A CONCEPTUAL REVIEW OF SURVEY ERROR DUE TO NONRESPONSE

William D. Kalsbeek, University of North Carolina at Chapel Hill

1. Introduction

Nonresponse has long been recognized as an important potential source of error in surveys with attention to it being preceded only perhaps by errors due to probability sampling. It represents a clearly visible "flaw" in data collection which can be seen and appreciated by both the statistician and the nonstatistician. The result is that the literature on nonresponse error is considerable and diverse with much of its diversity stemming from the variety of survey settings in which nonresponse has been encountered and from the numerous remedies or partial remedies that have been advanced.

The principal objective of this paper is to develop a characterization of survey errors due to nonresponse as evident from existing literature.[1] This will amount to first discussing the different definitions that have been used in various contributions to the existing literature. A more general view of the problem will then be suggested by attempting to identify linkages among the papers which were reviewed. Because of its scope, less attention will be given to technical details and more to how the problem of nonresponse is viewed by each contributor. For this reason, we might consider the paper to be a conceptual rather than a technical review of the literature dealing with this important cause of error.

2. Terminology

Two general impressions regarding terminology emerge from a review of the literature on nonresponse errors. One is the notable lack of specificity of definitions in many papers. More specific definitions tend to emerge in standard sampling textbooks like Kish [1965] and Cochran [1977] as well as in other publications dealing with specific statistical definitions like Kendall and Buckland [1960] and U.S. Bureau of the Census [1975]. On the other hand, authors in journal articles often refer to these concepts without specifically stating a definition or by stating a trite definition (sometimes in mathematical terms) without discussion. A second general impression of the literature is the considerable diversity of terminology which is used to define some of these concepts. Not only does this diversity apply to the term being defined but also to terms being used to produce the definition. Some indication of the degree of diversity can be seen by observing the variation in terminology associated with three common concepts: nonresponse, response (or nonresponse) rate, and nonresponse bias.

Kish [1965] and Cochran [1977] refer to the problem of failure to obtain a completed response from all sample members as "nonresponse" while authors like Zarkovich [1966] and Ford [1976] refer to the problem of "missing data." Sudman [1976] talks about biases due to "noncooperators," Suchman [1962] refers to the problem of "sampling mortality," and Sukhatme and Sukhatme [1970] describe the impact of "incomplete samples." Birnbaum and Sirken [1950] derive results for the bias due to "nonavailability of respondents" although their results are applicable to those who do not respond for other reasons. In all cases, these discussions appear to think of nonrespondents in terms of elements which are eligible for the study but fail to respond.

Response and nonresponse rates are complementary relative measures of the extent of nonresponse in a survey. They are, however, not always referenced in these terms by all authors. For example, Sudman [1976] refers to the "cooperation rate" while Kendall and Buckland [1960] suggest the terms "failure rate," "refusal rate," and "nonachievement rate" to signify certain specific relative measures. Hauck and Steinkamp [1964] define a "completeness rate" and a rather unusual "response rate" defined as the proportion of contacts which respond. In a survey of 40 market research firms, Wiseman and Mc Donald [1980] report that "response rates" were calculated in 29 different ways in summarizing the results of telephone interview surveys.

Bias associated with nonresponse has been referenced by several descriptive phrases other than the usual "nonresponse bias." Goudy [1976], for example, calls it "response bias" which also happens to be the name for a measurement error term. Birnbaum and Sirken [1950] refer to "nonavailability bias" and Politz and Simmons [1949] provide a remedy for what they call, "not-at-home bias."

3. Principal Dimensions

In this section we intend to characterize the existing literature on errors due to nonresponse in terms of several dimensions within which, we submit, most research on this topic can be classified. To facilitate this discussion we first make a brief digression to take a more careful look at the survey process in which nonresponse is generated. This leads to several definitions which help to clarify our later discussion of the proposed dimensions. For convenience we limit our attention to interview surveys, although the ensuing definitions can be applied to other types of surveys as well.

