SAMPLE DESIGN AND ESTIMATION PRACTICES IN FEDERAL ESTABLISHMENT SURVEYS

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1. INTRODUCTION

The Federal government sponsors, conducts, and publishes data from a number of surveys of establishments in the United States. These surveys provide a wealth of information about the economic well-being of the country for government policymakers and the business community. Although there is some overlap of sample design and estimation issues and approaches between establishment and household surveys, there exist a number of important differences between the two. Much has been written about sample design and estimation issues associated with household surveys. The extent of literature available for establishment surveys, however, is limited.

This paper is the result of work carried out by the Subcommittee on Measurement of Quality in Establishment Surveys, in its development of Statistical Policy Working Paper 15, Quality in Establishment Surveys (1988). Information on survey design practices was collected for 55 Federal establishment surveys from nine agencies to complement the discussion in the paper. The Subcommittee collected information on sample design, estimation, and control and measurement techniques.

The Subcommittee translated the notion of quality into the topic of errors associated with survey estimates. A survey design consists of a sample design, estimation procedures, and survey methods and operations. Each of these components may contribute to the error in the resulting survey estimates. Thus even a census is subject to errors of measurement resulting from the survey procedures used.

Survey estimates are subject to both variable error and bias. Variable error reflects random error resulting from the survey design, while bias reflects systematic error. More detailed discussion of the models available to represent survey errors may be found in most sample theory textbooks. Errors resulting from the sample design and estimation (both variable error and bias) are referred to here collectively as sampling error, while errors resulting from the survey methods and operations are referred to as nonsampling error.

This paper discusses sample design and estimation issues and approaches associated with establishment surveys. Discussion of establishment universe populations is included to provide the context for sample design and estimation. Establishment universe populations and frames are discussed in Section 2. Sample designs are discussed in Section 3. Common estimators used for establishment surveys are presented in Section 4. Variance estimation is discussed in Section 5. Summary results from the profile of 55 Federal surveys are presented in Section 6, and concluding remarks are provided in Section 7.

2. ESTABLISHMENT UNIVERSE POPULATIONS AND FRAMES

A. BACKGROUND

Establishment populations differ from household populations in several ways. These dissimilarities result in frame development, sample design, and estimation approaches which are in some areas markedly different from approaches for household surveys. Among the major distinctions between establishment and household populations and frames are: (1) establishments come from skewed populations wherein units do not contribute equally (or nearly equally) to characteristic totals, as is the case for households; and (2) accuracy of frame information about individual population units is crucial to sample design and estimation for establishment surveys, while for household surveys the accuracy of frame information concerning individual units is not as critical.

B. ESTABLISHMENT POPULATION DISTRIBUTIONS

Establishment surveys are characterized by the skewed nature of the establishment population. A few large firms commonly dominate the estimates for most of the characteristics of interest. This is especially true for characteristics tabulated within an industry. Small firms may be numerous, but often have little impact on survey estimates of level although they may be more critical to estimates of change over time or for measuring characteristics related to new businesses. This distribution has a major impact on both the frame development and maintenance and on the sample design used for establishment surveys.

C. SAMPLE FRAME APPROACHES

1) List Frames

List frames are widely used in establishment surveys conducted by the Federal government. The use of list frames for establishment surveys arose from the availability of administrative records on establishments compiled mainly for tax purposes. Theoretically, all establishments must pay (or justify not paying) Federal, State, and local income taxes (where applicable), social security tax, unemployment insurance tax, and other taxes. Filing requirements of State and Federal Government agencies provide the conceptual basis for frame coverage of establishments. In addition, regulatory reporting requirements provide lists of establishments in certain industries, such as oil refineries. However, because these administrative record files are not normally developed for statistical purposes, they often need refinement before being used as sampling frames for surveys of businesses. Thus addresses used for administrative purposes may not be adequate for survey purposes. For example, an address in the administrative files could be for the accounting firm that handles tax reports for the company on the list frame. Extensive resources are spent on maintaining the list frames since a significant source of nonsampling error may be due to inadequacies in the frame. Resources for improving frame coverage and the accuracy of identification data are typically spent on improving the data for the larger firms since they have a much greater impact on most survey estimates.

2) Area Frames

While most establishment surveys use list frames, surveys conducted by the Department of Agriculture rely heavily on area sampling in combination with list frames. Retail Trade Surveys conducted by the Bureau of the Census use an area sampling frame to supplement their list frame. Area sampling frames have the advantage of complete coverage of even new businesses. However, the costs involved in changing the stratification for an area frame limit the frequency with which sample design modifications can be made to reflect changing population distributions. Area frames are therefore more efficient when used on stable populations, such as agriculture.

