

## **Nonresponse Adjustment Procedures at the U.S. Bureau of the Census**

**DAVID W. CHAPMAN, LEROY BAILEY, and DANIEL KASPRZYK<sup>1</sup>**

### **ABSTRACT**

Nearly all surveys and censuses are subject to two types of nonresponse: unit (total) and item (partial). Several methods of compensating for nonresponse have been developed in an attempt to reduce the bias associated with nonresponse. This paper summarizes the nonresponse adjustment procedures used at the U.S. Census Bureau, focusing on unit nonresponse. Some discussion of current and future research in this area is also included.

**KEYWORDS:** Nonresponse adjustments; Imputation; Missing data; Weighting.

### **1. INTRODUCTION**

The Bureau of the Census has long recognized the potential seriousness of measurement errors ascribed to survey nonresponse, and has consistently incorporated nonresponse adjustment or compensation procedures in the estimation methodologies for its numerous and varied surveys and censuses. The objectives of this paper are to provide an overview of procedures employed by the Census Bureau in compensating for nonresponse, primarily unit nonresponse. By unit nonresponse we mean that little or no information for the principal survey variables is obtained for the sample unit in question.

This presentation will include (1) a discussion of the general weighting scheme used for the demographic surveys; (2) a review of some of the distinct problems associated with nonresponse in the Survey of Income and Program Participation (SIPP); (3) a discussion of the handling of unit nonresponse for the economic surveys and censuses; and (4) a section on imputation for earnings for the Current Population Survey. In addition to providing descriptions of the various nonresponse compensation methods used by the Census Bureau, the authors will cite specific problems associated with those methods and note the Bureau's current nonresponse research activities and concerns.

### **2. NONRESPONSE IN DEMOGRAPHIC SAMPLE SURVEYS**

At any given time, the Bureau of the Census may be involved with the conduct of 25-30 recurring or special demographic surveys. The concerns of these surveys include labor force participation, individual and family income, health care, transportation, leisure activities, crime, and other topics reflective of the current interests of the nation's people, governments, businesses, and institutions. Unit nonresponse rates for these surveys range from between three and four percent for the National Crime Survey to over 25 percent, which was recorded for the 1984 National Survey of Natural and Social Scientists and Engineers.

---

<sup>1</sup> David W. Chapman and Leroy Bailey are Principal Researchers, Statistical Research Division, U.S. Bureau of the Census, Washington D.C. 20233. Daniel Kasprzyk is a Special Assistant, Office of the Chief, Population Division, U.S. Bureau of the Census, Washington D.C. 20233.

Weight adjustment within classes (Oh and Scheuren 1983), or cell balancing, is the predominant technique used to compensate for unit nonresponse in the Census Bureau's demographic surveys. There is variation among the surveys relative to the determination of adjustment classes within which weighting occurs. For some surveys, ancillary data available to define weighting classes are limited to basic geographic and survey design information, while for others a considerable amount of demographic and economic data are accessible.

The nonresponse adjustment factors for the Bureau's demographic surveys are usually the inverse of the survey's weighted or unweighted response rate. In a small number of the surveys this adjustment factor is modified slightly to reflect information gleaned from follow-up subsamples of the initial nonrespondents. Since the Census Bureau's general approach to survey nonresponse is essentially the same for all of its major demographic surveys, a general description will be given in Section 2.1 of the nonresponse adjustment procedure for the National Crime Survey (NCS), as the example of a "typical" Census Bureau application of weighting. Section 2.2 will consist of a discussion of alternative procedures and current unit nonresponse research in the demographic areas.

## 2.1 The National Crime Survey

The NCS sample is a national probability sample of about 72,000 households which is divided into six panels, each of which is interviewed in a given month and again at six-month intervals over three years. The survey focuses on measuring household crimes and the extent of victimization of household members age 12 and older by assault (including rape), burglary, larceny, auto theft, and robbery. [For a detailed description of the NCS, see U.S. Department of Commerce, Bureau of the Census (1977).]

Estimates for the NCS, which are produced quarterly, are derived by initially inflating the sample data by the inverse of the related selection probabilities. The noncontacts and refusals account for about three to four percent of the survey's occupied units in any given month. Adjustments for these units are made by applying adjustment factors to the weighted respondent data in weighting classes. An attempt is made to define these classes in such a way that the respondents and nonrespondents in each class have similar survey characteristics. In order to temper the impact of the nonresponse adjustment on the variance of the survey estimates, some of the smaller weighting classes generally have to be collapsed with other classes before a final nonresponse adjustment can be effected. Collapsing of classes also takes place if the weight adjustment factor becomes too large for one or more classes. [See Hanson (1978).] Collapsing is discussed further in Section 4.

Since the NCS employs a self-response method of interviewing, there is concern about the amount of within household nonresponse. Consequently, a separate set of weighting cells exists to compensate for within-household nonresponse. These cells or weighting classes, as well as those used for the household nonresponse adjustment, are indicated in Tables 1-3. The NCS household and within household nonresponse rates for 1984 are shown in Table 4.

To illustrate the NCS estimator of a total, there is a selection probability  $\pi_i = 1, 2, \dots, N$ , associated with each of the  $N$  units in the population. It is assumed that among the  $n$  sample units,  $n_R$  are respondents. The NCS estimator for the population total, after adjusting for unit nonresponse, takes the following form:

$$\hat{Y}_{\text{NCS}} = \sum_{j=1}^M \sum_{k=1}^P (z_j u_k)^{-1} \sum_{\ell=1}^{n_{Rjk}} \frac{y_{jkl}}{\pi_{jkl}},$$

**Table 1**  
NCS Noninterview Adjustment Cells for  
Within Household Nonresponse

Household Relationship	Persons by Age, by Race of Head							
	Black				Non-black			
	12-24	25-44	45-64	65 +	12-24	25-44	45-64	65 +
Head of Household								
Wife of Head								
All other Persons								

**Table 2**  
NCS Household Noninterview  
Adjustment Cells for  
Standard Metropolitan  
Statistical Areas (SMSA's)

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

**Table 3**  
NCS  
Household Noninterview  
Adjustment Cells for  
Non-SMSA's

Race	Urban	Rural	
		Non-farm	Farm
White			
Not White			

where for sample units in the  $k^{th}$  within household and  $j^{th}$  household weighting classes,

$y_{jkl}$  = value of the  $l$  th sample respondent,

$n_{Rjk}$  = number of sample respondents,

$n_{jk}$  = number of sample cases,

$z_j$  = the estimated household response rate,

$u_k$  = the estimated within household response rate,

$\pi_{jkl}$  = selection probability for the  $l$  th sample respondent,

$P$  = total number of within household nonresponse weighting classes,

$M$  = total number of household nonresponse weighting classes.