We begin by defining three general steps in the survey process: location, solicitation, and data collection. Location refers to that step in the survey process in which the interviewer, having been given a name or address, attempts to locate and confront the element selected in the sample. Solicitation follows location and is defined as the interviewer's attempt to obtain agreement by the selected element to participate in an interview. Given success in this attempt, the selected element now becomes a "participant" in the survey thus leading to the third step. Data collection is the process of proceeding through a survey interview. It is hoped that a response will be obtained for all questionnaire items (i.e., questions); yet one must also consider the possibility that responses will not be obtained for some items. Having defined the three steps in the survey process, we now present several definitions associated with response at various stages of the survey process.

We first consider nonresponse occurring during the combined processes of location and solicitation. Let us define, for a population of N elements of which m are selected in a sample, the random vector $d_N=[d_1, d_2,\ldots d_N]'$ whose i-th entry is the random variable

$$d_i=\begin{cases}1 & \text{If the i-th population element, if selected, would participate in the interview.}\\ 0 & \text{If otherwise.}\end{cases}$$

For the sample of m selectees we define (comparably) $d_m=[d_1, d_2,\ldots d_m]'$. Associated with d_N and d_m are vectors of response probabilities $p_N=[p_1, p_2,\ldots p_N]'$ and $p_m=[p_1, p_2,\ldots,p_m]'$ where the i-th component of p_N and p_m is a response probability.

$p_i = Pr(d_i=1)$

= Probability that the i-th element will be located and agree to participate.

We next define some terms for nonresponse during data collection. Suppose that n of m selectees agree to become survey "participants." If the questionnaire consists of k items, define the n x k matrix of random variables $\Delta_n=\{\delta_{ij}\}$ where

$$\delta_{ij}=\begin{cases}1 & \text{If the i-th element (given selection and participation) provides information for the j-th questionnaire item.}\\ 0 & \text{If otherwise.}\end{cases}$$

Corresponding to each δ_{ij} is the probability

$\pi_{ij} = Pr(\delta_{ij}=1)$

= Probability that the i-th element (given selection and participation) provides the information for the j-th questionnaire item.

and the probability matrix $\Pi_n=\{\pi_{ij}\}$.

Dimension 1: Basic Conceptual View of Nonresponse

The basic view of how nonresponse occurs in surveys is categorized according to two different models. The choice between these models, as can be demonstrated, affects the nature and structure of errors due to nonresponse. For example, error models formulated from the stochastic view tend to be more complex than models developed from the deterministic view (see Platek, et al. [1977]). Thus, it is important to consider this dimension in the development of a taxonomy of nonresponse errors.

[1] Deterministic Model---In this view, the population of N elements is assumed to consist of two mutually exclusive and exhaustive subsets (or strata) of N_1 elements which would participate with certainty, if selected. Thus, $N_0+N_1=N$ and $\lambda_1=N_1/N$ and $\lambda_0=N_0/N$ are the respective proportions of the population elements. The sizes of λ_1 and λ_0 in this "fixed-stratum model" are dependent upon the location and solicitation procedures used. Considering the earlier definitions in this deterministic view of nonresponse, the d_i (and d_N) are (point) random variables such that,

$$d_N=p_N \text{ and } N_1=\sum_i^N d_i=\sum_i^N p_i.$$

Also, $p_m=d_m$ consists of n ones (participants) and m-n zeros (nonparticipants) such that

$$n=\sum_i^m d_i=\sum_i^m p_i \text{ and } r=\frac{n}{m} \text{ is the observed response rate.}$$

The deterministic view is followed in most sampling and survey textbooks and is the basis for much of the earlier literature on nonresponse errors. Although never specifically stating it, Hansen and Hurwitz [1946], in their landmark paper on accommodation by double sampling, clearly assume a deterministic model. Birnbaum and Sirken [1950] take a similar view since N_1 and N_0 are viewed as parameters of the population and therefore, not subject to random variation due to stochastic nonresponse. Authors like Ericson [1967], Rao [1968], and Srinath [1971], who have extended the Hansen-Hurwitz results, also implicitly follow this deterministic view. Ford [1976] and Bailar and Bailar [1978] adopt a similar view in discussing imputation methods.