D. COMMON CHARACTERISTICS OF ESTABLISHMENT LIST FRAMES

Establishment list frames typically are characterized by extensive establishment identification information, periodic updating of this information, and multiple sources for the information. Information usually includes the name and address of the establishment, industry and ownership codes, size data (employment, sales, enrollment, etc.), a unique identification number, a link to related establishments, and other data items specific to the surveys that the frame must service. The data on the frame are required for sample design, sample selection, identification of sample units, and estimation. The primary source of administrative records for a frame may have shortcomings which require the identification information to be supplemented using other sources of information. This may include using identification information from the surveys themselves. Supplemental files, including the use of area frames, may also be required to overcome coverage problems in the primary source. Duplication of sampling units is also a problem associated with the use of list frames. Refinement of the frame includes efforts to unduplicate units prior to sampling.

E. MAINTAINING A FRAME

The individual establishment information on the frame is critical to the effectiveness of the sample design and estimation for the survey. Maintaining a frame over time is complicated by the dynamic nature of the establishment population. Changes in ownership, mergers, buyouts, and internal reorganizations make frame maintenance a real challenge. Matching and maintaining unit integrity over time provides the opportunity for consistent unit identification in the numerous periodic surveys conducted by the Federal Government.

New establishments must be added to the frame. However, it is often difficult to differentiate, using administrative records, new establishments from old establishments that have changed their name or corporate identity. It is also difficult to link establishments over time when there have been ownership or other changes. Each survey may have different requirements as to the handling of new establishments and changes in existing establishments. The timeliness of adding new businesses to the frame and reflecting them in the sample is also a problem. The lag time between formation of new establishments and selecting them into the sample may be anywhere from several months to several years. While new establishments may have little impact on estimates of level, in some instances they may dominate estimate of change (See Grzesiak and Tupek, 1986).

The Bureau of the Census and the Bureau of Labor Statistics both have independent programs for maintaining frames for large and multiunit establishments, since provisions for confidentiality prevent sharing between agencies. The Census Bureau conducts an annual Company Organization Survey to determine and maintain the structure of business enterprises. The Bureau of Labor Statistics through cooperating State Employment Security Agencies conducts a quarterly survey of identified multiunit companies to determine units that have been bought, sold, or merged. These surveys are necessitated because: there are as many as 800,000 new nonagricultural employers each year; up to 5 percent of existing establishments may change industry classification; and the number of mergers is steadily increasing.

3. SAMPLE DESIGN

A. BACKGROUND

Establishment surveys differ from household surveys in the sample design approaches taken. Establishment surveys typically use single-stage designs, as opposed to the multistage designs typical for household surveys. The dominance by a small set of units on estimates of characteristics of interest leads to differential sampling by establishment size, with the use of certainty strata beyond that determined by the optimal allocation. The use of certainty strata is often to protect against the possibility of inefficiencies in the design parameters. Overlap of sample units across survey rounds is often optimized to improve estimates of change and reduce collection costs and nonresponse rates. These situations correspond to those found for household survey primary sampling units (PSUs), which typically have differential and certainty sampling as well as overlap of PSUs across survey rounds.

B. COMMON CHARACTERISTICS OF SAMPLE DESIGNS

Establishment surveys have similarities in sample design approaches as well as frame approaches. The approaches are due to the distribution of the population and the amount of unit information available on the frame. A typical establishment survey sample design is a single-stage, highly stratified design. Units are stratified by industry, size (employment, sales, etc.), and/or geographic location. The larger units are selected with certainty, and very small units may either be excluded from the target population or be given no chance of selection. Sampling within strata is either equal or probability proportional to size.

Administrative record data are often used as design variables for stratification and allocation. The administrative record data from the Internal Revenue Service, Social Security Administration, State Unemployment Insurance Agencies, and other sources may agree with survey definitions, but they are often not timely enough for survey schedules. The accuracy of data is undoubtedly a function of how critical the data values are to the administrative source collecting them. But even when administrative records are untimely or somewhat imprecise, they are often valuable as design characteristics.

Establishment surveys are often stratified first by geography and industry since separate estimates are often produced by geographic region and by industry. Even when geographic and industry breakouts are not produced, differences in the design variables by geographic area or industry may justify this stratification. A size measure such as employment or sales is often the most critical stratification variable. Since characteristics to be estimated are often highly correlated with the size measure, the use of the distribution of the size measure for stratification and allocation provides a highly efficient sample design.

