ADJUSTING FOR PANEL NONRESPONSE IN THE SURVEY OF INCOME AND PROGRAM PARTICIPATION*

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1. Introduction

This paper presents the findings of an investigation of alternative forms of weighting adjustment to compensate for panel nonresponse in the Survey of Income and Program Participation (SIPP), an ongoing household panel survey conducted by the U.S. Bureau of the Census. Panel surveys like the SIPP experience some level of total nonresponse at the initial wave of data collection. In addition, they experience further nonresponse at each of the subsequent waves of the panel. It is this additional nonresponse that is classified as panel nonresponse in this report. Panel nonresponse is thus the failure to collect the survey data for initial wave respondents for one or more waves of the panel for which they were eligible. The weighting adjustments studied here aim to modify the weights of panel respondents (i.e., those who provide data for all waves for which they are eligible) to compensate for the panel nonrespondents.

Under the current SIPP design, a national probability sample of households is interviewed each year, and all the adults aged 15 and over living in those households at the initial wave become panel members who are followed for approximately $2\frac{2}{3}$ years. Interviews are conducted with these panel members at four-month intervals to collect data about their economic well-being. Interviews are also conducted with the adults with whom they are living at the time of interview, and data are collected about children. See Jabine *et al.* (1990) for further information on the SIPP design.

The SIPP panel sample comprises all the adults living in the original sample of households at the time of first interview. Panel respondents are members of the panel sample for whom data are collected for every wave for which they reside in the noninstitutional U.S. population. Panel respondents thus include panel members for whom data are collected for every wave until they leave the survey universe (through death, entering an institution, entering an armed forces barracks, or leaving the country). Panel nonrespondents are panel members who respond at the initial wave of data collection but fail to provide data for one or more of the subsequent waves for which they are eligible.

* This paper reports the general results of research undertaken for the Census Bureau. The views expressed are attributable to the authors and do not necessarily reflect those of the Census Bureau.

The investigation reported here was conducted with the 1987 SIPP panel. That panel started with a sample of about 12,300 households and followed panel members for seven waves of data collection. Including children, 30,841 individuals were living in the responding households at the initial wave. Of these individuals, 20.8 percent failed to provide data for one or more for waves for which they were eligible, i.e., they were panel nonrespondents.

With the level of panel nonresponse experienced in the SIPP and the likelihood that panel respondents and nonrespondents will differ in terms of the survey variables, the issue of nonresponse bias is a serious concern. Moreover, a revised SIPP design is planned to be introduced in 1996 with a four-year panel duration. The level of panel nonresponse with that design can be expected to be higher than with the current design, thus increasing the concerns about nonresponse bias.

For the SIPP panel file, two separate weighting adjustments are made to attempt to compensate for nonresponse. The first attempts to compensate for the nonresponding households at the initial wave, and the second attempts to compensate for panel nonrespondents in households responding at the initial wave (see Chapman *et al.*, 1986). Once these adjustments are made, a final poststratification adjustment is made to force the weighted sample distributions for certain demographic variables to conform to the distributions of postcensal estimates for these variables.

Since panel nonrespondents have all responded to the initial wave of the survey, a great deal is known about them. Therefore, a wide choice of variables is available for use as auxiliary variables in the panel nonresponse weighting adjustment. The auxiliary variables currently being used are monthly household income, program participation status of the person's household, labor force status, race, years of school completed, and type of assets of the person's household.

The wealth of information about panel nonrespondents raises two issues for nonresponse weighting adjustments. First, there is the choice of auxiliary variables from the many variables available from the first wave responses. Second, there is the choice of a suitable weighting adjustment methodology to incorporate the chosen auxiliary variables. Both of these issues are treated in this research.

The first stage of the research is to identify variables from the first wave responses that are related to whether or not a panel member provides data for all the survey waves for which he or she was eligible. After an initial screening of variables, logistic regression models were used for this purpose. This stage of the research is described in the next section.

