# EFFECTS OF ADJUSTMENTS FOR WAVE NONRESPONSE ON PANEL SURVEY ESTIMATES

Graham Kalton and Michael E. Miller, University of Michigan

## 1. Introduction

Wave nonresponse occurs in a panel survey when a unit takes part in some but not all waves of data collection. The choice of adjustment procedure for wave nonresponse is not obvious (Kalton, 1986). If a single set of weights is used to compensate for wave nonrespondents, the data provided by the wave nonrespondents on waves for which they did respond are discarded, causing a loss of data. On the other hand, if imputation is used, complete waves of data have to be imputed, causing concerns about the fabrication of large amounts of data and the effect of the imputations on the relationships between variables. This paper examines the effects of these alternative strategies for handling wave nonresponse on survey estimates by means of a simulation study.

The simulation study is based on the 1984 Panel of the Survey of Income and Program Participation (SIPP). A description of the SIPP is provided by Nelson, McMillen and Kasprzyk (1985). The data set for this study was constructed by merging the public use files for the first three waves of the 1984 SIPP Panel. To create the simulation data set, the respondents on all three waves were taken from the merged file, and some waves of their data were deleted in a way that reflected the missing waves of data in the complete file. Details of the construction of the simulation data set are given in Section 2. Imputation and weighting adjustments were then each applied to compensate for the missing waves of data.

The imputation of missing wave responses was carried out by a simple cross-wave imputation procedure: a wave nonrespondent's responses on a missing wave were assigned the values of that nonrespondent's responses to the same items on the most recent earlier wave for which data were available. Section 3 examines the quality of the imputations produced by this simple "carry-over" imputation procedure.

The weighting adjustments were applied to the three-wave respondents to compensate for those who missed either the second or the third wave, or both. (In the 1984 SIPP Panel no attempt was made to interview first wave nonrespondents on subsequent waves; hence all first wave nonrespondents are total nonrespondents, and as such are excluded from the present investigation.) The auxiliary variables used for determining the weighting classes were responses to certain items at the first wave.

Survey estimates for the wave nonrespondents have been computed from the weighted sample of respondents to all three waves, from the data set with imputed values assigned for missing wave responses, and from the data set with the actual responses (i.e., with the deleted values in the simulation data set replaced). Section 4 compares the estimates obtained from these three procedures. The final section of the paper presents some conclusions from this study.

## 2. The Simulation Data Set

A sample of households is selected for the first wave of a SIPP panel, and all persons aged 15 and over in the selected households become panel members who are followed even if they change addresses or move out of their sampled households. Children under 15 in sampled households become panel members at later waves after reaching the age of 15 provided that they are still living with a panel member at that time. Persons who were not in the initial sample but who subsequently reside with panel members – termed associated persons – are included in the survey while they continue to live with panel members. Panel members and associated persons are interviewed every four months about their income and program participation in the preceding four months. The total sample is made up of four rotation groups which are interviewed in different months.

For the purposes of this study a number of exclusions have been made from the total data set for the first three waves of the 1984 SIPP Panel. First, rotation group 4 was excluded because data were not collected from this group in the second wave. Second, all associated persons have been excluded. Third, all children aged under 15 at the first wave have been excluded. Fourth, all panel members leaving the survey population (e.g., through death, entering an institution, or emigration) have been excluded. Fifth, all nonrespondents at the first wave have been excluded; this category includes both nonresponding households and individual nonrespondents in cooperating households. The study is thus confined to panel members aged 15 and over at the first wave who were respondents at that wave and who remained in the survey population throughout the first three waves. There were 30,004 such persons in the data set. The patterns of response/nonresponse for these 30,004 persons are shown in Table 1.

**Table 1. Person Response/Nonresponse Patterns Across the First Three Waves of the 1984 SIPP Panel for Respondents at the First Wave who Remained Eligible for the Panel for Three Waves***

| Response (X)/Nonresponse (0) | % |
|---|---|
| XXX | 90.0 |
| XX0 | 4.9 |
| X0X | 1.0 |
| X00 | 4.2 |
| Total | 100.0 |
| Number of persons | 30,004 |

*Rotation groups 1, 2 and 3 only.

