values of the characteristics for respondents and nonrespondents. With a small response rate, bias increases even if the difference in the means of respondents and nonrespondents is small.

Before discussing the critera for noninterview (NI) adjustment, let us consider the following situations:

1. $\bar{Y}_{i(\upsilon)} = \bar{Y}_{j(\upsilon)} = \bar{Y}_{(\dot{\upsilon})}$ and
   $\bar{Y}_{i(\dot{\upsilon})} = \bar{Y}_{j(\dot{\upsilon})} = \bar{Y}_{(\dot{\upsilon})}$ for $\forall$ i and j, or

2. $R_i = R_j = R$, $\forall$ i and j, or

3. $\left[\bar{Y}_{i(\upsilon)} - \bar{Y}_{i(\dot{\upsilon})}\right] = \left[\bar{Y}_{(\upsilon)} - \bar{Y}_{(\dot{\upsilon})}\right]$, $\forall$ i .

Under each of the three situations the bias is the same and is given by

$$\text{Bias}\left[\bar{y}_{(\upsilon)}\right] = (1-R)\left[\bar{Y}_{(\upsilon)} - \bar{Y}_{(\dot{\upsilon})}\right] \qquad (2.4)$$

and is equivalent to using a single NI adjustment cell.

It is obvious from equation (2.3) that the bias in an estimate will be reduced by using two or more cells if

$$\left| \bar{Y}_{i(\nu)} - \bar{Y}_{i(\nu)}' \right| \quad < \quad \left| \bar{Y}_{(\nu)} - \bar{Y}_{(\nu)}' \right| \qquad (2.5)$$

$$\text{and} \quad R_i \neq R_j \; , \quad \forall \; i, j. \qquad (2.6)$$

Therefore, the success of the NI adjustment procedure requires the identification of the survey variables which will define adjustment cells such that these cells vary both with respect to survey estimates and response rates. See Chapman (1976) for further details.

Note that there are other situations where bias could be reduced by use of more than one NI cell even if the above two conditions are not satisfied. For example, consider two cells. It is possible that one cell meets criteria (2.5) and the other does not, yet the population distribution into the cells and the response rates of the cells are such that the bias is less using two NI cells instead of one.

V. CRITERIA TO DEFINE NONINTERVIEW ADJUSTMENT CELLS

The objective of noninterview adjustment is to reduce the bias in survey estimates. A survey produces a large number of estimates, and adjustments which reduce bias for one set of estimates may not work well for another set of estimates. Therefore, it is essential to have a clear understanding of the relative importance of various estimates when implementing the criteria below to form NI cells. In addition to bias, it is occasionally necessary to consider reduction of mean square error. This is the case when the adjustment factor is large and, hence, increases the variance significantly.

A. Lower Bias

The following four criteria are used in selecting the cross-classification variables to reduce the bias in survey estimates.

1. The variables are significantly correlated with the survey estimates. The implicit assumption in selecting these variables is that if for respondents these variables show a significantly high correlation with survey estimates to be produced, then they will also show high correlation

among nonrespondents. Since these variables must be available for both respondents and nonrespondents, the choice of the variables is constrained. These variables are determined prior to data collection to ensure the necessary data is obtained and to avoid possible bias due to the particular sample selected.

2. Within each weighting class $E\left[\bar{y}_{i(\nu)}\right] = E\left[\bar{y}_{i(\dot{\nu})}\right]$ $\forall\ i$.

3. The means of any two noninterview adjustment cells differ,

   i.e., $E\left[\bar{y}_{i(\nu)}\right] \neq E\left[\bar{y}_{j(\nu)}\right]$ for $i \neq j$, $\forall\ i$ and j.

4. The response rate for any two cells differ, that is $R_i \neq R_j$, $i \neq j$, $\forall i$ and j.

B. Lower Variance

The variance contribution from a NI cell depends on the number of responding and nonresponding units in that cell. For small cells the nonresponse weight adjustment can be large. Therefore, the size of the cell is an important consideration in defining a cell. One needs to consider the trade-off between variance and bias in deciding the size of the cell as bias should be reduced with a homogeneous (usually a smaller) cell.

Cahoon and Bushery (1984) under a number of assumptions to simplify the mathematics involved showed that the va ance of an estimator for cells with 25 sample units each is out 0.5% higher assuming 5% nonresponse rate than a collapsec ll of 100 units. With 10% nonresponse rate it is about 1. igher. In deriving these results they assumed independence b een sample units within a cell and between cells, cells a f fixed equal size, and cells have the same expected re se rate, expected value and variability of the characteri s of interest.