[2] Stochastic Model---Representing perhaps a more realistic view, a stochastic model is distinguished from a deterministic model in that the p_i of p_N (or p_m) in the former case, can assume any value between zero and one, whereas, in the latter case we must have $p_i=0$ or $p_i=1$. By relaxing our restriction on the p_i we create an additional analytic complexity in that another source of variation is created. For example, we now have uncertainty associated with the outcome of the d_i in d_m since in the stochastic view we will observe $d_i=1$ a proportion p_i of the time (or trials) and $d_i=0$ the remaining proportion $1-p_i$ of the time.

Considerable variation exists within the stochastic view. One view is attributable to Politz and Simmons [1949] who developed (from an earlier idea by Hartley [1946]) perhaps the first method designed to accommodate the nonresponse problem while following a stochastic view. This approach assumes p_N with unknown $0\le p_i\le 1$, $(i=1, 2,\ldots,N)$, which follows some discrete distribution over N elements. Deming [1953], in his justification for utilizing multiple call-backs to selectees, views the population as consisting of six classes, according to the average proportion of interviews that would be completed successfully out of 8 attempts. Rubin [1977] follows the Bayesian viewpoint to formulate a measure of the impact of nonresponse. Reference here is made to a stochastic view in terms of one's propensity to be a nonrespondent, which is seen as dependent on certain background characteristics like age, race, income, etc. Platek, et al. [1977], provide a conceptual review of several alternative methods for handling nonresponse in a complete enumeration setting. Of major importance here is the development of a so-called "response-nonresponse error model" incorporating contributions due to both measurement and nonresponse errors. The population is viewed as a collection of elements, each of which has a given response probability, given that the element is selected. An extension to the Platek, et al. results for panel surveys is given by Lessler [1979], the principal distinction being that response probabilities are defined in terms of elements and panels over time. Finally, Frankel and Dutka [1979] consider a model in which the response probabilities in the population are assumed to follow a "latent response function," f(p) which is the continuous density function of a beta distribution, $f(p)=p^{u-1}(1-p)^{v-1}$.

Dimension 2: Type of Parameter Being Estimated

A second dimension in our view of the literature on nonresponse error is the type of population parameter that is involved in analysis. Within this dimension three levels are suggested, based more upon the frequency with which they were encountered in our literature review than upon conceptual differences.

[1] Population Mean---With a few notable exceptions, which are discussed below, most sampling and survey textbooks, as well as the remainder of the existing literature on nonresponse errors, deal with the problem of estimating a generalized population mean. Papers like Birnbaum and Sirken [1950] are minor exceptions in that they deal with proportions.

[2] Population Total---Several papers in the literature on nonresponse errors consider totals as the type of parameter. Notable among these are two of the foundation papers by Politz and Simmons [1949] and Hansen and Hurwitz [1946]. More recently, the theory given by Platek, et al. [1977] focuses on the problem of estimating totals from a general stochastic response model. Others have presented various results for both means and totals combined. Kish [1965], for example, contrasts the relative biases of estimated means and totals. Deming [1953] quantifies the relative bias of nonresponse for means and totals after varying the number of call-backs. Estimators and corresponding variances are derived by Rao [1968] for means and totals where nonresponse occurs in connection with frame duplication.

[3] Other Types of Parameters---A single level encompasses all remaining population parameters since little research has been published. The principal deterrent, we suspect, is the difficulty in conceptualizing and formulating the bias. In our review of the literature, investigations of the effect of nonresponse error on "other" types of parameters tended to consist mainly of empirical comparisons of estimates by "wave analysis." This technique involves creating estimates for respondents according to the degree of difficulty in getting them to respond. "Difficulty" is usually determined by the number of follow-up attempts required to obtain cooperation. For example, Goudy [1976] detects some notable differences in the size of regression coefficients obtained from cumulative waves of respondents. Suchman [1962], on the other hand, analyzes the effects of nonresponse on "interrelationships among variables."