The first step in the creation of the simulation data set was to seek predictors for the four response patterns exhibited in Table 1. This step was conducted using SEARCH analyses, employing the option that maximizes the variation explained in terms of a $\chi^2$ statistic (Sonquist, Baker, and Morgan, 1973). The predictor variables included in these analyses were any first wave variables that had some degree of association with the response patterns. The objective for the SEARCH analyses was to develop a detailed and complex model for the response patterns. Since the model was to be used for constructing the simulation data set, not for substantive analysis, a complex but unstable model was preferred to a simpler, more stable, one.

The SEARCH analysis adopted for the creation of the simulation data divided the sample into 41 groups. The percentage of respondents on all three waves (XXX) varies from 61.6% to 98.6% across the groups, the percentage of the XX0 pattern varies from 0% to 18.6%, the percentage of the X0X pattern varies from 0% to 12.3%, and the percentage of the X00 pattern varies from 0% to 22.2%.

The simulation data set was formed from respondents to the first three waves in the following manner. First, within each of the 41 SEARCH groups, a random sample of the XXX respondents was taken. The sample size in each group was set at 61.6% of the total number of panel members in that group. The 61.6% figure was chosen because it is the lowest percentage of XXX respondents across the 41 groups. The purpose of this procedure was to generate a sample of XXX respondents that has the same distribution across the 41 groups as the total sample. The sample of XXX respondents thus created comprises 18,481 persons.

The last stage in producing the simulation data set was to assign a response pattern to each of the 18,481 members of the sample of XXX respondents. The response patterns were assigned at random within each SEARCH group, according to the distribution of the response patterns for that group. A variable was added to each data record to indicate the record's assigned response status. When the variable indicated that a sample member was a nonrespondent on one or more waves, the data for those waves are then treated as missing in the data set. In the analysis, weighting adjustments or imputations are used in an attempt to compensate for these missing data.

Although the simulation data set was constructed from respondents to all three waves, it needs to be recognized that not all the data are actual responses. Some respondents failed to answer some of the items, and in these cases the values in the data set are the values imputed by the Bureau's cross-sectional imputation procedures. Since these imputed values may distort the survey estimates – particularly estimates of change across waves – some of the results presented below relate only to records with no imputed values on the variables employed in the particular analysis.

There are weights on the original SIPP records that include an allowance for the nonrespondents at the first wave, that is the total nonrespondents. These weights are not employed for any of the analyses in this paper. The only weights used here are the weights developed to handle wave nonrespondents, as described in Section 4.

## 3. Quality of Carry-Over Imputations

A standard procedure for evaluating the quality of an imputation scheme in a simulation study is to examine how well the scheme reproduces the actual, but deleted, values. We use two indices to measure the quality of the imputations, the mean deviation (MD) and either the mean square deviation (MSD) or its square root, the root mean square deviation (RMSD). The mean deviation is given by $MD = \Sigma(\hat{y}_i - y_i)/n$, where $\hat{y}_i$ is the imputed value, $y_i$ is the actual value for the $i$th missing response, and $n$ is the number of imputed responses. The mean deviation is the difference in the means of the imputed and actual values. The mean square deviation is given by $MSD = \Sigma(\hat{y}_i - y_i)^2/n$ . It measures the closeness of the imputed to the actual values.

For items with simple Yes/No responses, "Yes" answers can be scored 1 and "No's" scored 0. Then the MD is the difference in the proportions of "Yes" answers between the imputed and actual responses, and the MSD is the proportion of incorrect imputations. Table 2 gives the MD's and MSD's for a selection of items with simple Yes/No responses. The table gives the MD's and MSD's separately for imputed values at the second wave (response patterns XOX and XOO) and at the third wave (response patterns XXO and XOO).