Most survey estimates are dominated by characteristics of a few large firms, hence almost all designs sample more heavily from larger firms than from smaller firms, with most designs having certainty selection of the largest firms. The largest establishments will likely be in a "take all" stratum when optimum stratification techniques are used. In practice, a certainty stratum is often employed even when the allocation may not dictate it because a certain amount of protection is needed from imprecise design variables. Also, a standard certainty size class stratum may be employed across industries and geographic areas, rather than allowing the allocation to be determined by the design variables.

The importance and dominance of large firms have given rise to some nonclassical designs. The smallest estab-

lishments may not be given a chance of selection since they contribute only marginally to the total estimates, are often covered inadequately on the frame, have erroneous data, are costly to collect, and tend to be volatile. A number of establishment surveys employ a form of cutoff sampling where no units are selected below a specified size. Data for smaller firms are either imputed from administrative records or from large firm characteristics, or they are excluded from the target population altogether. Obviously surveys that purport to cover all establishments must adjust for units not given a chance for selection.

The allocation of the sample will usually vary considerably by size of establishment. Units slightly smaller than the certainty cutoff will be given a much higher chance of selection than the smallest units. It is also common for designs to include differential target errors for the various industry and geographic estimating cells. This may be due to tradeoffs in the design between aggregate and detailed level estimates as well as to cost considerations. Small or volatile industries would command a significant portion of the sample if all estimating cells had a common target error.

Conflicting design objectives are common for establishment surveys, as is true for many household surveys. Tradeoffs exist between the need for detailed publication cells, limited or insufficient population design parameter data for detailed cells, and the survey cost related to increasing sample size. The sample design needed for detailed publication cells often increases the size of the sample significantly, with little gain in reliability in the aggregate cells.

Establishment surveys are conducted monthly, quarterly, annually, and sometimes less frequently. Annual surveys often select independent samples from one year to the next. However, a number of surveys conducted by the Federal government use the same panel of units over time. Although estimates of level are the primary objectives of most surveys, estimates of change are also important. The use of a panel sample over time can improve the reliability of estimates of change for a given sample size. Panel units do not have to be reinitiated into the sample, lowering costs and increasing response rates. Household surveys view length of time in sample as a possible detriment to quality, due to the decreased response rates and the potential for conditioning effects on respondents. Given the hard data sources expected for establishment surveys, once a unit is accustomed to reporting data under the definitions required for a survey, extended length of time in sample may not be detriment to data quality.

Periodic establishment surveys often have special requirements which impact sample design and selection. These may include the need for large sample overlap from one survey round to the next or the need to minimize the sample overlap between survey rounds. Requirements such as these are intended to reduce the workload for the data collection staff, improve response rates, or reduce the burden on individual small establishments. To accommodate these and other requirements, rotating panel designs are used, or modifications are made to the independent sample selection of units from one survey round to the next. Even when independent samples are drawn, a large overlap in sample members is not uncommon due to the certainty size cutoff and the selection of a dense sample of larger firms.

C. SAMPLE REDESIGNS

Redesigning the survey periodically is an integral part of the survey process. Design objectives, population characteristics, survey resources, and features of the frame change over time. Requirements for survey estimates may change as funding changes or as the demand for estimates at various levels changes. The growth and decline of various industries can also affect the criteria used for the sample design. Moreover, the availability of frames and the information on these frames may necessitate a complete redesign of the survey. Updates to the current design, including partial reselection of samples and revision of original probabilities of selection, may be adequate for a period of time. but eventually a redesign is essential.

A number of issues must be considered when redesigning a survey, such as continuity of the data series, the availability of and the ability to analyze data for determining the sample design, and the cost of the redesign relative to the ongoing survey. Maintaining the continuity of the data series requires a great deal of attention since the usefulness of the data may be due to its longitudinal aspects as much as it is to current measurement. Parallel processing under two designs is not uncommon, and helps ease the transition between designs.

Redesigns are often built into the survey process based on the recurrence of new frames or censuses. The economic censuses conducted by the Census Bureau every 5 years provide an opportunity for redesign of their periodic surveys. The redesign of surveys may be conducted on an as-needed basis, such as when the current design is deemed inefficient or when more flexibility in the design is desired.