Implicit in the formation of the NCS nonresponse weighting classes, as well as those for other demographic surveys, are the following assumptions:

1. There is "significant" correlation between the major survey variables and the covariates used to define noninterview adjacent classes.
2. Within each household nonresponse weighting class,  $E(\bar{y}_{Rj}) = E(\bar{y}_{Rj})$ , where  $\bar{y}_{Rj}$  and  $\bar{y}_{Rj}$  are the means for the sample respondents and nonrespondents, respectively, in the  $j^{th}$  weighting class.
3. The weighting class means differ, that is,  $E(\bar{y}_{Rj}) \neq E(\bar{y}_{Rj'})$ ,  $j \neq j'$ .

(Assumptions analogous to 2 and 3 above are also implicit for *within* household nonresponse adjustment classes.)

**Table 4**  
NCS Noninterview Rates - 1984

	Average 1984	Jan.	Feb.	Mar.	Apr.	May	June
<b>Household Noninterviews</b>							
Total Interviewed HH's	11,769	11,916	11,925	11,743	11,809	11,918	9,482
Total	430	446	540	481	446	388	348
Rate	3.5	3.6	4.3	3.9	3.6	3.2	3.5
No one at home	0.9	0.8	1.1	0.9	0.9	0.7	1.0
Temporarily Absent	0.6	0.6	0.6	0.8	0.6	0.4	0.7
Refusal	1.9	2.1	2.6	2.2	2.2	2.0	1.9
Other	0.1	0.2	0.2	0.1	0.1	0.1	0.1
<b>Within Household Noninterviews</b>							
Total	685	655	751	701	806	804	697
Rate	2.5	2.6	3.0	2.8	3.0	2.9	3.2
		July	Aug.	Sept.	Oct.	Nov.	Dec.
<b>Household Noninterviews</b>							
Total Interviewed HH's		9,869	9,446	9,895	9,350	9,692	9,410
Total		411	409	337	406	387	346
Rate		4.0	4.2	3.3	4.2	3.8	3.5
No one at home		0.9	0.9	0.6	1.0	1.2	1.0
Temporarily Absent		1.0	1.0	0.6	0.6	0.4	0.4
Refusal		2.1	2.3	2.0	2.4	2.1	2.1
Other		0.1	0.1	0.1	0.3	0.3	0.1
<b>Within Household Noninterviews</b>							
Total		709	678	666	728	735	803
Rate		3.1	3.1	2.9	3.4	3.3	3.7

The selection of weighting classes for this procedure is constrained by the requirement that measurements for the weighting class variables (covariates) must be available (either before or during the survey) for both the respondents and the nonrespondents. This essentially restricts the characteristics by which classes are defined to those associated with geography, race, urbanicity, housing unit characteristics, and design levels. The bias reduction capability of the procedure depends, in part, on the extent to which the NCS nonresponse weighting classes satisfy the three assumptions given above. No definitive results relating to this concern are currently available, but relevant research is underway and more empirical studies seem warranted.

## 2.2 Alternatives to Sample Weighting

There are a number of plausible alternatives to weighting to adjust for nonresponse. See, for example, Little (1986, Section 5). However, there are no definitive results which show that any of them offer appreciable advantages. Subsections 2.2.1 and 2.2.2 contain brief descriptions of two alternatives which are currently being investigated for application to demographic surveys.

### 2.2.1 Separate Estimates for Dissimilar Types of Nonresponse

In demographic surveys, nonrespondents can be placed into four categories: refusal (REF), not-at-home (NAH), other occupied unit (OTO), or a unit from which a response was not obtained due to extenuating circumstances. These are referred to as type A noninterviews. The NAH group can be divided into those households or individuals whose extended absence from their homes precludes an interview during the scheduled interview period (NAH<sub>E</sub>), and the group which is expected to return home sometime during the survey period (NAH<sub>S</sub>).

The authors are not aware of any data which show that the four nonresponse groups are generally similar. In fact, the Census Bureau's Current Population Survey and the Canadian Labour Force Survey suggest that the NAH<sub>S</sub> households are likely to be smaller, younger, and have a larger proportion of employed people than the other groups. The NAH<sub>E</sub> group is usually older with a relatively low employment rate. The interviewed group may be more reflective of the REF and OTO groups. [See Palmer and Jones (1967) and Paul and Lawes (1982).] It is conceivable that separate treatment of the four nonresponse groups could produce a better overall adjustment for nonresponse than is obtained from the current procedure. This option is being investigated by an NCS nonresponse adjustment research group.

### 2.2.2 Weighting With Response Probabilities

Several weighting techniques have been advanced which make use of the concept of response probabilities. Most of these techniques are based on concepts introduced by Politz and Simmons (1949) which group sample respondents according to estimates of their probabilities of responding. The factors with which the sample data in the resultant weighting groups are inflated are the inverses of the estimated response probabilities. The Politz-Simmons procedure has some serious limitations, such as its inapplicability to refusals. However, there have been a number of fairly recent extensions and applications of the procedure, including those presented by Anderson (1978), Thomsen and Sirling (1983). These methods may be applicable to recurring surveys for which extensive callbacks are made.

Research is in progress regarding the development of models which may be used to estimate response probabilities for several demographic surveys for units with similar values of the "independent variables." The feasibility and merits of computing nonresponse adjustment factors, as well as constructing weighting classes based on such models (sometimes referred to as response propensity stratification), are being examined. [See Rosenbaum and Rubin (1983) and Little and Samuhel (1983).] Moreover there are continued efforts to develop more objective methods of sample weighting for nonresponse, which are designed to control nonresponse-related errors.