The second stage in the development of panel nonresponse weighting adjustments was to incorporate the chosen auxiliary variables into a weighting adjustment procedure. Several alternative weighting adjustment procedures were used, and different sets of auxiliary variables were used with each procedure. These procedures and the properties of the resultant weights are described in Section 3.

Section 4 provides a comparative evaluation of the various weighting procedures developed and of the current procedure employed. The evaluation is performed by comparing a range of estimates produced with the alternative sets of weights with one another and with some benchmark estimates. The final section summarizes the results and draws conclusions about the effectiveness of the alternative weighting schemes investigated. Further details of the research are given in a report by Rizzo, Kalton, and Brick (1994).

2. Predictors of Response Propensity

The first step in developing panel nonresponse adjustments is deciding which of the large number of items available from the first wave should be used in the adjustment procedures. The selection of items to use in the adjustment process is the focus of this section.

The approach adopted is to choose items with responses that discriminate persons by their likelihood of responding in later waves. Fifty-eight Wave 1 items were available as potential explanatory variables for panel nonresponse. All of the variables used currently by Census for panel nonresponse adjustment were part of this set, with the exception of MSA (Metropolitan Statistical Area) status (which is not available on the public use tape).

The first step in the analysis was to construct an initial screening of the variables to eliminate variables with no appreciable relationship to panel nonresponse. As a general rule, we decided to retain an item for further analyses as a potential predictor of panel nonresponse only if the difference in response rates between any two response categories for the item was both statistically significant and four percentage points or more.

The 31 specific items retained from the screening process were: tenure, public housing, household type, census region, household education, household size, household income, householder financial instruments (bonds), gender, race, Hispanic, relationship to reference person (RRP), age, marital status, family type, education, student status, Medicare benefits, laid off, personal income, multiple jobs, working class, Medicaid, Women, Infants, and Children (WIC), Aid to Families with Dependent Children (AFDC), food stamps, general assistance, Social Security, other welfare, Veteran's status, and number of imputed items. Rizzo, Kalton, and Brick (1994) provide more detail.

The last item (number of imputed items) was a constructed variable. Other studies have found that individuals who are less cooperative at the initial wave of the panel survey are more likely to be nonrespondents at later waves (see, for example, Kalton, *et al.*, 1990). We constructed an index of the number of items imputed at Wave 1 as a measure of cooperation at Wave 1. As described below, this index turned out to be highly related to panel nonresponse.

2.1 Logistic Regression Analysis

Since the 31 items identified in the screening analysis were correlated with panel nonresponse, their use in a panel nonresponse weighting adjustment holds promise for reducing the nonresponse bias in some of the survey estimates. However, the screening analysis was limited because it did not consider the interrelationships between the items. To address this issue, the next step in selecting predictors of panel nonresponse was to investigate which combinations of the screened items could be used to form the best nonresponse adjustment categories.

A logistic regression approach was used to the examine the joint relationships of several items with response status. The final regression models were fitted using the Wave 1 cross-sectional weights that account for unequal selection probabilities and initial wave non-response. The weights were incorporated by using a weighted count of the number of persons in each cross-classification of the covariates, with the weights normalized to sum to the sample size.

After examining a number of possible models, one model was selected. This main effects model includes ten predictor variables:

- Age (5 categories)
- RRP (2 categories)
- Race of householder (3 categories)
- Tenure (3 categories)
- Census region (7 categories)
- Imputation flags (4 categories)
- Bond-holding status (2 categories)
- Layoff (2 categories)
- Food stamps (2 categories)
- Class of work (3 categories)

For the last four items, children were assigned the status of the householder. The coefficients of all variables were highly significant in the logistic regression model.

Models with interactions between the variables were also examined to determine if more extensive models would be useful in explaining panel nonresponse. None were important in adding explanatory power.