Dimension 3: Effect of Nonresponse Bias

By "effect of nonresponse bias" we generally refer to that component or components of nonresponse error which are either reported or accommodated. For this reason, the third dimension might also be called the "view of nonresponse bias" since much of what we consider here reflects the various interpretations of the definition of nonresponse bias.

Justification for the categories of this dimension can be recognized by noting the basic components of nonresponse bias. For this, we consider the problem of estimating a population mean using the simple but common deterministic two-stratum model discussed earlier. It can be shown that the nonresponse bias of an estimator for which no adjustments for nonresponse have been made is $I = \mathcal{E}\mathcal{D}$, where I is the size of the bias, $\mathcal{E} \equiv \lambda_0 = 1-\lambda_1$, and $\mathcal{D} \equiv (\bar{Y}_1 - \bar{Y}_0)$ is the difference of means for respondents and nonrespondents.

[1] Impact---We define the "impact" effect of nonresponse as the quantifiable size of the bias which results. Impact is, therefore, a direct measure of the effect of nonresponse. In the case of a two-stratum deterministic model where the objective is to estimate a population mean (or total), impact corresponds to the term . More generally, for an estimator $(\hat{\theta}_1)$ of θ derived from respondent data alone, $I = E(\hat{\theta}_1) - \theta$.

Our review of the literature identified few attempts to measure impact directly. Kalsbeek and Lessler [1977] produce measures of bias and "bias-ratios" for an assessment of nonresponse in a large educational assessment survey. Rubin [1977] uses Bayesian methods to calculate confidence bounds on sample estimators developed as if complete response had occurred.

[2] Extent---"Extent" refers to the quantifiable amount of nonresponse (or conversely, response) found in a survey. This is often measured by the so-called "response rate" (or, conversely, the nonresponse rate). Considering the earlier formulation for bias, we might view extent in terms of $\mathcal{E}$ for estimated means. In the literature, one usually notes extent measured in terms of response rates $1-\mathcal{E}$. Several authors, including Love and Turner [1975], Bailar and Lanphier [1978, pp. 36-37], Cannell [1977, pp. 13-17], Kish [1965, pp. 539-541], Moser and Kalton [1972, pp. 171-173], and Benus and Ackerman [1971] present a set of response rates from recent surveys. In addition, most good present-day surveys compile and report response rates as part of routine project documentation and publication in the general literature.

[3] Respondent--Nonrespondent Differences---A third important component of this dimension is $\mathcal{D} = \bar{Y}_1 - \bar{Y}_0$ representing mean differences between responding and nonresponding elements. A relatively small but significant segment of the literature on nonresponse includes studies which attempt to establish whether $\mathcal{D} = 0$ in which case, nonresponse might no longer be considered a "problem."

In most instances, $\mathcal{D}$ cannot be estimated directly. Instead, considerable attention has been given to comparing sample respondents and nonrespondents with respect to variables which are available for both groups and thought to be related to important survey measurements. Recent contributions adopting this stance include Pucel, et al. [1971], Pavalko and Lutterman [1973], and Gannon, et al. [1971].

Dimension 4: Level of Nonresponse

Recalling our earlier definitions, attrition occurring during location, solicitation, and data collection was described in terms of the random vector d_m and the matrix Δ_n. These two stochastic entities represent categories of a fourth dimension of the problem of nonresponse errors.

[1] Element Nonresponse---We assume that the population from which we sample consists of basic units called "elements" from which our survey observations (i.e., interview data) are obtained. "Element nonresponse" refers to nonparticipation resulting from failure to successfully complete location or solicitation of these elements. The outcome at this level of nonresponse is indicated by the vector d_m with corresponding probability vector, p_m.

Our review of the literature reveals that most contributions deal with (or at least implicate) the notion of element nonresponse. Discussion in most of the standard textbooks focuses on survey nonresponse in such a way as to clearly point to the element level. Perhaps, in these and other similar references, the intent is to view the one-question survey setting as specified by Birnbaum and Sirken [1950] in which case the matrix Δ_n is not required since k=1.