The mean deviations in Table 2 represent the differences between the percentages of "Yes" answers in the imputed values and in the actual, but deleted, values for those assigned for the simulation to represent wave nonrespondents. Thus, for instance, the figure of 1.7% in the top left-hand corner of the table relates to the 173 respondents who had their second wave responses deleted in the simulation data set. With the carry-over imputation procedure, they were assigned their first wave responses for the missing second wave responses. Based on these imputed values, 73.4% of them were classified as having a job in the second wave. Based on their actual second wave responses, the corresponding percentage is 71.7%. The difference between these percentages is the mean deviation of 1.7% in the table.

With the carry-over imputation procedure, a mean deviation of 0 occurs with a given response pattern when the percentage of the nonrespondents endorsing the item is the same at the missing wave as at the wave from which the carry-over imputed values are taken. Most of the mean deviations for the wave nonrespondents in Table 2 are close to 0. Four of them are, however, significantly different from 0. These four reflect changes between waves in the levels of endorsement of the items in question. The carry-over imputation procedure risks serious bias when the level of endorsement of an item varies appreciably over waves. Some other form of cross-wave imputation may be needed in this case.

**Table 2. Mean Deviations and Mean Square Deviations for Several Items for Second and Third Wave Imputations by Response Pattern**

| Item | Second Wave Imputations | | Third Wave Imputations | |
|---|---|---|---|---|
| | XOX % | XOO % | XXO % | XOO % |
| | **Mean Deviations** | | | |
| Having a Job | 1.7 | 3.0* | −2.6** | 1.6 |
| Looking for Work+ | 0.0 | −1.0 | 2.1** | −1.0 |
| Receiving Social Security | −0.6 | 0.1 | −0.4 | 0.0 |
| Receiving Food Stamps | 0.6 | 0.1 | 0.4 | 0.0 |
| Having Savings Accounts | 1.7 | 3.3** | 0.0 | 1.4 |
| Having Certificates of Deposit | 0.6 | 0.7 | −0.3 | 0.0 |
| | **Mean Square Deviations** | | | |
| Having a Job | 7.5 | 10.0 | 8.4 | 10.7 |
| Looking for Work+ | 3.3 | 6.0 | 4.8 | 6.0 |
| Receiving Social Security | 0.6 | 0.7 | 1.1 | 1.8 |
| Receiving Food Stamps | 0.6 | 1.7 | 1.3 | 1.3 |
| Having Savings Accounts | 7.5 | 10.0 | 5.3 | 12.9 |
| Having Certificates of Deposit | 1.7 | 4.0 | 2.8 | 4.7 |
| Number of imputations | 173 | 767 | 906 | 767 |
| (Number of imputations for looking for work item) | (123) | (484) | (578) | (484) |

+Only for those in the labor force at all waves
* and ** Significant at the 5% and 1% levels respectively, using McNemar's test

The mean square deviations in Table 2 represent the percentages of incorrect imputations (e.g., imputing having a job when the respondent has no job or vice versa). The percentage of correct imputations is generally high, but there is nevertheless a not insignificant number of errors made.

We now turn to consider the quality of the carry-over imputation procedure for a numerical variable, Social Security income, that is obtained monthly. In this case, the first carry-over imputation we use assigns the amount for the latest available month for each missing month. The analysis reported here is restricted to those who receive Social Security income in the latest available month and in the months for which the responses are deleted. The analysis does not therefore reflect the effect of changes in recipiency status for Social Security income. Records with Bureau of the Census cross-sectional imputations for item nonresponses on Social Security income are deleted because they would distort the analysis. Monthly amounts of $1500 or more and changes of more than $200 between months are also deleted (ten records had amounts of $1500 or more in one or more months and six records had changes of more than $200 between months).

Table 3 presents the mean deviations (as percentages of the actual monthly means) and root mean square deviations for Social Security amounts that qualify after the above exclusions are made. A notable feature of the mean deviations is the significant negative biases in the imputed amounts from month 7 onwards for the XOX and XOO patterns. These biases may be explained by the fact that with these patterns the imputed values are carried over from months prior to January, 1984, and therefore do not take account of a 3.5% increase that occurred in that month. With the XXO pattern, the imputed values are taken from months after January and hence include the increase.