## 3. THE SURVEY OF INCOME AND PROGRAM PARTICIPATION

The Survey of Income and Program Participation (SIPP) is a new, ongoing national household survey program of the U.S. Bureau of the Census. The purpose of SIPP is to improve the measurement of information related to the economic situation of households

and persons in the United States. It is the culmination of a large-scale development program, the Income Survey Development Program (ISDP), which examined concepts, procedures, questionnaires, recall periods, and the like. For a description of the ISDP, see Ycas and Linger (1981). Data from SIPP are expected to be useful in studying the Federal transfer system, estimating program costs under changes in program eligibility rules, evaluating the effects of program changes on selected population subgroups, as well as studying changes to the tax system.

In October 1983 SIPP began as an ongoing survey program with one sample panel of approximately 21,000 occupied households eligible for interview in 174 Primary Sample Units (PSU's) selected to represent the noninstitutional population of the United States. (Beginning in 1985 a new panel is being introduced in February of each year; the 1985 panel consisted of 14,500 households eligible for interview.)

Each household is interviewed once every four months for approximately 2½ years to produce sufficient data for longitudinal analysis while providing a relatively short recall period for reporting monthly income. The reference period for the principal survey items is the 4 months preceding the interview. This design provides eight interviews per household, and allows cross-sectional estimates to be produced from more than one panel.

To facilitate field and processing operations, each sample panel is divided into four approximately equal subsamples, called rotation groups; one rotation group is interviewed in a given month. Thus, one cycle or "wave" of interviewing, using the same questionnaire, takes four consecutive months. Cumulative *household* noninterview rates are given in Table 5 for the 1984 SIPP panel.

At the time of the interviewer's visit, each person 15 years old or older who is present is asked to provide information about himself/herself; a proxy respondent is asked to provide information for those who are not available. An important design feature of SIPP is that all persons in a sample household at the time of the first interview remain in the sample even if they move to a new address during the next 2½ years. For cost and operational reasons, in-person interviews are only conducted at new addresses that are within 100 miles of a SIPP primary sampling unit. The geographic areas defined by these rules contain over 96% of the U.S. population. An attempt is made to conduct a telephone interview with those moving outside the 100-mile limit.

**Table 5**  
Cumulative Household Noninterview Rates  
for the 1984 SIPP Panels

Wave	Sample Loss
1	4.9%
2	9.4%
3	12.3%
4	15.4%
5	17.4%
6	19.4%
7	21.0%
8	22.0%
9	22.3%

After the first interview, the SIPP sample is a person-based sample, consisting of all individuals who were living in the sample unit at the time of the first interview. Individuals aged 15 and over who subsequently share living quarters with original sample people are also interviewed in order to provide the overall economic context of the original sample persons.

More detailed information concerning the SIPP design, content, and operations can be found in Nelson, McMillen, and Kasprzyk (1985).

### **3.1 Nonresponse Adjustments in SIPP**

Data collected in SIPP can be viewed from two perspectives: cross-sectional or longitudinal. From the former point of view, each SIPP interview is treated as a separate cross-sectional survey, providing point-in-time estimates. For examples of these estimates, see U.S. Department of Commerce, Bureau of the Census (1984a). From the longitudinal point of view, data are collected at more than one point-in-time, and the survey record is viewed not as a set of unrelated observations, but as a set of variables with logical dependency between two or more points-in-time. Data processing operations, as well as statistical estimation, are treated from this point of view, and therefore, rely on the use of data collected at two or more interviews.

Since SIPP can be viewed from both the longitudinal and cross-sectional perspectives, SIPP's public-use microdata files include cross-sectional data files issued on a wave-by-wave basis as well as longitudinal files. This implies two distinct systems to treat survey nonresponse.

#### **3.1.1 Cross-Sectional Unit Nonresponse Adjustments**

The cross-sectional unit nonresponse adjustment in SIPP is similar to the way noninterview adjustments are made in other Census Bureau recurring surveys. The following variables were used to define household noninterview adjustment cells for the first interview wave of SIPP. See U.S. Department of Commerce, Bureau of the Census (1983 and 1984b).

1. Census Region – Northeast, Midwest, South, West.
2. Residence – Standard Metropolitan Statistical Area (SMSA), non-SMSA.
3. Place/not place – defined for units not in an SMSA,  
Central city/balance – defined for units in SMSA's.
4. Race of reference person – black, non-black
5. Tenure – owner of home, renter.
6. Household size – 1, 2, 3, 4 or more.
7. Rotation group – 1, 2, 3, 4.

Two criteria must be met by each weighting class: (1) the weighting class must contain at least 30 unweighted units and (2) the noninterview adjustment factor for a weighting class must be less than or equal to 2.0. For a given rotation group, the collapsing procedure to satisfy these two criteria is applied independently for each of the four tenure by race combinations. (For the first wave, there was no *within*-household nonresponse adjustment factor.)

In subsequent waves of SIPP, the household nonresponse adjustment factor accounts for noninterviews associated with units which have moved and cannot be located or have moved more than 100 miles from a SIPP PSU and cannot be contacted by telephone as well as units which are refusals, etc. Adjustments are performed for each month of the reference period, as well as the interview month, to account for an increase in the number of noninterviews

caused by splits of sample households. The procedure is similar to that described for determining the Wave 1 household nonresponse adjustment factor; however, the variables used to define the weighting classes differ. Those variables are:

1. Race (white, nonwhite) and Spanish-origin (Spanish, non-Spanish) of reference person: a) reference person is white and not Spanish, and b) others.
2. Household type – three categories: a) female householder, no husband present, with own children under 16, b) householder's age is sixty-five years or older, and c) others.
3. Education level of the reference person: a) less than 8 years, b) 8-11 years, c) 12-15 years, and d) 16 or more years.
4. Type of income received (using the most recently completed interview for members of the household) – two categories: a) households which received at least one of the following sources of income – Supplemental Security Income; Black Lung Payments; Aid to Families with Dependent Children; General Assistance, Indian, Cuban, or Refugee Assistance; foster child care payment; Women's, Infants', and Children's Nutrition program; Food Stamps; and Medicaid; and b) others.
5. Assets – two categories: a) households in which at least one member held an asset type other than a savings account or an interest-bearing checking account, and b) all others.
6. Tenure: a) owner of home and b) renter.
7. Public housing or rent subsidies--renters are identified as a) those living in public housing projects or receiving rent subsidies from the government; and b) those not living in public housing projects and not receiving rent subsidies from the government.
8. Household size: 1, 2, 3, 4 or more.