3. Alternative Panel Nonresponse Weight Adjustments

The methodology currently used in the SIPP to adjust the sampling weights for panel nonresponse is described in Chapman, Bailey, and Kasprzyk (1986). In this approach, nonresponse adjustment cells are formed based on the responses from a set of Wave 1 variables. The cells formed by the cross-classification of the variables are collapsed so that the resulting sample sizes in each collapsed cell are 30 or more. The reciprocal of the observed response rate in each collapsed cell is the panel nonresponse adjustment for panel respondents in that cell. The panel nonresponse adjustment is multiplied by the panel respondent's Wave 1 weight to create a nonresponse adjusted weight. The Wave 1 weight used is the weight before poststratification adjustment.

This section examines alternative methods of forming the panel nonresponse adjustments. These methods can be categorized into three groups:

- Logistic regression methods.
- CHAID methods.
- Generalized raking methods.

Each of the three alternative approaches to nonresponse adjustment is discussed below. The procedures for developing the weighting adjustments are detailed along with important statistical properties of the adjustments.

3.1 Panel Nonresponse Adjustments

We will discuss first the three weighting adjustments developed directly from the logistic regression model discussed in Section 2. Since this logistic regression model is a main effects model, the predicted nonresponse rate in any cell formed by cross-classifying the response categories of the variables is a function of the parameter estimates from the logistic regression model. The first alternative panel nonresponse weighting adjustment, called the *predicted logistic adjustment*, was computed by taking the inverse of the predicted response rate from the model based on each person's responses to the ten variables.

With a main effects model, the parameters for computing the predicted nonresponse rate are estimated from the marginal responses for the variables. Thus, the sample sizes in the cells of the cross-classification of all the variables are not a concern. However, this benefit is gained by ignoring possible interactions between the variables in the model. One approach to capture some of this information is to use the observed response rate in a cell, provided the sample size for the cell is large enough to ensure the stability of the observed response rate. If the cell is not large enough, the predicted response rate is used.

The second member of this class of alternative adjustments we examined uses this mixed strategy. If 25 or more sample persons were in a cell, then the nonresponse adjustment was the inverse of the observed cell response rate. If the cell had less than 25 sample cases, the nonresponse adjustment was the inverse of the predicted response rate. This adjustment is called the *mixed logistic adjustment.*

A third nonresponse adjustment in this class that we studied is similar to the current SIPP procedures. The logistic regression model was used to define initial cells. The cells were then combined until the sample size in each cell exceeded 30, and the inverse of the observed response rate within a cell was used as the nonresponse adjustment. The strategy for combining cells for the collapsed logistic adjustment was to group together cells with similar predicted nonresponse rates. This nonresponse adjustment is called the *collapsed logistic adjustment.*

3.1.2 Adjustments Based on CHAID Models

The second class of methods for adjusting for panel nonresponse used a categorical search algorithm called CHAID. The general approach is to find cells defined in terms of combination of responses to the explanatory variables that have the greatest discrimination with respect to nonresponse rates while maintaining a minimum sample size in each cell. The panel nonresponse adjustment is the inverse of the observed response rate in a cell.

The CHAID methodology creates a cell structure based on splitting the data set progressively in a tree structure. The iterative splitting along each newly created branch is done by choosing the 'best' variable which has not yet been used on that branch, using modified χ^2 tests. If a variable has more than two categories (e.g. Census region), the appropriate split along that variable is found using χ^2 criteria. Kass (1980) presents the theory underlying the CHAID technique.

The CHAID model included the most important seven predictors in the logistic regression model plus gender. This model resulted in 99 nonresponse adjustment cells. Each cell contained at least 25 sampled persons and the adjustment is the inverse of the observed response rate in each cell. This nonresponse adjustment is called the *CHAID* adjustment.

3.1.3 Adjustments Based on Generalized Raking

The third class of methods for adjusting for panel nonresponse is generalized raking. Raking is directly applied to the panel respondents so that the marginal sum of the adjusted weights for the respondents across dimensions defined by the predictor variables is equal to the marginal sum of the number of respondents and nonrespondents. The approach is called generalized raking because the marginal sums can be equalized in a variety of ways, one of which is the standard raking algorithm (Deming and Stephan, 1942).