**Table 3. Mean Deviations and Root Mean Square Deviations for Social Security Imputed Monthly Incomes in the Second and Third Waves by Response Patterns**

| | XOX | | XOO | | XXO | |
|---|---|---|---|---|---|---|
| Month | MD+ % | RMSD $ | MD+ % | RMSD $ | MD+ % | RMSD $ |
| 5 | 0.1 | 10.8 | −0.1 | 23.7 | – | – |
| 6 | −0.6 | 13.2 | −1.0 | 24.3 | – | – |
| 7 | −2.1** | 17.9 | −1.4* | 24.7 | – | – |
| 8 | −3.2** | 18.8 | −2.2** | 29.6 | – | – |
| 9 | – | – | −3.8** | 32.9 | 0.5 | 16.2 |
| 10 | – | – | −3.8** | 32.8 | 0.9 | 25.1 |
| 11 | – | – | −4.0** | 33.5 | 0.5 | 16.2 |
| 12 | – | – | −4.3** | 38.0 | 0.6 | 15.8 |
| Approx. no. of imputations | 20 | 20 | 97 | 97 | 110 | 110 |

+As a percentage of the mean of the actual responses.
* and **Significant at the 5% and 1% levels respectively, using a matched sample 't' test

The root mean square deviation bears some similarity to a residual standard deviation around the predicted values. The standard deviations of the Social Security monthly amounts in this restricted data set are around $180. The small magnitudes of the RMSD's compared with this standard deviation indicate the effectiveness of the carry-over imputation procedure for Social Security amounts (once the outliers have been removed).

An obvious modification to make to the carry-over imputation procedure for Social Security amounts is to increase all amounts carried over from months before January to January or later by 3.5%. This modification affects only the XOX and XOO response patterns. Table 4 gives the mean deviations and root mean square deviations for this modified carry-over imputation procedure for these two patterns for the same set of records as Table 3. As can be seen from the table, there are now no significant biases and the RMSD's are slightly lower than the corresponding ones in Table 3. The modification thus produces a useful improvement in the imputed values.

Finally, it should be noted that the results in this section understate the quality of the imputations made by the carry-over imputation procedure to some extent. The quality of carry-over imputations depends on the stability of responses across waves. The true stability of responses is understated in the actual data set because of the effects of variability in measurement errors across waves. Aspects of the survey operation that are likely to give rise to variability in measurement errors include simple response variability, changing informants across waves (e.g., self-report on one wave, proxy report on another), matching errors, and keying errors. Kalton, McMillen and Kasprzyk (1986) provide some evidence on the existence of variability in measurement errors in the 1984 SIPP Panel.

**Table 4. Mean Deviations and Root Mean Square Deviations for Social Security Imputed Monthly Incomes, Adjusted for January Increase, in the Second and Third Waves by Response Pattern**

| | XOX | | XOO | |
|---|---|---|---|---|
| Month | MD+ | RMSD | MD+ | RMSD |
| 5 | 0.1 | 10.8 | −0.1 | 23.7 |
| 6 | 0.3 | 9.4 | 0.3 | 23.4 |
| 7 | 0.1 | 9.2 | 0.8 | 23.4 |
| 8 | 0.2 | 10.7 | 0.6 | 20.2 |
| 9 | – | – | −0.5 | 29.9 |
| 10 | – | – | −0.5 | 29.9 |
| 11 | – | – | −0.6 | 30.5 |
| 12 | – | – | −1.0 | 35.3 |
| Approximate no. of imputations | 20 | 20 | 97 | 97 |

+As a percentage of the mean of the actual responses

## 4. Comparison of Imputed and Weighted Estimates

One way to handle wave nonresponse is by some form of imputation, such as the carry-over imputation procedure discussed in the previous section. An alternative way is by a weighting adjustment. This section compares these alternatives.

It is possible to develop a number of different sets of weights to compensate for wave nonresponse, with the choice of the weights to be used in a particular analysis depending on the waves from which data are needed for that analysis (Kalton, 1986). The use of different sets of weights enables use to be made of all the responses on the waves for which data are available, but it adds to the complexity of the data set. For this investigation, we have developed a single set of weights to compensate for all wave nonrespondents; this is the approach being adopted by the Bureau in creating a twelve month file for the SIPP. The use of a single set of weights has the attraction of simplicity, but it is wasteful of the data collected on wave nonrespondents.