The variables used for household nonresponse adjustments for the second and subsequent SIPP interviews differ from the first wave variables because of additional data available after the first interview for use in nonresponse procedures for later interviews. Fifty-three weighting classes were created using these variables with tenure as the principal variable for partitioning the sample. [For a description of these weighting classes see U.S. Department of Commerce, Bureau of the Census (1984c).] Although a cell collapsing strategy has been defined which merges cases in cells exhibiting similar poverty-related characteristics, little collapsing takes place since the nonresponse adjustment factors are calculated for three rotation groups (the SIPP data processing cycle) rather than one rotation group, as in the first interview.

There is a within-household nonresponse compensation procedure for the second and subsequent waves. This procedure is to "hot deck" (i.e., duplicate) the entire record of a sample respondent who presumably has survey characteristics that are similar to those of the nonrespondent.

### 3.1.2 Longitudinal Nonresponse Adjustments

Since persons identified as living at the sample address at the time of the first interview constitute the SIPP sample for waves subsequent to the first, the most useful and logical way of describing the nature of the SIPP nonresponse problem from the longitudinal viewpoint is in terms of individuals or persons. Each individual's microdata record is an extended record containing variables which oftentimes reflect the same measure at different points in time. Thus, in a panel survey of  $n$  waves there exist  $2^n$  possible noninterview patterns for a sample person. Noninterview patterns of the original sample persons for the first five interviews (waves) of the 1984 panel are given in Table 6, adapted from Kalton, McMillen, and Kasprzyk (1986).



**Table 6**  
Interview patterns of the Original Sample Persons for the First Five Interviews  
of the 1984 SIPP Panel

Response Pattern	Percent
Response every interview (5 interviews)	
Pattern: XXXXX	79.1
Apparent attrition cases	13.8
Patterns: XXXXO	3.8
XXXOO	3.1
XXOOO	3.2
XOOOO	3.7
First and fifth interviews conducted, but one and more intervening interview missing	4.1
Patterns: XXXOX	1.6
XOXXX	0.6
XXOXX	1.2
XXOOX	0.1
XOXOX	0.1
XOOOX	0.3
XOOXX	0.2
Fifth interview missing and one or more intervening interviews missing	0.7
Patterns: XOXXO, XOXOO, XOOXO, XXOXO	
Left the universe (deceased, institutionalized, living in armed forces barracks, moved overseas)	2.3
Total	100.0 (25,128)

The first SIPP longitudinal microdata file will contain twelve months (three interviews) of data from the 1984 SIPP panel, with the individual as the principal analytic unit. The sample of cases to be weighted for this file will be only those persons with three completed interviews. Those sample persons with only one or two interviews will be treated as nonrespondents. Their reported data will help to define nonresponse adjustment classes.

Since the first microdata longitudinal file contains only persons responding to all three interviews, the nonresponse adjustment issue is virtually the same as for the cross-section case. There are, however, two nonresponse adjustment factors applied to the initial sampling weights. See Kobilarcik and Singh (1986). The first adjustment factor accounts for households classified as noninterviews in the first interview wave. The second factor accounts for persons who did not supply all three interviews.

For the first adjustment factor, only those household variables available at the first interview can be used. Adjustment factors are calculated separately within cells defined by the following variables:

- a. Census Region
- b. Residence (metropolitan, non-metropolitan)
- c. Race of reference person
- d. Tenure (own, rent)
- e. Household size

The second set of adjustment factors is implemented on a person basis. The factors are calculated within cells defined by the following characteristics:

- a. Monthly household income
- b. Program participation status of the person's household
- c. Labor force status
- d. Race
- e. Years of school completed
- f. Type of assets of person's household

Cells are collapsed whenever they do not contain thirty sample persons or the nonresponse adjustment factor exceeds 2.

As the survey progresses, more sophisticated methods of adjusting for longitudinal nonresponse will be developed which make use of the data provided for partial respondents (i.e., for sample persons that provide some, but not all, of the interview waves requested). It is not obvious how to treat the partial response cases. Data gaps associated with persons who miss one or more interviews can be viewed as either person nonresponse, and typically handled by weighting adjustments, or as item nonresponse, usually handled by some type of imputation method. For example, one might consider an individual with a (R,NR,R) pattern as a case of item nonresponse since the missing interview is bounded on both sides by completed interviews; but one might consider an individual with an (NR,R,NR) pattern as total unit nonresponse, treating it the same as (NR,NR,NR). However, we need to recognize that even in the case of the response pattern (R,NR,R) for an individual, four kinds of response patterns are still possible at the item level. Thus, many options can be considered when developing nonresponse compensation procedures for the SIPP longitudinal data base. This issue is discussed by Kalton (1986) and by Kalton, Lepkowski, and Lin (1985).

### 3.2 SIPP Research Activities

There are two areas where work has recently begun which should aid future decisions concerning nonresponse adjustments. First, the SIPP questionnaire, beginning during the fourth interview, contains a "Missing Wave" section. This section uses a short series of questions on labor force participation, income sources, and asset ownership/nonownership for respondents in the current wave who did not respond in the preceding wave. Respondents who miss two or more consecutive interviews are not eligible to complete the "Missing Wave" section. By emphasizing data collection at the expense of minor reporting burden, the person nonresponse problem can be reduced to an item nonresponse problem. An evaluation of the quality of the retrospective data will be necessary prior to using these data.

The second area of work concerns general strategies in the treatment of person-wave nonresponse in the SIPP. Graham Kalton and his colleagues at the Survey Research Center will (1) compare longitudinal imputation and weighting strategies for handling person-wave nonresponse, (2) evaluate imputation and weighting models in terms of the analysis of change across waves and aggregation across waves, and (3) develop preliminary criteria for the choice of method for treating person-wave nonresponse. A discussion of these and other issues which will be studied can be found in Kalton (1986), and Kalton and Miller (1986).

Finally, there are several other research topics for which work is planned. These include: (1) quantifying the selection of variables used for determining weighting classes; (2) assessing the robustness of the survey estimates on the population and selected subgroups under different nonresponse compensation procedures, and different weighting class cell collapsing

strategies; (3) investigating the potential for making separate nonresponse adjustments by type of noninterview; (4) investigating the effect of deleting reported survey data to simplify the nature of the SIPP missing data problem; and (5) evaluating the longitudinal nonresponse compensation procedures adopted for the first SIPP longitudinal research file.