4. ESTIMATION

A. BACKGROUND

Without a measurement for the complete population of interest, inferences about the population must be based on sample estimates. This section deals with how results from the sample are used to make estimates. There are several commonly used estimator types for establishment surveys. The choice among estimators usually depends on the sample design itself and on the resources available to the agency for computing them. Before choosing a particular type of estimator, a number of issues are considered, usually as a package at the time the sample is designed: sample design implemented; types of estimates desired, levels or change; type of survey, one-time or repeated; number of related items to be measured; correlation of the items; availability of auxiliary information that can be used to improve the accuracy and precision of the estimates.

B. COMMONLY USED ESTIMATORS

1) Direct Expansion Estimator

This estimator can be used in most simple probability designs. It is often used in establishment surveys since many use single-stage, highly stratified designs. This estimator can be used in cases with a random sample of units within strata with stratum weights, N_j/n_j, to be applied to each sampled unit in the jth stratum. It can also be used in conjunction with a probability proportionate to size sample design with establishment weights being inversely proportional to the probability of selection. This estimator does not use any auxiliary information not used in the actual sample selection, but it can be used as the basis for other estimators which do use this information.

The advantages of the Direct Expansion estimator are that it is operationally simple, it is unbiased, and its variance estimator has a linear form. Its major disadvantage is that it may not be a very efficient estimator, as it does not make use of auxiliary information which may be available. (See Cochran, 1977.)

2) Ratio Estimator

A second commonly-used estimator is the ratio estimator. This estimator is used when the survey practitioner has some additional information about the population of interest, such as a measurement of the variable of interest for some

other period of time or the population value for some related variable. The ratio estimator utilizes this information to improve the predictive ability of the sample. When the numerator and denominator of the ratio are at least moderately positively correlated, the ratio estimator is an improvement over the simple Direct Expansion estimator.

Given the universe information which is commonly available, often the value of the characteristic at some earlier time, ratio estimation is often used in establishment surveys. Ratio estimation is particularly useful when the variables in the survey to be measured are correlated or when auxiliary information exists with some known total to adjust the estimates. When a plot of the X and Y variables goes through the origin or nearly so and a positive correlation exists, gains in both accuracy and efficiency of the estimates can be realized.

The ratio estimator is subject to a bias which arises from its nonlinear form. The size of the bias is a function of the sample size (small sample sizes are more subject to bias than large sample sizes).

3) Link-Relative Estimator

When the primary interest is one of estimating period-to-period change, sometimes one may consider the use of the link-relative estimator. This estimator is similar in many ways to the ratio estimator. It is commonly used when poor levels of response and limited ability to impute make the use of a strict Direct Expansion estimator for the numerator and denominator of the ratio impractical. This estimator uses only the reported values of Y_i and X_i and may or may not include weights. It is used mostly to carry forward previous population totals. For example, suppose the total ending inventories for establishments in a particular Standard Industrial Classification (SIC) code are known at the end of a calendar year. A measure of how this value changes from month to month during the coming year is desired. The sample that has been selected is a cutoff sample representing some convenient group of establishments in the SIC code. Because of the nonrandom nature of the sample, stand alone estimates of monthly totals are not possible. However, if one is willing to assume that the month-to-month movements of the reporting establishments is adequate to measure the month-to-month movement of the universe as a whole, then a link-relative estimator may be used.

The link-relative estimator is biased. If the assumption that the reporting establishments are representative of the universe is not true, estimates formed using this procedure are biased. In practice the bias can be severe. A common use of this estimator involves measuring change for very large establishments only and then assuming that the changes are reflective of the small establishments as well. (See Madow and Madow, 1978.)

4) Unweighted Estimator

This estimator is used less frequently. Occasionally one is called upon to measure a highly skewed distribution, a cutoff of the largest units is selected, and only those who report are tabulated. Typically the estimates are used to show relationships, but they understate the true levels. Usually when this type of estimator is used, some attempt is made to indicate the degree of coverage the given sample has for the universe. For some establishment surveys, particularly establishments in manufacturing, the use of an unweighted sample benchmarked to control totals can be useful. This estimator is always biased even for trends but the cost and operational simplicity may cause it to be considered.