We used the ten predictor variables from the logistic regression model of Section 2 to define marginal totals. The raking problem was 10 dimensional, with one dimension for each predictor variable. The marginal totals for each dimension were defined to be the sum of the Wave 1 weights for all persons (i.e., panel respondents and panel nonrespondents) in each response category of the predictor variable.

The adjustments were obtained using the CALMAR software described by Deville, *et al.* (1993). We used the multiplicative method option. We had also used two of the other options offered by the CALMAR software: the linear method, and the truncated multiplicative method. The adjustments for all three distance functions were nearly identical, so only the multiplicative method adjustments were used in later computations. This adjustment is called the *Raking* adjustment.

3.1.4 Distributions of Nonresponse Adjustments

The adjustments for each of the schemes described above were computed for the 1987 SIPP panel file. Table 3-1 gives a summary of the distribution of the resulting nonresponse adjustments. The summary is for the adjustments only, not the product of the adjustments and the Wave 1 weights. Table 3-1 shows the mean, median, extreme values, and ($1+CV^2$) for each adjustment, where CV is the coefficient of the variation for each adjustment; and, the second section shows the correlations among the adjustments. The statistic ($1+CV^2$) is included as an indicator of the increase in variance of the estimates introduced by having variable nonresponse adjustment factors (see Kish, 1992).

The standard deviations and $1+CV^2$ values are fairly consistent across the various adjustments. The raking adjustment has the lowest variability, but it is not very different from most of the other methods.

3.2 Poststratification of Adjusted Weights

Five alternative nonresponse adjusted weights were computed by multiplying each of the alternative nonresponse adjustments by the Wave 1 weights. These alternative weights are not yet comparable to the standard SIPP panel weight because the panel weight is poststratified to control totals derived primarily from the Current Population Survey (CPS). To make estimates based on the SIPP panel weight and the alternative weights more comparable, the alternative nonresponse adjusted weights were poststratified to the same control totals. The poststratification procedure we used was equivalent to the current SIPP procedure, with only minor differences.

The poststratified weights were used to compute the estimates from the SIPP panel file that are discussed in the next section. The six new poststratified weights were developed by poststratifying the product of the Wave 1 weight with the predicted logistic, mixed logistic, collapsed logistic, CHAID, and raking adjustments discussed in Section 3.1. The sixth poststratified weight is the standard SIPP panel weight, which is currently used for weighting.

To examine the distribution of the weights after poststratification, the correlations between the weights were computed and are given in Table 3-2. In addition the measure of variability used previously ($1+CV^2$) is given below in Table 3-2. The correlations shown here were weighted by the Wave 1 nonresponse adjusted weights. The correlations between the poststratified weights are all relatively high. The correlations between the SIPP Panel weight and the alternative weights are consistently lower than any others in the table. This result is probably due to the fact that the variables included in forming the nonresponse adjustments for this weight differ from those used for the alternative weights. The correlations between the alternative weights are all 0.85 or higher.

In the next section, we apply these alternative weights to the data from the 1987 SIPP panel file to develop estimates under the alternative schemes. These estimates are then compared with other data sources to estimate the potential of the alternative schemes for reducing the bias due to panel nonresponse.

4. Comparison of Survey Estimates Using Alternative Weighting Procedures

The previous section described the development of five alternative weighting schemes for use in conducting analyses of panel respondents in a SIPP panel. This section compares a set of estimates weighting schemes with one another and with the

Table 3-1. Distribution of nonresponse adjustments

	Mean	Minimum	Median	Maximum	$1+CV^2$
Predicted logistic	1.260	1.040	1.204	4.282	1.023
Mixed logistic	1.259	1.000	1.203	4.282	1.026
Collapsed logistic	1.261	1.000	1.202	3.431	1.023
CHAID	1.261	1.018	1.215	3.491	1.029
Raking	1.260	0.906	1.227	2.506	1.020