#### **4. UNIT NONRESPONSE PROCEDURES FOR ECONOMIC CENSUSES AND SURVEYS**

The Bureau of the Census carries out six economic censuses every five years, the most recent ones covering 1982. These six economic censuses are identified by the following trade areas:

- (1) Retail Trade
- (2) Wholesale Trade
- (3) Service Industries
- (4) Manufactures
- (5) Mineral Industries
- (6) Construction

In addition to the economic censuses, the Census Bureau carries out the Census of Governments and the Census of Agriculture. Though not part of the economic censuses, they are conducted during the same years as the economic censuses for processing efficiencies and to allow for data linkage. In nearly all of these economic areas the Census Bureau also carries out a number of monthly, quarterly, and annual surveys.

Like the demographic areas, there is some unit nonresponse for all of the economic censuses and surveys. In most cases, missing data are imputed based on (a) previous responses provided by the nonrespondent, (b) data from administrative records, and (c) relationships established between various data items. Rather than reporting the percent of units not responding, the level of nonresponse for an economic census or survey is usually given as the percent of one or more item totals that are imputed. These percents will be referred to as imputation rates.

Explanations of the unit nonresponse methods used for five of the six economic censuses are given in Section 4.1. Section 4.2 addresses unit nonresponse procedures for three economic surveys, and Section 4.3 covers such procedures for the Census of Agriculture. Research and evaluation activities with regard to nonresponse procedures for economic censuses and surveys are discussed in Section 4.4.

More detailed explanations of the nonresponse procedures used in these censuses and several related surveys are given by Bailey, Chapman and Kasprzyk (1985).

##### **4.1 The Economic Censuses**

The frame for the economic censuses is the Standard Statistical Establishment List (SSEL), a computer file maintained by the Census Bureau. The SSEL is comprised of all employer establishments reported by multi-unit employer companies in the Census Bureau's Company Organization Survey (COS) and all single-unit companies that filed a tax form with IRS. The COS is an annual survey of multi-unit companies. Companies that have at least 50 employees are surveyed each year, while companies with fewer than 50 employees are surveyed every three years. Each company in the COS is sent a list of the establishments it reported most recently in the survey and asked to update the list. They are also asked to provide, for each establishment, employee counts for the first quarter of the previous year and total payroll

for the previous year. For the economic censuses, each establishment on the SSEL, except small single-unit establishments, is sent a census questionnaire (via its company) designed for its standard industrial classification (SIC) code.

Although there are many similarities among the unit nonresponse procedures used in the six trade areas, some important differences exist. In the following description of the unit nonresponse adjustment procedures used for five of the economic censuses, the trade areas that use essentially the same procedure will be grouped together as follows:

- (a) Retail trade, wholesale trade, services
- (b) Manufactures, mineral industries

#### **4.1.1. Retail Trade, Wholesale Trade, Service Industries**

These three parts of the economic censuses are often referred to collectively as the business census. For these trade areas, data for the census year are collected on sales receipts, employment, and payroll. The imputation rate for sales/receipts varies from 10 to 15 percent for retail and wholesale trade and is about 20 percent for service industries.

For any establishment that does not provide the census data, responses are generally imputed using tax form information available from the Internal Revenue Service (IRS). For payroll information, the IRS has four quarters of data available for each employer identification (EI) number from tax forms. A company may have one or more EI numbers. Payroll data for a particular company are obtained by adding up the payroll figures for all EI numbers used by the company. First quarter employment counts are also available by EI number from IRS records and can be aggregated to the company level. For sales/receipts, various IRS forms are used depending on whether the nonresponding company is a sole proprietorship, partnership, or corporation.

The imputation procedure is complicated by the difference between the census enumeration unit and the IRS tax unit. For the business census, the unit of enumeration is the establishment (i.e., a single location). However, the tax unit for the IRS is an EI number. There may be one or more establishments reporting under the same EI number. If a nonresponding company has only one location (i.e., is a single-unit company), then it will have only one EI number and imputation is straightforward. However, for a multi-unit nonresponding company imputation is more complex since, in general, IRS data will not be available for each establishment. In such a case, the company structure is determined first by referring to the SSEL to obtain a list of all establishments contained in a company and all EI numbers used by the company. The total for a company for each data item is obtained by adding the item across all EI numbers used by the company, as discussed above. The company total is distributed to establishments by prorating the total based on the most recent data available for the company from an annual or monthly survey. If no data are available, an equal proration is used. If there is nonresponse for only a portion of the establishments in a multi-unit company, data for the nonresponding establishment are imputed based on prior year relationships.

#### **4.1.2 Manufactures, Mineral Industries**

In these two economic censuses, general information is obtained on the number of employees, hours worked, and on production levels by four-digit standard industrial classification (SIC) codes. Imputation rates vary from about 10 to 15 percent. The unit

nonresponse procedure used depends on the type of company that did not respond (i.e., single-unit or multi-unit) and on whether or not a previous year's record is available. Thus, there are four types of nonresponse cases that occur. The method of treating nonresponse for these four cases follows:

- (1) Single-unit company, previous year data are available from the Annual Survey of Manufactures.

In this case annual payroll is obtained from IRS tax forms and compared to the previous payroll total reported. The percent change from the previous period is determined. This percent change is applied to all data items in the previous record to obtain an imputed current record, except for employment and value of shipments whenever these are available from IRS.

- (2) Single-unit company, no previous year data are available.

In this case, sets of ratios are developed between census items within each four-digit SIC, with payroll as the "seed." That is, the relationships are developed in such a way that all items can be imputed from these relationships either directly or indirectly if a payroll figure is obtained. The specific relationships are derived from historic data reported by the respondents in the same industry. Then the (seed) value of payroll is obtained from IRS tax records and all other items are imputed from the relationships derived.

- (3) Establishment in a multi-unit company, previous year data are available for the establishment.

First, for each four-digit SIC, an aggregate growth factor between the previous and current period is developed from external sources for each of the following key items: payroll, employment, change in inventory, and change in capital expenditures. These four growth factors are applied to the appropriate prior year data items for each establishment to obtain imputed responses for the current period. These four imputed items are then used as "seeds" to impute other items.

- (4) Establishment in a multi-unit company, no previous year data are available for the establishment.