The weighting scheme used for this study assigns weights to the 16,635 respondents to all three waves (pattern XXX) to compensate for the 1846 wave nonrespondents (patterns XXO, XOX and XOO). Data collected at the first wave were used to form weighting classes within which the three-wave respondents were weighted up to represent the wave nonrespondents. The weighting classes were formed by a classification according to sex, four age groups, three household income levels, race, three educational levels, whether receiving certain types of welfare or not, whether in the labor force or not, and whether unemployed or not. The classification was collapsed until all weighting classes contained a minimum of 20 three-wave respondents. The weights for the resultant classes vary between 1.0 and 1.5.

One approach for comparing the effectivenesss of weighting and imputation for handling wave nonresponse is to examine their effects on total sample estimates. However, with wave nonrespondents comprising only 10% of the sample, this approach is an insensitive one. A more insightful analysis is to examine how well these two forms of nonresponse adjustments represent the wave nonrespondents. In the case of imputation, this analysis can be readily conducted by comparing the estimates obtained for the wave nonrespondents (i) from the actual values and (ii) from the combination of actual and imputed values, where imputed values are assigned when missing waves occur. In the case of weighting adjustments, the wave nonrespondents are represented by increases in the weights to the three-wave respondents. Weighted estimates for the wave nonrespondents can therefore be obtained from weighted analyses of the three-wave respondents' data set, where the weights are now taken to be just the increases in the weights assigned to represent the wave nonrespondents. Since, for the purposes of this study, all respondents in the data set were given an initial weight of 1, the increase in weight allocated to the $i$th three-wave respondent is simply $(w_i - 1)$, where $w_i$ is the weight assigned to compensate for the wave nonresponse.

Table 5 compares the response distributions across the three waves for two Yes/No items for wave nonrespondents for (a) the actual responses, (b) the data with wave nonrespondents' missing values imputed by the carry-over imputation procedure and (c) the data with the three-wave respondents' values weighted by $(w_i - 1)$. Several features of the imputed results may be noted. First, the distributions for the imputed data have zero entries for the patterns YNY and NYN; in fact, these patterns cannot occur among wave nonrespondents with the carry-over imputation procedure. Secondly, the patterns YYN and NNY occur rarely in the imputed data set; they can arise only from the XOX response pattern, and this pattern occurs infrequently. Thirdly, the imputed data set consistently overestimates the frequencies of the consistent patterns YYY and NNN: these patterns are indeed the only patterns that can occur with the response pattern XOO. As a result of these effects, the imputed distributions deviate systematically from the actual distributions.

**Table 5. Distributions of Responses across Waves for Two Items for the Wave Nonrespondents (a) with the Actual Responses (b) with Imputed Responses for Missing Waves and (c) with Weighting Adjustments for Wave Nonrespondents**

| Y=Yes<br>N=No | (a)<br>Actual<br>% | (b)<br>Imputed<br>% | (c)<br>Weighted<br>% |
|---|---|---|---|
| | **Having a Job** | | |
| YYY | 58.1 | 63.3 | 57.4 |
| YYN | 2.4 | 0.4 | 2.4 |
| YNY | 2.5 | – | 2.5 |
| YNN | 3.2 | 2.6 | 3.1 |
| NYY | 2.5 | 1.5 | 2.6 |
| NYN | 0.7 | – | 0.7 |
| NNY | 2.7 | 0.4 | 2.7 |
| NNN | 27.8 | 31.8 | 28.6 |
| | 100.0 | 100.0 | 100.0 |
| | **Having Savings Accounts** | | |
| YYY | 45.1 | 49.9 | 48.9 |
| YYN | 2.4 | 0.7 | 2.7 |
| YNY | 1.2 | – | 1.2 |
| YNN | 4.4 | 2.4 | 3.3 |
| NYY | 2.8 | 1.3 | 2.7 |
| NYN | 0.2 | – | 0.4 |
| NNY | 2.4 | 0.8 | 2.3 |
| NNN | 41.5 | 44.9 | 38.5 |
| | 100.0 | 100.0 | 100.0 |
| No. of persons (sum of weights) | 1846 | 1846 | (1846) |

On the other hand, the weighted distributions show no systematic deviations from the actual distributions. There is, for instance, no tendency to overrepresent the consistent patterns at the expense of the inconsistent ones. The weighted distributions do, however, differ from the distributions of actual values in a few places.