Table 3-2. Correlations between poststratified weights with variance inflation measures

	SIPP panel	Predicted logistic	Mixed logistic	Collapsed logistic	CHAID I	Raking
SIPP Panel	1.00	0.75	0.74	0.75	0.71	0.77
Predicted logistic		1.00	0.99	0.91	0.90	0.98
Mixed logistic			1.00	0.91	0.90	0.97
Collapsed logistic				1.00	0.89	0.93
CHAID					1.00	0.91
Raking						1.00
$1+CV^2$	1.08	1.09	1.09	1.08	1.09	1.08

corresponding estimates obtained using the current SIPP panel weighting scheme. In addition to internal comparisons between estimates obtained with the different weighting schemes with the 1987 SIPP longitudinal panel file, for some estimates comparisons are also made with benchmark estimates from external sources.

In making comparisons with estimates from these benchmark data, any differences observed may be explained by a variety of different factors. Panel nonresponse is only one possible explanation and may often be less likely than others. For example, response errors and differences in definitions may explain differences between SIPP estimates and estimates obtained from administrative data. Response errors in both the SIPP and the CPS may explain differences between estimates from the two surveys, together with other design differences between the surveys. Differences between estimates obtained from the 1987 and 1989 SIPP panels are perhaps the most likely to be caused by panel nonresponse. However, even in this case, there are possible alternative explanations such as panel conditioning (although the work of Pennell and Lepkowski, 1992, indicates that panel conditioning is not a major concern in the SIPP).

Table 4-1 presents a set of estimates from the 1987 SIPP panel file using the SIPP panel weight and using the five alternative weighting schemes and a benchmark estimate. Unless otherwise indicated, the figures in the table are percentages, given to two decimal places.

The estimates in Table 4-1 mostly relate to two different time periods: June 1987 and January 1989. Thus, the participation rate for a particular program is the percentage of individuals on that program in the specified month.

The most notable finding from Table 4-1 is the similarity of the estimates computed with all the weighting schemes. Rounded to one decimal place, the difference across all eight estimates is often less than 0.1 percent and only once exceeds 0.4 percent.

In addition to the alternative estimates from the 1987 SIPP panel, the last two columns of Table 4-1 contain benchmark estimates from the 1989 SIPP panel and from other sources. Since the 1987 SIPP panel estimates with the alternative sets of weights are so similar to one another, no evidence exists that any one of the sets of weights produces estimates that are closer to the benchmark estimates. The differences between the benchmark estimates and the various 1987 SIPP panel estimates are generally much greater than the differences within the 1987 SIPP panel estimates**. In making this observation, the 1987 SIPP panel estimates all employ the same sample, whereas the benchmark estimates are derived from different data sources.

5. Conclusions

The analyses conducted in this study have identified a number of Wave 1 variables that are related to panel nonresponse and that are not employed in the current SIPP panel nonresponse adjustments. These include age, relationship to the household reference person, census region, tenure, and the number of imputed items. Age and relationship to household reference person are, however, included in the poststratification adjustment.

These and other variables were included as auxiliary variables in developing panel weights for the 1987 SIPP panel using a number of alternative weighting schemes. The weights resulting from these alternative schemes were found to be highly correlated with one another, whereas their correlations with the current SIPP panel weights were somewhat lower. This finding suggests that the choice of auxiliary variables to use may be of greater significance than the choice of the weighting methodology. Nevertheless, after poststratification, the correlations of all the alternative sets of weights, including the current SIPP panel weights, were high.

The examination of estimates from the 1987 SIPP panel using the alternative weighting schemes showed that all the schemes, including the current scheme, produced similar estimates. There is no real evidence that the alternative schemes are more effective in compensating for panel nonresponse, at least for the range of estimates included in this study.