In this case, basic data on payroll and employment are obtained for each establishment from the SSEL discussed earlier in Section 4.1. As indicated, the SSEL obtains data on employment and payroll obtained for all establishments included in the COS. Then, using the SSEL data as a base, the data record for each establishment is imputed from relationships developed between the SSEL data items and the other census items. This procedure is analogous to that used in case (2) above.

## 4.2 Economic Surveys

The Census Bureau conducts a large number of monthly, quarterly, and annual economic surveys in addition to the economic censuses. In particular, most of the six census trade areas have monthly or annual surveys. The unit nonresponse procedures used for the Monthly Retail Trade Survey and the Truck Inventory and Use Survey are described below. The unit nonresponse adjustment procedure used for the Annual Survey of Manufactures (ASM) is not described here since it is virtually the same as that used for the Census of Manufactures, described in Section 4.1.2. Imputation rates for the ASM vary from 5 to 10 percent.

#### 4.2.1 Monthly Retail Trade

The Monthly Retail Trade Survey includes about 30,000 reporting units: about 3,000 selected with certainty and 27,000 selected on a probability basis. The certainty cases are surveyed each month, while a third of the noncertainty cases are surveyed each month. This provides a monthly mailing of about 12,000 reporting units. For a multi-unit company in the survey, a subsample of the establishments in the company is selected for inclusion. Monthly retail sales is the only item enumerated in the survey. The imputation rate for retail sales is about 11 percent.

If a single-unit certainty company or a sample establishment in a multi-unit certainty company does not report for a given month, a value for sales is imputed from the previous month's figure by multiplying it by a "ratio of identicals." This adjustment ratio is derived by dividing the weighted sum of the current month sales by the weighted sum of the previous month sales for all establishments in the same adjustment cell for which sales were reported for both the current and previous months. Adjustment cells are generally defined by the first three digits (or four digits in a few cases) of the SIC code, by type of establishment (i.e., whether or not it belongs to a large multi-unit firm), and by sales size class. The weight used for each reporting unit used in computing the ratio of identicals is the inverse of the probability of selection of the reporting unit.

If a multi-unit certainty company does not report sales for any of its establishments, the sales values are imputed for each establishment and for the entire company as in the previous case: applying the ratio of identicals for the appropriate adjustment cell to the previous month sales figures. If such a company does report current monthly sales for the entire company, the imputed establishment responses are ratio adjusted to be consistent with the reported total for the entire company.

For noncertainty companies, imputation for missing sales data is carried out in a way similar to that used for certainty cases, except that an extra step is required since noncertainty companies report every three months. The first step is to impute the previous month's sales for a nonrespondent based on the response provided three months ago. This is done by multiplying the sales reported three months ago by a ratio of identicals based on the weighted sum of sales during the previous month and the weighted sum of sales three months ago (cell by cell). Once the previous month sales are imputed, the current month sales is generated from the imputed value for the previous month using the same method described for certainty cases.

If a nonrespondent is in the survey for the first time, the previous month's sales (if it's a certainty case) or the sales figure three months earlier (if it's a noncertainty case) is imputed from the sales reported in the most recent census, if available. If the nonrespondent was not in the most recent census, then it would be a birth case for which two months of sales data generally would have been provided at the time the company was added to the frame. This data would be seasonally adjusted and then inflated to an annual-based figure. The imputation would then be carried out as though a census sales figure had been available for the nonrespondent.

#### 4.2.2 Truck Inventory and Use Survey (TIUS)

The TIUS is conducted every five years and provides data on the physical and operational characteristics of trucks nationwide. These characteristics include type of trailer (vehicle configuration), kinds of products carried, type of gasoline used, and annual miles driven. The universe for the survey consists of the truck registrations from all 50 states and the District of Columbia. The sample size is about 120,000 truck registrations. About 75 percent of the trucks selected for the survey respond.

Adjustments for unit nonresponse are made by “weighting up” the respondents to the total sample, separately within weighting classes. The weighting classes are taken to be the sample strata which consist of cross-classifications by state and body type (5 categories). The nonresponse weight adjustment is based on the number of trucks; within each class (stratum), the initial weight of each respondent is multiplied by the ratio of the number of trucks in the stratum to the sum of the initial weights of the respondents in the stratum.

Of the economic surveys investigated, the TIUS is the only one that uses a weight adjustment procedure to account for unit nonresponse. With other economic surveys, alternate sources of basic information are generally available to “build” a record for a nonrespondent.

#### **4.3 Census of Agriculture**

The census of agriculture provides data relating to the Nation’s farming, ranching, and related activities. It is the leading source of agricultural statistics and the only source of consistent, comparable data about agriculture at the county, State, and national levels.

The task of nonresponse adjustment for the census of agriculture is made complex by the fact that the SSEL cannot be as effectively used as it is in the other economic areas. The agricultural census mailing list is constructed by combining several overlapping sources. The resultant frame may contain some duplication and always contains some nonfarm entities. Thus, the nonresponse methodology must first identify, or estimate, the extent to which an adjustment is needed before it can take place.

For the 1982 census, nonrespondents were designated as large or small based on whether their expected sales were above or below \$100,000. A 100% telephone follow-up was conducted for all of the large nonrespondents. The small nonrespondents were then stratified based on other mail list characteristics. A sample of these units was followed up by mail and telephone to obtain estimates, by strata within states, of the percent of nonrespondents which were actually farms. These estimates were then used, along with data on in-scope percents of *respondents* by county, to make estimates of the number of nonrespondent farms at the county level for each stratum. The weights of a randomly selected sample of respondents by county, consistent with the estimated number of nonresponding farms, were then inflated by two. All other respondents retained their weight of one.

#### **4.4 Research Activities for Nonresponse Adjustments in Economic Surveys**

Probably the most important source of information for unit nonresponse imputation in economic surveys is IRS data from tax forms. Some differences between the IRS figures and those collected in the economic census may arise because of differences in definitions, forms, or the data collection procedures used. A study by Dyke (1984) compared administrative (IRS) data used to impute sales/receipts, payroll, and employment in the 1977 business census with corresponding responses obtained in a follow-up sample of nonrespondents. In general, he found that the survey values reported in the follow-up survey exceeded those obtained from administrative sources. The sizes of the differences varied by item. Also, the differences were more pronounced for multi-unit establishments. Additional comparisons of this type are needed. If systematic differences are identified, adjustment factors to apply to IRS figures may be developed.