As a summary of Table 5, Table 6 presents the percentages of "Yes" responses for each of the three items by wave. As can be seen from the table, the percentages of "Yes" responses from the actual and imputed data sets are the same at the first wave, despite the differences in the distributions across waves noted in Table 5. In fact, these two percentages are necessarily equal, because first wave responses are available for all, both three-wave respondents and wave nonrespondents. Hence no imputations are needed at the first wave. On the other hand, with weighting adjustments, the first wave responses of wave nonrespondents are not retained. In consequence, the percentages of first wave "Yes" responses do differ between the actual and weighted data sets.

**Table 6. Percentages of "Yes" Responses at Each Wave for Two Items for the Wave Nonrespondents (a) with the Actual Responses, (b) With Imputed Responses for Missing Waves, and (c) with Weighting Adjustments for Wave Nonrespondents**

| | (a)<br>Actual<br>% | (b)<br>Imputed<br>% | (c)<br>Weighted<br>% |
|---|---|---|---|
| | | **Having a Job** | |
| Wave 1 | 66.2 | 66.2 | 65.4 |
| Wave 2 | 63.7 | 65.2 | 63.1 |
| Wave 3 | 65.8 | 65.2 | 65.2 |
| | | **Having Savings Accounts** | |
| Wave 1 | 53.1 | 53.1 | 56.1 |
| Wave 2 | 50.5 | 51.9 | 54.7 |
| Wave 3 | 51.5 | 52.0 | 55.1 |

As noted in Section 3, the carry-over imputation procedure leads to biased estimates when the level of endorsement of an item changes across waves. Evidence of this bias can be seen in the imputed second wave percentages in Table 6. In both cases, the actual percentages having the attribute declined from the first to second waves. The carry-over imputation procedure dampens down the amount of decline, so that the second wave imputed estimates are too high. As a consequence, the imputed data set underestimates the amount of net change: for instance the actual change between the first and second waves in the percentages having a job is −2.5%, whereas the imputed data set shows a change of only −1.0%. The weighted estimates of change do not suffer this distortion; although they appear less stable, they give better measures of net change.

An even more serious problem with the carry-over imputation procedure is its effect on gross change. All carry-over imputations involve no change, so gross change is underestimated. As an illustration, the actual percentage of wave nonrespondents changing between having and not having jobs from the second to third waves is 8.3%. The estimate from the weighted analysis is 8.3%, but that from the imputed data set is only 0.8% (arising from the XOX response pattern).

Finally, Table 7 considers the effects of the alternative nonresponse adjustment procedures on the means of the monthly Social Security amounts. Column (a) in the table gives the twelve mean monthly amounts for the wave nonrespondents receiving Social Security income computed from their actual responses. Column (b) gives the differences between the imputed means and the actual means when the simple carry-over imputation procedure is used, and column (c) gives the corresponding differences when the carry-over imputation scheme adjusted for the 3.5% January increase is used. Column (d) gives the difference between the weighted means and actual means for the wave nonrespondents. The figures in columns (b) and (c) represent the survey results that would be obtained for the wave nonrespondents by using these imputation procedures. Unlike Tables 3 and 4, the columns based on actual and imputed values do not relate to the same set of individuals. In particular, individuals starting to receive Social Security payments after the point at which they were simulated to be wave nonrespondents are included in the calculations of the means of the actual amounts, and individuals who ceased to receive amounts but were assigned amounts by the carry-over imputation procedures are included in the calculations of the imputed means. Since those starting and ceasing to receive Social Security amounts tend to receive below average amounts, the means of the actual and the imputed amounts for the last four months in Table 7 are lower than those that applied for Tables 3 and 4. The general conclusions are, however, the same: the simple carry-over imputation procedure underestimates the means for the last six months, but the allowance for the January increase in the adjusted procedure (column (c)) provides a reasonable correction for this bias.