To reduce variance, NI cells are collapsed if the number respondents in them is small or the noninterview adjustme factor

$$\left[\sum_{j=1}^{n_i} (\pi_{ij})^{-1} \Big/ \sum_{j=1}^{n_{i\nu}} (\pi_{ij})^{-1} \right]$$ is too large. These limits are

somewhat subjective. For most of the demographic surveys at the Bureau, these limits are: a) minimum interviewed cases in a cell are 20-35, and b) maximum NI adjustment factor is 2. If one of these criteria is not satisfied by the cell it needs to be collapsed with another cell. The following collapsing criteria attempt to minimize the increase in mean square error of the survey estimates of interest. A cell i should be collapsed with a cell j if:

1. $\left| E\left[\bar{y}_{i(\nu)}\right] - E\left[\bar{y}_{j(\nu)}\right] \right| \leq \left| E\left[\bar{y}_{i(\nu)}\right] - E\left[\bar{y}_{l(\nu)}\right] \right|$

   $\forall\ l,\ l \neq j.$

2. $\left| R_i - R_j \right| \leq \left| R_i - R_l \right|$

   $\forall\ l,\ j \neq l.$

Usually, these two conditions are not satisfied by the same pair of cells. In those circumstances, either more emphasis should be placed on condition 1, or a pair should be found which reduces the mean square error even if neither of the two conditions is satisfied. Furthermore, if there is strong evidence that for a cell with a very high noninterview adjustment factor $E\left[\bar{y}_{i(\nu)}\right]$ is very different from any other cell, then the cell should be kept seperate to minimize the bias due to nonresponse (Shapiro, 1980). (Since the amounts of bias and mean square error are unknown, experience is used to make judgements regarding expected reductions in mean square error and bias.)

VI. THE SURVEY OF INCOME AND PROGRAM PARTICIPATION

The Survey of Income and Program Participation (SIPP) is a new, ongoing national household survey administered by the Bureau of the Census. It is designed to provide improved data on income and participation in government administered programs such as food stamps, Aid to Families with Dependent Children (AFDC), Supplemental Security Income (SSI), etc. Data on demographic characteristics, labor force, education, etc. are also collected.

The SIPP is a multistage, stratified, systematic sample of the noninstitutionalized resident population of the United States.

This population includes persons living in group quarters such as dormitories, rooming houses, and religious group dwellings. Noncitizens of the United States who work or attend schoo in this country and their families are also eligible. Crew membe of merchant vessels, Armed Forces personnel living in milita barracks, and institutionalized persons such as correctio facility inmates and nursing home residents are ineligible.Initially, a sample of living quarters in sele ed Primary Sampling Units (PSUs) is taken. (Living quarters re those in which the occupants do not live and eat with ar person in the structure and that have either direct access fro he outside of the building or through a common hall, or c lete kitchen facilities for that unit only.) Persons resid in these living quarters at the time of the first interview are considered to be in sample. However, only persons who are at least 15 years of age at this interview are eligible for interview. mited data on children are also collected by proxy interviews.

The SIPP sample is divided into four groups of equal size called rotation groups. One rotation group is interviewed each month. In general, one cycle of four rotation groups is called a wave. This design provides a steady work load for data collection and processing. Persons 15 years old and over in the sample are interviewed once every four months for approximately 2.5 years. With certain restrictions, these sample persons are followed if they move to a new address. Persons who began living with sample persons after the first interview are considered to be part of the sample only while residing with the sample persons. The reference period for the interview is the four months preceding the interview month. For example, for the first SIPP sample, the reference period for the November 1983 interview month was July through October 1983. These sample persons were interviewed again in March 1984 for the November 1983 through February 1984 period. More details on the SIPP design are given in Nelson, McMillen, and Kasprzyk (1985).

The SIPP questionnaire is long and complex. Questions are asked by specific type of cash and non-cash income on month received and amounts per month. For many types of income, add ional questions are asked of recipients. For example, in h eholds with children covered by Medicaid, up to 8 questions t health insurance are asked. Questions are also asked about ts and labor force status. Topical modules on various subjec are also included in most interviews.

For the subsequent waves, only original sample persons (t se interviewed in the first wave) and perso ng with th are eligible to be interviewed. With certain restrictions, ginal sample persons are to be followed if they moved to a new address. All noninterviewed households from Wave 1 are designated as noninterviews for all subsequent waves. Additional noninterviews result when original sample persons move without leaving a forwarding address or move to extremely remote parts of the country.

Due to the longitudinal nature (multiple interviews) of the survey, the noninterview rate accumlates over the life of the panel. Starting at about 5% - 7% at the time of the first interview, it reaches slightly over 20 percent for the last interview of the panel. The following briefly explains noninterview adjustment methods developed for the SIPP cross-sectional and longitudinal estimates.

A. Noninterview Adjustment for Cross-Sectional Estimates

Noninterview adjustment for cross-sectional estimates are made at the household level. At the time of the first interview very little information (such as race of the reference person, owner-occupied or renter-occupied housing unit, size of the household, and the Census region) is available about the noninterviewed households. Therefore, a limited number of variables correlated to the SIPP characteristics of interest can be used to form noninterview cells. For first wave data, noninterview cells were formed using the following variables. See King (1985) for a detailed explanation.

a. Census region (Northeast, Midwest, South, West)

b. Residence (metropolitian statistical areas (MSA), not MSA)

c. Race of reference person (black, non-black)

d. Tenure (owner, renter)

e. Household size (1, 2, 3, 4 or more)