For several of the censuses and surveys, a “ratio of identicals” is calculated and used to obtain a factor to apply to a previous-period figure to obtain an imputed value for the current period. It is possible that this ratio computed among *all* sample cases that reported in both periods may not apply very well to the nonrespondents for some items. Bailey (1986) looked at alternatives to using ratios of identicals for imputing missing values such as linear regression and quadratic regression, using various sets of independent variables.

With many of the economic unit nonresponse imputation methods, the sample cases – both respondents and nonrespondents – are placed into cells prior to computing (a) some type of ratio between current and prior periods for an item or (b) some type of relationship between the survey items and the basic items: payroll, employment, and receipts. A research project to investigate alternate choices of cell definition for the Monthly Retail Trade Survey was recently completed by Huang (1986). She found that for some SIC’s an alternate procedure of defining cells reduces the mean square error (MSE) of estimated sales substantially. In addition, she compared the current method of imputing – using ratios of identicals – to three alternate methods with respect to bias and MSE. The current method was evaluated as the second best procedure. However, she concluded that the slight gains of the optimum procedure may not be worth the additional requirements associated with using it.

## **5. IMPUTATION FOR EARNINGS IN THE CURRENT POPULATION SURVEY**

### **5.1 The Hierarchical Hot Deck**

The Current Population Survey (CPS) is a Census Bureau ongoing monthly survey of about 60,000 U.S. households per month. The CPS, sponsored by the Bureau of Labor Statistics, primarily collects labor force and employment information. Each March, the CPS administers an income supplement as part of the survey questionnaire. About 11-12% of the sample members do not respond to the income questions. Therefore, a special procedure, referred to as the “hierarchical hot deck,” has been developed to impute for missing responses.

With the hierarchical hot deck, missing earnings values are inserted from the response record of another sample unit – a donor. The goal in selecting a donor is to find one with survey characteristics similar to those of the item nonrespondent. The first step in the process of finding suitable donors is to partition the entire sample, excluding total noninterview cases, into cells based on multi-way classifications of a number of survey characteristics. Within each cell a list is made of the respondents and nonrespondents for a given item. Donors from the list of respondents are assigned to the nonrespondents systematically, with a random start. If there are more nonrespondents than there are respondents in a cell for a given item, the responses of some, or perhaps all, of the respondents in the cell will be used more than once. In some cells, there may be one or more nonrespondents but no respondents for an item.

To avoid the problem of having nonrespondents with no donors available, the process of defining cells and selecting donors for the item nonrespondents is carried out several times. At each stage, fewer cells are defined than were defined for the previous stage. For the final stage the number of cells defined is small enough so that it is certain that there will be donors available in each cell. The cells defined at successive stages are formed by collapsing the cells used at the previous stage. Each item nonrespondent will have one or more donors assigned. The donor used to obtain an imputed value will be the one identified at the earliest stage.



The major advantage of this hierarchical procedure is that a very large number of cells can be defined at the first stage, due to the backup stages used. Whenever a donor is found at the first stage, the item nonrespondent and donor will be matched on a large number of survey characteristics. In such cases there should be a good chance that an adequate imputation is made. In other cases the item nonrespondents and donors will be matched on fewer characteristics. This hierarchical procedure tries to pick donors in a way that maximizes the number of matched relevant survey characteristics.

For a more detailed description of this of this procedure, see Welniak and Coder (1980), Oh and Scheuren (1980a), or David, Little, Samuhel, and Triest (1986, Section 2).

## 5.2 Evaluation of the CPS Hierarchical Hot Deck

There have been some evaluation studies of the CPS Hot Deck: Welniak and Coder (1980); Oh and Scheuren (1980a and 1980b); Lillard, Smith, and Welch (1982); and David *et al.* (1986). One of the weaknesses noted of the CPS hot deck is that donor values may be used repeatedly, resulting in variance increases. The procedure could be modified to avoid using donor values more than once or twice; however, this change has not been made. The CPS hot deck procedure is based on the assumption that the distribution of responses for a survey variable is the same for respondents and nonrespondents in the same cell – the ignorability assumption.

David *et al.* (1986) developed several model-based alternatives to the CPS hot deck and evaluated them and the CPS hot deck with respect to mean absolute and mean relative error. These evaluations were based on a CPS-IRS matched file. In creating this file, an attempt was made to match the March 1981 CPS file to the IRS tax records for 1980. Despite the hot deck's apparent limitations, the CPS hot deck had a lower mean absolute and mean relative error than did the model-based alternatives. However, the models were developed for only 10% of the full CPS sample used to develop the hot deck procedure.

## 6. SUMMARY AND AREAS OF FUTURE STUDY

In this paper an attempt has been made, primarily through examples, to describe the current approaches being taken to nonresponse adjustments in the U.S. Census Bureau's censuses and surveys. Emphasis has been placed on the need for additional empirical and theoretical studies in both the demographic and economic areas in order to provide more objective guidelines (a) to design nonresponse compensation procedures and (b) to measure the effects of nonresponse on survey results for a variety of survey conditions.

Some of the research called for in this paper is already underway but more will be needed. For example, to what extent can available ancillary data be used in conjunction with modeling and data analysis procedures to identify the key functional relationships needed to provide a "reasonably" accurate description of the response/nonresponse structure applicable to a given survey?

In general, adjusting for nonresponse is just one of several steps taken to reduce the variance and bias of survey results. The degree to which these other steps aid in reducing the impact of nonresponse is an area for further research. Moreover, there should be continued efforts in support of research on recurring issues such as the impact of unit nonresponse weights and item nonresponse imputation on complex variance estimators, model approaches to determining appropriate adjustment factors, and the effectiveness of combining various types of nonresponse adjustment techniques.

## ACKNOWLEDGEMENTS

The authors are very appreciative of the useful information received on the nonresponse adjustment procedures used for many of the U.S. Census Bureau's Censuses and Surveys.

This information was provided by personnel in several Census Bureau divisions, including Agriculture Division, Business Division, Construction Statistics Division, Economic Surveys Division, Governments Division, Industry Division, Statistical Methods Division, and the Statistical Research Division.

The authors are grateful to Dr. Fritz Scheuren for reviewing the draft and providing many helpful comments.