The weighted means deviate more from the actual means than do the means for the adjusted imputed amounts. In the first four months, the imputed means are necessarily equal to the actual means because there is no wave nonresponse at the first wave. In the second four months, the imputed means still include actual values for almost half of the wave nonrespondents (i.e., those in the pattern XXO). This fact helps to explain why the imputed means track the actual means more closely.

**Table 7. Actual Mean Monthly Social Security Incomes for Wave Nonrespondents Receiving Such Income and Differences from the Actual Means of (b) the Means with Carry-Over Imputations for the Missing Waves, (c) the Means with Carry-Over Imputations for the Missing Waves Adjusted for the January Increase, and (d) the Means from the Weighting Adjustments***

| (a) Actual $ | (b) Imputed $ | (c) Adjusted Imputed $ | (d) Weighted $ |
|---|---|---|---|
| 388 | 0 | 0 | −2 |
| 395 | 0 | 0 | −9 |
| 389 | 0 | 0 | −4 |
| 387 | 0 | 0 | −1 |
| 381 | +1 | +1 | +7 |
| 383 | −1 | +1 | +7 |
| 387 | −1 | +3 | +7 |
| 390 | −3 | +3 | +8 |
| 400 | −9 | −4 | −1 |
| 395 | −4 | +1 | +5 |
| 398 | −7 | −2 | +3 |
| 399 | −8 | −3 | +2 |

*Excluding monthly amounts of $1500 or more.

## 5. Discussion

The preceding results are extremely limited in scope, but they nevertheless do identify some factors involved in making the choice between cross-wave imputation and weighting for handling wave nonresponse. A prime consideration for imputation is the availability of auxiliary information with high predictive power for the missing waves. The few examples investigated in this study agree with other results (e.g., Kalton, Lepkowski and Lin, 1985) that many of the types of variables included in the SIPP are very stable over time. Thus, the values of the variables on a missing wave can be well predicted by the values of the same variables on another wave.

The carry-over, or direct substitution, imputation procedure is one way for utilizing the available wave data for cross-wave imputations. The procedure has a notable advantage of great simplicity, but as our analyses have illustrated it fails to track net changes in means or proportions when these vary over time. The extent of bias in the survey estimates caused by this failure depends on the degree of net change that occurs and the amount of wave nonresponse. It will be small when there is not much net change and a low level of wave nonresponse, as will often be the case. More seriously, the carry-over imputation procedure causes an underestimation of gross change, since all imputed values are assigned the same response as the last available wave. This simple procedure causes the amount of gross change to be underestimated by a proportion equal to the proportion of carry-over imputations.

Kalton and Lepkowski (1983) describe some alternatives to the carry-over imputation procedure that avoid the distortions caused by this simple procedure. These procedures take account of changes over time by imputing changes for some wave nonrespondents. Thus, for instance, if 8% of the respondents change from having to not having a job between the first and second waves, 8% of second wave nonrespondents with jobs at the first wave would be assigned changes (and this can be extended to be applied separately, with different rates of change, in a set of imputation classes). While these procedures are attractive for reflecting change, they suffer other disadvantages. Unless great care is taken, they may lead to the imputation of sets of responses that are inconsistent, and in any case they will cause distortions in the relationships between some of the responses (see Kalton and Kasprzyk, 1982, Section 3.3). The simple carry-over procedure retains the relationships between responses that occur on the wave used for imputation; provided that these relationships do not change over time, this is an attractive feature.