[2] Item Nonresponse---Given participation at the element level, "item nonresponse" is said to have occurred when data for a particular questionnaire item are unavailable for survey analysis. Most frequently, this level of nonresponse occurs because the participant refuses to answer a sensitive or personal question or because the interviewer fails to legibly record the participant's answer to the question. Following earlier notation, the outcome at this level of nonresponse is indicated by the matrix Δ_n with corresponding probability matrix Π_n.

The literature on item nonresponse appears to be characterized by papers which either consider a specific technique for accommodating the problem or compare a subset of these techniques, either analytically or empirically. For example, Buck [1960] presents a multivariate approach to item imputation. Ford [1976], on the other hand, describes the results of a simulation study which compares several item imputation methods as applied to simple stratified sampling designs. Bailar and Bailar [1978] discuss an analytical comparison of two item imputation methods, the "hot-deck" procedure and the uniform nonresponse adjustment. Finally, Chapman [1976] presents a comparative discussion of existing imputation methods for both element and item nonresponse.

Dimension 5: Source of Nonresponse

A fifth dimension of the problem of nonresponse can be viewed simply as the "source of nonresponse," or equivalently as types of or reasons for nonresponse. It is within this dimension that one observes the greatest diversity in terminology and where general categories are not readily obvious. The explanation, as one might suspect, is that reasons for failing to respond in each survey are particular to the general type of survey. Five levels for this dimension are proposed below.

[1] Ineligible--Out-of-scope for survey observation due to failure to meet eligibility criteria or due to certain field errors (e.g., household listed outside of a sample area). Examples: not a housing unit, deceased, vacant housing unit, and demolished housing unit.

[2] Unable to Locate--Nonresponse occurring during the "location" step of the survey process. Examples: not-at-home, noncontact, and respondent temporarily unavailable.

[3] Located but Unwilling--Successful location but unsuccessful solicitation due to unwillingness on the part of the selected element or interviewer. Examples: refusal and failure to return (mail) questionnaire.

[4] Located but Incapable--Successful location but unsuccessful solicitation due to physical, mental, or emotional incapacity. Examples: deaf, infirmed, and unsuitable for interview.

[5] Other Eligible--Catch-all category for remaining eligible nonrespondents. Examples: lost questionnaire and cut-off.

Dimension 6: Accommodation of Nonresponse

The final dimension we consider deals with the nature of steps taken by the survey investigator in acknowledgement of the potential difficulty the nonresponse errors can pose. In concrete terms this refers to these efforts made to calibrate, reduce, or (ideally) eliminate the impact of nonresponse on analysis.

[1] Preventive Methods---The preventive level of accommodation methods generally refers to nonstatistical steps that are taken before or during field operations with the intention of increasing the tendency of elements in the survey to participate. Fundamental to this view is that by so-doing, one will reduce the size of the nonresponse bias or any other error component arising as a result of nonresponse. Extensive general discussions of preventive measures are presented in Kish [1965], Zarkovich [1966], Daniel [1975], and Warwick and Lininger [1975]. Other more specific measures are presented elsewhere. For example, Chromy and Horvitz [1978] have examined the utility of incentives in surveys, while Kalsbeek and Hartwell [1977] have studied the effect of professional endorsements on response rates.

[2] Post Hoc Methods---The post hoc level of accommodation consists mainly of statistical procedures which serve as "stop gap" measures and which are designed to either measure or reduce the impact of nonresponse errors. Most of these methods are applied during or after data collection and may involve either explicit or implicit development of imputed values for missing data items. Eight types of post hoc methods are briefly discussed below:

[A] Identification Studies--This is the term given to a variety of investigations which seek to establish the likelihood that nonresponse causes a nonzero impact on analyses performed on data from specific surveys. These investigations tend to be empirical and of two general types. In one type of study, survey respondents and nonrespondents are compared using auxiliary data available to both groups, the rationale being that differences in auxiliary data raise the possibility of a nonresponse problem. In the second type, survey analyses are performed on separate waves of the survey. For example, "waves" in mail surveys refer to individuals responding after successive follow-up mailings or telephone reminders. The rationale here is that elements which agree to participate after t calls become increasingly similar to nonrespondents as t increases.

