Journal of Official Statistics
Vol. 2, No. 4, 1986, pp. 381–395


# Complete Censuses and Samples[1]

*Leslie Kish*[2] *and Vijay Verma*[3]

**Abstract:** Complete decennial censuses are needed for small areas and other domains. Sample surveys yield diverse and timely data. Censuses can also be combined with samples, and sometimes with data from registers, for diverse estimates that are detailed over both space and time, and hence are timely for small domains. Methods of "postcensal estimates" for small domains are described. We note uses of censuses for improving samples and of samples for improving censuses, and propose a method for cumulating data from "rolling" (or rotating) periodic (weekly, monthly or quarterly) samples specifically designed to cover the population in detail over designed spans (annual and quinquennial).

**Key words:** Censuses; samples and censuses; population census; small domains; local area estimates.

[1] This is a modified version of our paper given at the Madrid meetings of the ISI and IASS (Kish and Verma (1983)). We benefited from suggestions of the editor, two referees and colleagues. This is not a theoretical-methodological review (if such were possible). It is a review for nonmethodologists inside and outside central statistical offices, of the many relations between censuses and samples. One of these methods alone can fill a book; hence a thorough treatment of all methods cannot be expected here. For similar reasons we cannot give citations for all of the many methods described here. Also, some of our sweeping statements (preceded by "usually", "commonly", "often") will not hold for specific countries in specific years. We are also limited, by time and experience, to population censuses, although most of the remarks have relevance for other censuses also (housing, agriculture, industry, business).

Furthermore, the conduct of censuses differs among countries and among decades within countries, and we cannot possibly describe correctly the scores, or hundreds of varieties (which arise often more for idiosyncratic than for cultural reasons). Nor can we count or quantify the frequencies of practices; such a task belongs to the United Nations Statistical Office. Our descriptions reflect reading and contacts rather than quantitative research on practices. Especially, "any resemblance" of our descriptions to the U.S. Census is "purely coincidental," because we tried to avoid this atypical case.

[2] Professor Emeritus, University of Michigan, Ann Arbor, Michigan, U.S.A.
[3] Director, ISI Research Center.

## 1. Purposes, Needs and Resources

Sample surveys can yield good national data on many subjects in most countries today, not only for the national populations but also for major domains such as major provinces and major subclasses by age, education, occupation, etc. For example, the World Fertility Surveys provided widespread evidence in recent years of the broad advances in the methods of survey sampling.

However, the statistical needs of nations cannot be satisfied with only occasional sample surveys, because of frequent and legitimate needs for more detailed information. *Complete censuses* are the chief vehicle for obtaining detailed information about small subpopulations, especially for small administrative areas. The 1980–81 round of decennial censuses was more widespread, more inclusive and probably better than any previous round, and the United Nations Statistical Office has helped to stimulate those efforts.

On the other hand, decennial censuses cannot give the details over time that the dynamics of the modern world need, and more frequent and more detailed censuses are rare and unlikely to occur in the future. For details over time and for more interrelated data, there are by now many *periodic surveys*: yearly, quarterly and monthly. The monthly Current Population Surveys for labor force data and weekly Health Interview Surveys are two examples from the USA. Many developing countries are establishing systems for integrated *sample surveys on a continuing basis,* covering a variety of topics in a planned manner and utilizing common facilities and resources to meet diverse data needs. The United Nations National Household Survey Capability Programme is providing a major impetus to these developments (United Nations (1981, 1983), Rao and Verma (1982)).

A third major method for data collection consists of *administrative registers* and records of various kinds, which can provide details both over space and time. In Scandinavian countries population registers provide some good data, but we should not expect an early spread of population registers to provide good statistical data in many countries. In any case the data from registers are, and will most likely remain, of limited scope and depth.

These three methods – censuses, samples and registers – may be usefully viewed as competitive, and the relative advantages and disadvantages of these will be compared on several criteria in Section 2. However, in this paper we deal mainly with how censuses and samples can also be combined for better, more complete and more detailed data, and we shall deal mainly with those cooperative aspects. We could not discuss thoroughly the uses of registers because of their great diversity and unique problems, but they enter the discussion of postcensal estimation in Section 5.

## 2. Samples Compared to Censuses

In comparing sample surveys to censuses, our objective is not to consider one method as a substitute for the other but instead to emphasize their complementary nature. The relative advantages of samples and censuses are complementary; one is stronger where the other is weaker. "If there is anything we statisticians have learned through practical experience, it is that we need each of the methods (including administrative records) to repair the defects of the other" (Marks (1973)).

Differences between the potential uses of censuses and samples arise primarily from differences in the *scale* of the operations involved and the consequent differences in methodology and practical conditions of data collection. Complete enumeration of the entire population (of people, farms, establishments, etc.) requires mobilization of financial and human resources on a large scale, and this cannot be sustained for a prolonged period, nor repeated frequently. The need to deploy a large – hence a less well trained and less closely supervised – field force means that the type of information appropriately collected in a census, while extensive in coverage, must be relatively simple in content. Simplicity is also necessary to keep the volume of data to be processed manageable. Complete censuses are nevertheless relatively expensive and slow, and even with today's modern and efficient procedures it can take four years to get most of the census data into the hands of the users. These are the basic reasons for not taking censuses more often, or with greater depth of richness of data.

Therefore the primary objective of a census is typically to obtain a detailed and complete picture of the number (size) and basic structural and related characteristics of the population, and to provide as much detail as possible for small domains and especially for local areas.