5) Estimation Techniques for Cutoff Samples

A number of establishment surveys are employing a form of cutoff sampling in which no units below a specified size are selected. One cutoff design is not actually cutoff sampling but rather a redefinition of the target population. In these cases the target population has been defined to be only units in the population larger than a specified size. Some surveys purport to be covering all establishments but just impute for units not given a chance of selection. Imputation may be either explicit of implicit. Explicit imputation methods typically use administrative data for the missing establishments as proxy for survey data. This is statistically sound as long as the concept being measured is identical in both data sources. Implicit imputation uses data from larger establishments or historical data as proxy data for units not surveyed. This latter approach is clearly less desirable since no current direct information is used for the establishment being imputed. A combination of explicit and implicit imputations is not uncommon within one survey.

5. SAMPLING ERROR ESTIMATION

A. BACKGROUND

The standard measure of the accuracy of an estimator is its mean-squared error. The mean-squared error is defined to be the expected value of the squared difference between an estimate and the value it is trying to estimate (Cochran, 1977). The mean-squared error is composed of two parts. One part is a sampling variance and the other is a square of the bias. Estimation assumptions can result in sources of bias. While the bias squared may be the dominant piece of the total mean-squared error, it is very difficult and expensive to measure and in practice little quantitative information about it is available for establishment surveys.

The sampling variance, the uncertainty caused by the fact that data are collected from only a part of the universe, is often estimable from the sample data itself. Sampling variances are used to quantify the accuracy of estimates and to confirm the sample design hypothesis. They are also used by some agencies as standards for what can and cannot be highlighted in press releases or in the narrative accompanying publications. Analysts often use these estimates to aid them in interpreting agency statistics.

B. COMMON APPROACHES TO VARIANCE ESTIMATION

There are numerous different approaches to the calculation of sampling variances. Wolter (1985) is devoted entirely to the estimation of variances. The text provides an exhaustive treatment of most of the currently used types of variance estimation as well as some rationale for choosing among them.

Federal establishment surveys employ a wide range of variance estimators, including the traditional design-based variance estimators, which often are approximations due to the use of nonlinear estimators and adjustment techniques for nonrespondents and atypical reporters which are difficult to handle in developing design-based variance estimators.

Other techniques used include random groups, jackknife, and other replicate methods, as well as Taylor series approximations for complex nonlinear estimators. Generalized variances are not yet commonly used in Federal establishment surveys, but are likely to become more popular in time.

C. FACTORS AFFECTING THE USE OF VARIANCES IN ESTABLISHMENT SURVEYS

Establishment surveys conducted within the government cover a broad range of sample designs and variance estimators. Probability samples are generally preferred, but are not uniformly used. Even when a good probability design is selected and maintained, it is likely that the nonresponse pat-

tern will not be random and will result in biases in the estimates. The two main motivations for probability designs are the representative nature of the sample and the ability to compute variances from probability samples. The extent to which variances are actually computed varies both as to frequency and as to the level of detail. Reasons for not computing and/or not publishing variance estimates for surveys relate to the cost both in time and computer resources of computing variances and to the perceived lack of use of such measures. In order to accurately compute variances, additional data files need to be maintained and utilized. Timing for establishment surveys is critical and the delay needed to compute variances is sometimes viewed as too great a price to pay.

For some surveys, particularly economic indicator surveys, where the period-to period trend is judged to be the primary measure of interest, often nonprobability designs are used. They are generally simpler to use and maintain and the biases associated with incomplete coverage of the universe are not as serious in the measurement of change. For these nonprobability surveys, variances are not computed. For some surveys, general measures of mean-squared errors based on levels of revisions are computed to give the users a rough idea of sample variability.

The general consensus is that a well maintained probability sample design with frequently computed and published variance estimates is the ideal standard. Lack of resources to devote to the work of maintaining the samples and computing the variance results in many designs not meeting these standards.

6. SUMMARY PROFILE

A. SAMPLE DESIGN

Perhaps the most striking result obtained from the information on sample design for the in-scope surveys is the extent of nonprobability sample designs, approximately one-fifth of the surveys (one-fourth of the sample surveys). Some surveys do plan probability sample designs, but in the course of sample selection, data collection, estimation, etc., control of the sample in terms of a probability design is lost. Others are designed as nonprobability by excluding a large portion of the target population or using judgmental selection of units.

Approximately half of the nonprobability surveys were classified by design rather than due to implementation difficulties. Several surveys spanning most of the major statistical agencies used cutoff sampling, or judgmental sample selection. The other half of the nonprobability surveys were designed on a probability basis, but were not controlled in a manner the Subcommittee defined as probability (substitution for nonresponse, probability of selection not used, other control problems).