Although the results do not show significantly better methods for reducing panel nonresponse bias, we recommend consideration of the use of some of the variables identified here as related to panel nonresponse in the SIPP panel nonresponse adjustment. While the use of these variables may not noticeably improve the quality of many of the survey estimates, they may do so for some estimates that were not examined in this study. Even if the additional variables do not improve the predictions of panel nonresponse, they may still reduce the panel nonresponse bias due to their association with key SIPP estimates. Since the variables can be added without introducing substantial increases in the variances of the estimates, it is worthwhile to do so.

Before reaching a final conclusion on the choice of variables to include in the weighting adjustment, it would be useful to repeat the analysis to determine Wave 1 predictors of panel nonresponse with another SIPP panel to check the stability of the relationships of

**These differences were standardized by dividing by an estimator of the sampling standard error of the difference. The standardized differences between the 1987 Panel estimates, using all weights, and the 1989 Panel estimates were always less than 2, and therefore explainable by sampling error. The standardized differences with the benchmark were larger than 2 in absolute value in a majority of the cases, indicating differences not explainable by sampling error.

these variables to panel nonresponse across panels. If the same variables are found in another panel, it should be simple to develop a standard procedure for all future panels.

A range of different weighting methodologies has been examined in this study. None proved superior to the others. Therefore, ease of implementation is a factor that should be taken into account.

6. References

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Table 4-1. Estimates for the Total Population from the 1987 SIPP Panel with Alternative Weighting Schemes and Estimates from Other Sources

	SIPP panel	Predicted logistic	Mixed logistic	Collapsed logistic	CHAID	Raking	1989 SIPP	Bench-mark
AFDC - June 1987	3.73	3.70	3.70	3.72	3.71	3.69		4.28[1]
AFDC - Jan. 1989	3.10	3.12	3.14	3.12	3.14	3.10	3.56	4.24[2]
Food stamps - June 1987	7.43	7.26	7.30	7.34	7.38	7.21		7.35[3]
Food Stamps - Jan. 1989	6.71	6.63	6.67	6.64	6.70	6.58	6.30	7.29[3]
SSI - June 1987	1.68	1.70	1.69	1.67	1.69	1.69		1.68[2]
SSI - Jan. 1989	1.65	1.67	1.66	1.64	1.66	1.66	1.65	1.74[2]
SSI - Annual 1987	1.80	1.82	1.82	1.80	1.82	1.82		
Soc. Sec. - Jan. 1989	14.92	14.87	14.87	14.89	14.88	14.85	15.14	
Months w/o health insurance in 87	1.66	1.69	1.70	1.67	1.67	1.69		
Poverty rate - June 1987	10.88	10.75	10.79	10.76	10.79	10.74		
Poverty rate - Jan. 1989	12.91	12.98	13.02	12.97	12.99	12.93	14.46	
Entering poverty 1987/1988	2.25	2.31	2.32	2.30	2.29	2.31		
Leaving poverty 1987/1988	2.69	2.63	2.64	2.60	2.62	2.63		
Med. HH income - Jan. 1989	2,601	2,600	2,597	2,607	2,607	2,602	2,550	
Employed - Jan. 1989	62.74	62.36	62.34	62.43	62.42	62.42	61.60	
Unemployed - Jan. 1989	3.57	3.64	3.63	3.60	3.58	3.63	4.52	
Out of labor force - Jan. 1989	33.69	34.01	34.03	33.96	34.01	33.95	33.88	
Married in 1987	1.39	1.41	1.40	1.39	1.39	1.41		1.86[4]
Divorced in 1987	0.51	0.50	0.50	0.49	0.50	0.49		0.90[5]
Changed address in 1987	12.88	13.32	13.32	13.19	13.36	13.33		17.99[5]

[1]Social Security Bulletin, Volume 52, No. 3.
[2]Social Security Bulletin, Volume 51, No. 7.
[3]USDA Food and Nutrition Service, unpublished data.
[4]National Center for Health Statistics: Vital Statistics of the U.S., 1987 Volume III, Marriage and Divorce, DHHS Pub. No. (PHS) 91-1103.
[5]U.S. Bureau of the Census, Current Population Reports, Population Characteristics, P-20, No. 473.