[B] Direct Imputation Methods---"Gaps" in survey data files due to missing item data are "patched up" in this class of imputation methods by explicitly substituting a reasonable replacement value given the characteristics of the element. For individual questionnaire items, survey data files contain a measurement for each element which can then be applied for whatever analytical purpose. In our current terminology, an explicit Z_i exists wherever missing data occur. Examples of such methods are: (1) cold-deck procedure in which Z_i is obtained from "similar" elements from an external source, (2) hot-deck procedure in which Z_i is obtained from the current survey, (3) administrative record match procedure in which Z_i is obtained via matching for each element from external data for the same element, and (4) regression method in which Z_i is an estimate from a fitted regression model.

[C] Indirect Imputation Methods--Indirect imputation methods generally produce data files in which respondent data have been "adjusted" in any of several ways. This adjustment process, as can be illustrated, is equivalent to implicitly assigning (but never using) a Z_i imputed value for each missing element. Examples of indirect methods are: (1) overall nonresponse adjustment in which Z_i implicitly assumes the value of the mean of all responding elements, (2) weighting class adjustment in which Z_i implicitly becomes the mean of responding elements in homogeneous classes of elements, (3) Politz-Simmons' method in which each sample observation is weighted by the inverse of a measure of the observation's sample selection probability, and (4) multiple regression methods where response probabilities are estimated from a regression model.

[D] Other Adjustment Methods--This class of post hoc methods includes all other methods where data are adjusted in compensation for nonresponse. Included among these methods are: (1) double sampling ratio and regression methods utilizing correlated information available for both respondents and nonrespondents and (2) "raking methods" in which sample weights or element counts are adjusted by an iterative process so that marginal totals for certain correlate variables are attained.

[E] Substitution Methods--This method of replacing another sample selection for one that fails to respond is often used as a presumed complete remedy for nonresponse. However, the remedial effects of substitution may be falacious since, as Kish [1965, Section 13.6B] points out, substitutes in many instances "merely replace responses with more elements that resemble the responses already in the sample." This is obvious since substitutes are likely to be subject to the same disinclinations to respond as the original sample of elements.

[F] Nonrespondent Subsampling Methods--This category of post hoc accommodation methods contains probably the first well-documented effort to produce estimators while technically, if not effectively, are unbiased estimators in surveys where response is a problem. Following the original methodological idea by Hansen and Hurwitz [1946], a number of extensions and variations to this original approach have emerged.

[G] Bayesian Methods--An emerging class of methods utilizes the Bayesian approach to statistical analysis. These methods are characterized by analysis which is derived from both expressions of prior knowledge as well as from the observed sample data. Two particular contributions are noteworthy since both use the Bayesian framework but attack the problem of nonresponse from somewhat different angles.

Ericson [1967], in one of the first adaptations of Bayesian methods to the problem of survey nonresponse, develops an estimator for a population mean within the same double sampling context as the Hansen-Hurwitz method. Another contribution following this same general approach is presented by Rubin [1977] who adds the dimension of utilizing auxiliary (correlate) information which is linearly related to the variable of interest. Here, the general aim is to combine prior knowledge concerning the regression model for nonrespondents with auxiliary data for all members of a specific sample as well as data on the variable of interest for respondents only.

[H] Extrapolation Methods--One final category of post hoc accommodation methods considers the problem of predicting the behavior of nonrespondents from "trends" observed by analysis of respondents. Each is thereby distinguished by a model which links the variables of interest to some measure which can be made on the entire sample. In a sense, this general approach represents an extension to the "wave analysis" as discussed earlier.

Notes

[1]A more comprehensive paper on this topic is available upon request to the author.

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