As our study of the imputation of Social Security amounts brought out, even the carry-over imputation procedure should not be applied uncritically with numerical variables. Social Security amounts in general fall within definite limits, but nevertheless some outliers do occur. In the simulation data set, there was, for instance, one person who received $4359 in one month, nothing in the previous month, and only $337 in each of the two subsequent months. Another person purportedly received $2242 in one month, $242 in the preceding month, and $251 in each of the two subsequent months (an amount 3.5% larger than the $242 amount). While some of the outliers may be erroneous values (as seems probable in this second case), they cannot always automatically be treated as such because large payments in a single month are possible. The assignment of these large amounts to subsequent months by the carry-over imputation procedure would however create unrealistic longitudinal records.

Weighting has the attraction over imputation that it avoids the above problems. The weighting scheme employed in the simulation study, however, suffers the disadvantage that it discards a good deal of information: first wave responses are available for all wave nonrespondents, but apart from those used in forming weighting classes, these responses are discarded; similarly, second and third wave responses are available for one-half and one-tenth of the wave nonrespondents, respectively, but they are also discarded. This discarding of data can be avoided by the use of several different sets of weights, but this solution adds to the complexity of the data set, and it can lead to inconsistencies in the results of different analyses. In addition to this discarding of actual responses, weighting does not take advantage of the high predictability of many of the wave nonrespondents' missing values that cross-wave imputation employs.

No measure of the effective sample size is available for the situation where imputation is used to handle missing responses. Table 1 shows that there was 10% of wave nonresponse in the first three waves of the 1984 SIPP Panel. However, only 4.7% of the responses were missing because of wave nonresponse, and moreover many of these missing responses could be imputed with little error from other waves. Thus it seems that the effective sample size is only a few percentage points below the first wave sample size. The sample size when the simple single set of weights is used is 10% lower than that of the first wave, and in addition the use of weights decreases the effective sample size still further. This further decrease may be approximately measured by the multiplying factor $(\Sigma w_i)^2/(n\Sigma w_i^2)$, where $w_i$ is the weight of the $i$th sampled element. In the simulation data set, this factor is very close to 1 because of the small variation in the weights. Thus, the effective sample size with the weighting solution is about 90% of the sample size at the first wave.

The choice between imputation and weighting for handling wave nonresponse is complicated by the fact that the survey data will be subjected to many types of analyses, involving different forms of estimates and being based on varying-sized subclasses of the total sample. Since imputation can distort some forms of estimates, weighting may be the preferred solution for large subclasses when the reduction in effective sample size is tolerable. However, imputation may be better for estimates based on small subclasses, when the loss in effective sample size matters and when any bias caused by imputation is less important relative to the sampling error. The choice of one or other of these adjustment procedures for multipurpose use must balance out these considerations. In the case of the three-wave SIPP file, the difference in the effective sample sizes between the imputation and weighting solutions is not great, and therefore weighting may be the safer general purpose solution.

**References**


Kalton, G. (1986). Handling wave nonresponse in panel surveys. *Journal of Official Statistics*, forthcoming.

Kalton, G. and Kasprzyk, D. (1982). Imputing for missing survey responses. *Proceedings of the Section on Survey Research Methods, American Statistical Association*, 22-31.

Kalton, G. and Lepkowski, J. (1983). Cross-wave item imputation. In *Technical, Conceptual, and Administrative Lessons of the Income Survey Development Program (ISDP)*, M. David, ed., 171-198. New York: Social Science Research Council.

Kalton, G., Lepkowski, J. and Lin, T. (1985). Compensating for wave nonresponse in the 1979 ISDP Research Panel. *Proceedings of the Section on Survey Research Methods, American Statistical Association*, 372-377.

Kalton, G., McMillen, D.B. and Kasprzyk, D. (1986). Nonsampling error issues in the Survey of Income and Program Participation. *Proceedings of the U.S. Bureau of the Census Second Annual Research Conference*, 147-164.

Nelson, D., McMillen, D.B. and Kasprzyk, D. (1985). An overview of the Survey of Income and Program Participation: Update 1. SIPP Working Paper Series No. 8401, Washington, D.C.: U.S. Bureau of the Census.

Sonquist, J.A., Baker, E.L. and Morgan, J.N. (1973). *Searching for Structure*. Ann Arbor, Michigan: Institute for Social Research.