Approximately four-fifths of the sample surveys use certainty levels (e.g., all units above a designated size are included in the sample with certainty). Approximately 30 percent have sample cutoffs (e.g., all units below a designated size have no chance of selection). Some of the surveys do not include units below the sample cutoff in the target population while other surveys, as mentioned above, do include units below the sample cutoff in the target population.

Over four-fifths of the sample surveys have only one stage of selection. This is in contrast to household surveys which typically use multi-stage sample designs.

B. ESTIMATION / VARIANCE ESTIMATION

Most survey estimates were derived using either Direct Expansion or ratio type estimators. The link-relative estimator was used for roughly 15 percent of the surveys with around 10 percent of the surveys reporting some other type of estimation. Generally surveys measuring indexes of month-to-month changes were more likely to use a link-relative or other form of estimator. The more traditional estimates of totals were generated by expansion or ratio type estimators. In the area of variance estimation several interesting findings are apparent. Slightly over one-quarter of the sample surveys do not compute variances at all, even for internal purposes. Approximately one-third of the sample surveys used a design-based variance formula, which varied from survey to survey due to the nature of the sample design. The remaining sample surveys used a replicate or Taylor series method of variance estimation.

The surveys are classified by whether or not the variances were included in the publications. Almost half of the sample surveys covered do not publish variances. This seems unusually high and marks a major difference between household and economic surveys.

The distribution of surveys not showing variances did not seem to be confined to one or a few agencies, but in general when link-relative or other nonstandard estimation was employed the variances were not published. A second theme not specifically shown in the figure but frequently mentioned was the perception on the part of survey practitioners that their users neither knew nor understood what variances are. This view of the relative unimportance of measures of reliability may well have contributed to the high percentage of surveys not publishing variances.

7. CONCLUSIONS

The sample designs, including estimators and variance estimators, for ongoing Federal establishment surveys , although varied, have many similarities. The skewed nature of the populations, the common use of list frames, heavily stratified sample designs are characteristic of many Federal establishment surveys. Maintaining the list frames, and estimation procedures which take into account the heavy dependence on large firms also characterize the work of the various agencies involved in Federal establishment surveys.

The major weaknesses are the use of what may be termed nonprobability survey implementations and the lack of variance estimates, whether published or calculated. Both of these weaknesses are apparently due to cost/quality tradeoffs.

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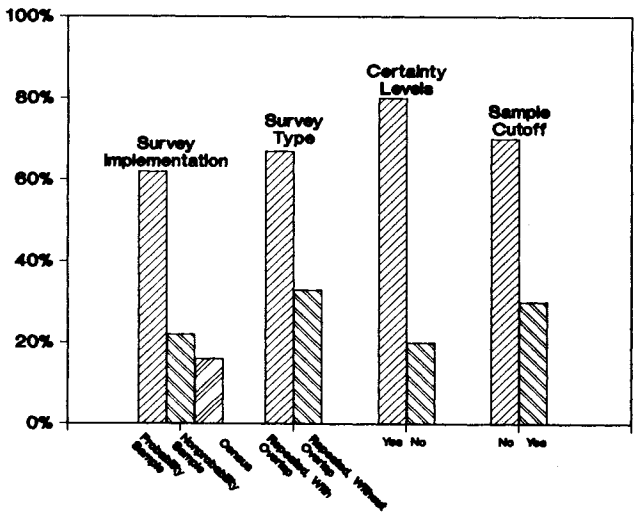
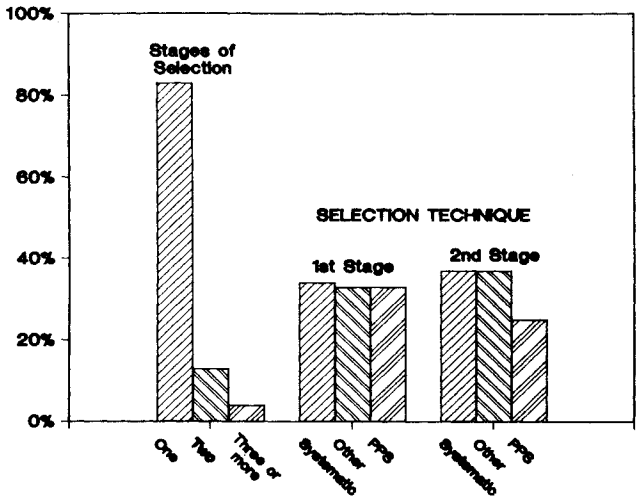
SAMPLE DESIGN

Figure 1



SAMPLE DESIGN

Figure 2



ESTIMATION

Figure 3