The authors are also indebted to Hazel Beaton, Alice Bell, and Valerie Howard for the diligence and patience they displayed in typing the manuscript.

## REFERENCES

- ANDERSON, H. (1978). On nonresponse bias and response probabilities. *Scandinavian Journal of Statistics*, 6, 107-112.
- BAILEY, L. (1986). A study of alternative imputation techniques for surveys in the Current Industrial Reports. Internal Census Bureau Report, December 24.
- BAILEY, L., CHAPMAN, D.W., and KASPRZYK, D. (1985). Nonresponse adjustment procedures at the Census Bureau: A Review. *Proceedings of the Bureau of the Census First Annual Research Conference*, 421-444.
- DAVID, M., LITTLE, R.J.A., SAMUHEL, M.E., and TRIEST, R.K. (1986). Methods for CPS income imputation. *Journal of the American Statistical Association*, 81, 29-41.
- DYKE, T.C. (1984). Evaluation of the use of administrative record data for establishments which were non-respondents to the 1977 Census of Wholesale Trade, Retail Trade, or Selected Services. Internal report: Statistical Research Division Report Series, No. Census/SRD/RR-84/08, U.S. Bureau of the Census.
- HANSON, R. (1978). The Current Population Survey: Design and Methodology. Technical Paper No. 40, Washington, D.C.: U.S. Bureau of the Census, pp. 55-59.
- HUANG, E.T. (1986). Comparison of different imputation procedures in the Monthly Retail Trade Survey. To appear in the *Proceedings of the Section on Survey Research Methods, American Statistical Association*.
- KALTON, G. (1986). Handling wave nonresponse in panel surveys. *Journal of Official Statistics*, 2, 303-314.
- KALTON, G., and 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. and KASPRZYK, D. (1986). Nonsampling error issues in the Survey of Income and Program Participation. *Proceedings of the Bureau of the Census Second Annual Research Conference*, 147-164.
- KALTON, G., and MILLER, M. (1986). Effects of Adjustments for Wave Nonresponse on Panel Survey Estimates. To appear in the *Proceedings of the Section on Survey Research Methods, American Statistical Association*.
- KOBILARCIK, E.L., and SINGH, R.P., (1986). SIPP: Longitudinal estimation for persons' characteristics. To appear in the *Proceedings of the Section on Survey Research Methods, American Statistical Association*.
- LILLARD, L., SMITH, J.P., and WELCH, F. (1982). What do we really know about wages: The importance of non-reporting and census imputation. *Journal of Political Economy*, 94, 489-506.
- LITTLE, R.J.A. (1986). Missing data in Census Bureau Surveys. *Proceedings of the Bureau of the Census Second Annual Research Conference*, 442-454.

- LITTLE, R.J.A., and SAMUHEL, M.E. (1983). Imputation models on the propensity to respond. *Proceedings of the Section on Survey Research Methods, American Statistical Association*, 415-420.
- NELSON, D., McMILLEN, D., and KASPRZYK, D. (1985). An overview of the Survey of Income and Program Participation: Update 1. SIPP Working Paper Series No. 8401, U.S. Bureau of the Census.
- OH, H.L., and SCHEUREN, F.J. (1980a). Estimating the variance impact of missing CPS income data. *Proceedings of the Survey Research Methods Section, American Statistical Association*, 408-415.
- OH, H.L., and SCHEUREN, F.J. (1980b). Differential bias impacts of alternative Census Bureau hot deck procedures for imputing missing CPS income data. *Proceeding of the Survey Research Methods Section, American Statistical Association*, 416-420.
- OH, H.L., and SCHEUREN, F.J. (1983). Weighting adjustment for unit nonresponse. In *Incomplete Data in Sample Surveys*, Vol. 2, (Eds. W.G. Madow, I. Olkin, and D.B. Rubin), New York: Academic Press, 143-184.
- PALMER, S., and JONES, C. (1967). A look at alternate imputation procedures for CPS noninterview. *Proceedings of the Social Statistics Section, American Statistical Association*, 73-80.
- PAUL, E.C., and LAWES, M. (1982). Characteristics of respondent and nonrespondent households in the Canadian Labour Force Survey. *Survey Methodology*, 8, 48-85.
- POLITZ, A., and SIMMONS, W. (1949). An attempt to get the 'Not-At-Homes' into the sample without callbacks. *Journal of the American Statistical Association*, 44, 9-31.
- ROSENBAUM, P., and RUBIN, D. (1983). The central role of the propensity score in observational studies for causal effects. *Biometrika*, 70, 41-55.
- THOMSEN, I., and SIRLING, E. (1983). On the causes and effects of nonresponse: Norwegian experiences. In *Incomplete Data in Sample Surveys*, Vol. 3, (Eds. W.G. Madow, I. Olkin, and D.B. Rubin), New York: Academic Press, 25-59.
- U.S. Department of Commerce, Bureau of the Census (1977). National Crime Survey, national sample, survey documentation. U.S. Bureau of the Census Report.
- U.S. Department of Commerce, Bureau of the Census (1983). Cross-sectional weighting specifications for the first wave of the 1984 panel of the Survey of Income and Program Participation (SIPP). Internal U.S. Bureau of the Census Memorandum from C. Jones to T. Walsh, November 25.
- U.S. Department of Commerce, Bureau of the Census (1984a). Economic characteristics of households in the United States: Third Quarter 1983. *Current Population Reports, Series P-70, No. 1*, Washington, D.C.: U.S. Government Printing Office.
- U.S. Department of Commerce, Bureau of the Census (1984b). 1984 SIPP first wave weighting-first stage estimate factors and specifications for collapsing noninterview adjustment calls. Internal U.S. Bureau of the Census Memorandum from C. Jones to T. Walsh, February 16.
- U.S. Department of Commerce, Bureau of the Census (1984c). SIPP weighting: subsequent wave cross-sectional - revised. Internal U.S. Bureau of the Census Memorandum from C. Jones to T. Walsh, October 12.
- WELNIAK, E.J., and CODER, J.F. (1980). A measure of the bias in the March CPS earnings imputation scheme. *Proceedings of the Survey Research Methods Section, American Statistical Association*, 421-425.
- YCAS, M., and LININGER, C. (1981). The income survey development program: Design features and initial findings. *Social Security Bulletin*, Vol. 44, No. 11, November.