The noninterview adjustments for subsequent waves are in addition to the wave 1 adjustment, i.e., the NI adjustment made as a part of wave 1 weighting becomes an integral part of subsequent waves weighting. In subsequent waves, additional information obtained on previous wave respondents is available for use in developing noninterview cells. Using 1980 Decennial Census data, it was found that education level, race and origin of householder, household type, and tenure are highly correlated with the important characteristics (income, poverty, etc) estimated by the SIPP. Also, Kalton et al.(1985) showed that the participation of a household in a given government program during the reference period covered by interview (K)is highly correlated with its participation in interview (K-1). For example, the correlations for food stamps and SSI were observed to be about .9 and .8 respectively. The relationship is also strong between interviews (K) and (K-2). For example, the correlation for food stamp participants between interviews (K) and (K-2) is .8. These correlations were obtained from the data collected in the Income Survey Development Program (ISDP), a precedent of the SIPP.

Based on the above knowledge and experience of the Bureau staff, the following household level variables were chosen to construct noninterview adjustment cells for second and subsequent waves. A detailed description of these cells is presented in King (1986).

a. Race and Spanish origin of reference person (non-Spanish white, other).

b. Household type (female householder with own children under 16 years of age but no husband present, householder is 65 years of age or older, others).

c. Education level of reference person (less than 8 years, 8-11 years, 12-15 years, and 16 or more years)

d. Type of income (welfare etc., others)

e. Assets (bonds etc., others)

f. Tenure (owner, renter)

g. Public housing or rent subsidized (resident of public housing or recipient of government rent subsidies, others)

h. Household size (1, 2, 3, 4 or more)

Cells which do not meet the following conditions are collapsed in a predetermined manner.

1. Number of interviewed households in a cell is greater than or equal to 30.

2. Noninterview adjustment factor is less than or equal to 2.

B. Noninterview Adjustment for Longitudinal Estimates

At present, longitudinal weighting procedures are developed only for the estimates of persons. Two levels of non-interview adjustment are used in these procedures. The first is at the household level and is similar to the wave 1 adjustments for the cross-sectional estimate. It accounts for persons who could not be interviewed at the first wave of the reference period covered by the interval for which the longitudinal weights are developed. The second adjustment is made at the person level to account for those persons who could not be interviewed for at least one of the later waves covering the reference period of interest. An alternative to the weighting adjustment is imputation of the complete record for NI persons. (This is similar to imputation of type Zs in cross-sectional weighting.) However, this approach may have a significant adverse affect (increase bias) on estimates of gross flows, one of the most important longitudinal estimates. See Kalton (1986) and Singh et al. (1988).

The following variables were selected for use in the second level longitudinal NI adjustment procedures in the same way as for the cross-sectional adjustments and are based on the first interview covering the time interval for which the longitudinal weighting is developed. Note that certain person level variables are defined based on the household level variables. For example, a household in which at least one HH member received income from food stamps, the household is defined as having income from food stamps and each member of the household is considered a food stamp recipient. See Huggins (1988) for more information.

a. Average monthly HH income (<$1,200, $1,200-$3,999, ≥ $4,000)

b. Employment status (Self-employed, others)

c. Type of income (welfare etc., unemployment compensation, others)

d. Assets (bonds, others)

e. Education level (< 12 years, 12-15 years, 16 or more years)

f. Race and origin (white and not Spanish, others)

g. Labor force status (in labor force, not in labor force)

The cells formed using the above variables are collapsed before making noninterview adjustments if the number of interviewed persons in a given cell are either less than 30 and/or the noninterview adjustment factor is greater than 2.0.

VII. NONINTERVIEW AJDUSTMENT RESEARCH

To our knowledge, no study has been conducted to evaluate the effectivness of noninterview adjustment methods for the demographic surveys. Therefore, the effectiveness of these procedures to reduce bias in estimates is unknown. A study (Singh, 1987) to evaluate the SIPP noninterview adjustment methods for cross-sectional estimates is underway. The results from this study should be available later this year. Even then no general statement can be made, since the SIPP provides a large number of estimates. Some indirect evaluation of these procedures could be done. For example, the SIPP estimates from wave 1 and from a later wave (say wave 4) for a given characteristic could be compared against corresponding estimates from an independent source, especially administrative records. However, the validity of such an evaluation will be questionable.

The Bureau of the Census has conducted noninterview adjustment related research for its demographic surveys. Some of the research was performed for the American Housing Survey (AHS-National). Parmer (1986) examined correlations between variables of interest, between variables of interest and evaluation variables and the nonresponse rates for the selected variables of interest. He also examined stability of the variables considered to define noninterview adjustment cells. Research is also being conducted on improving noninterview adjustment for the SIPP (Petroni, 1988). Similar research may also prove useful for other demographic surveys.

Some research to examine the feasibility and merits of computing nonresponse adjustment factors as well as constructing weighting cells is being conducted by Rosenbaum and Rubin (1983) and Little and Samuhel (1983). Research is also needed in developing models which may be used to estimate response probabilities for units. This could be done for several demographic surveys with similar values of independent variables.

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