For example, the population census provides information on the size, age-sex composition, geographic distribution, and basic demographic and socioeconomic characteristics of the population; similarly, agricultural censuses are designed to provide basic data on structural and related characteristics of agriculture, including numbers of holdings by size, location, type and land-use (Khamis and Alonzo (1975)).

By contrast, inquiries confined to samples of the population can, by virtue of their smaller sizes, be designed to obtain a wide variety of data for the study of changes and interrelationships. Such data are not gathered in a complete census: attempts to do so would result in very high costs and, even more important, in low quality. (This is illustrated by misguided attempts in some countries to collect data on abortions or disability in population censuses.) Furthermore, sample surveys can be tailored to fit a variety of needs and methods of collection. The content of the study population can be better controlled and directed towards the specific survey aims; such flexibility may be prohibited by the public aspects of the census. Sample surveys are much cheaper and can be much more timely. They can be repeated more often to provide information on rapidly changing or fluctuating variables.

Self-enumeration, which may spread with literacy, can alter these comparisons somewhat: 1) Censuses can become cheaper to collect and also to tabulate electronically; but probably not really cheap. 2) Answers should be made simple (multiple choice?) for the mail-in forms and for easy tabulation. 3) Response variances, which arise ordinarily from differences between interviewers, are largely eliminated. 4) Good population frames are very important for self-enumeration.

"Sample census" is a term used for large samples, perhaps 10 or 5 or 1 percent, which are used only rarely to substitute for complete censuses. (Though some people prefer to reserve the term "census" for complete coverage). They are larger than ordinary sample surveys, and can provide greater detail for small domains. However, it seems that the savings from enumerating less than the complete population are not at all proportionate to the reductions in sample proportions, due to constant costs in planning, analysis and in constructing a population frame. A 10 percent sample census may cost more than half as much as a complete census.

The major limitation of sample surveys is their inability to provide sufficient detail for small domains and especially for local areas. This is the principal reason for the continuing utility of complete censuses (though even here there are certain important qualifications; see Hansen et al. (1961), Waksberg (1968), Kish (1979a)). Furthermore, censuses can often or usually (though not always, nor necessarily) obtain better coverage and response rates than sample surveys. This is partly because it is less difficult to check complete (census) coverage than sample coverage, but mostly because of the credibility aroused by the public relations campaigns for censuses. In fact, the problem of coverage is one aspect of the broader issue of a sample being "representative" of the population of interest. This representativeness depends critically on the quality and completeness of the sampling frame on the basis of which the sample is selected.

Another limitation of samples is their dependence on information from external sources, not only for frames for sample selection, but often also for more precise estimation. For samples of small to moderate size, the relative precision of estimates of proportions, means and ratios, etc. tends to be much better than the precision of estimates of population totals when obtained directly by inflating sample totals, because these simple

*Table 1. Eight Criteria for Comparing Three Sources of Data*

| Criteria | Samples | Census | Administrative Registers |
|---|---|---|---|
| Rich, Complex, Diverse, Flexible | *** | | |
| Accurate, Relevant, Pertinent | * | | ? |
| Inexpensive | * | | *** |
| Timely, Opportune, Seasonal | ** | | * |
| Precise (Large and Complete) | | * | * |
| Detailed for Small Domains | | ** | * |
| Inclusive (Coverage), Credible, P.R. | | * | ? |
| Population Content | ** | * | |

expansions have variances inflated by variations of size of the sample clusters. These totals are estimated more precisely as ratio estimates: ratios from the sample multiplied by totals from outside sources, often from censuses.

The table above (Kish (1979a)) summarizes the relative advantages of samples and censuses, and also of registers for comparison. The appropriate degree of advantage is indicated by the number of stars (*).

The relative advantages of censuses and samples are complementary. The contrasts are more striking for larger populations. They also depend upon the objectives, content and size of the sample inquiry. At the one extreme, very large samples may closely resemble and substitute for complete censuses when the latter are not feasible (even if highly desirable); or when complete coverage is not considered necessary, as for example information on housing in some population censuses, unless needed for very small areas (United Nations (1971)). Similarly, most agricultural "censuses" are in fact conducted on a (large) sample basis. At the other extreme we have indepth and highly specialized "case studies," deep and rich in content but based on small samples.

Choices between censuses versus either samples or registers also involve policy decisions and strategies for specific situations. Discussions often involve needless confusion, due to differences of needs and of opportunities – differences that fall into three groups:

1) The *statistical resources* of the countries differ among:
   (a) countries with good population registers (especially north-western Europe and some socialist states);
   (b) other developed countries, and
   (c) the rather heterogeneous group of less developed countries. Here we refer to statistical rather than to economic development.
2) The *nature of the data* to be collected, for example:
   (a) basic population and housing data;
   (b) health, education and other social data;
   (c) industrial, business, income and expenditure and other economic data;
   (d) agricultural statistics;
   (e) labor force and related data; and
   (f) data on attitudes, opinions and intentions.
3) The required *frequency of collection,* which may be:
   (a) decennial,
   (b) quinquennial,
   (c) annual,
   (d) quarterly,
   (e) monthly,
   (f) weekly.

Even for population data (2a) we see great differences between countries with different resources. Some Scandinavian countries (1a)

are considering using registers instead of censuses even for decennial data (3a). There exist current disputes about how to meet the need for quinquennial or more frequent population counts (3b,c,d), with proponents for censuses, for registers, and for rolling samples (Section 6). Also, combinations of two or even all three of the methods can be used in postcensal estimates (Section 5).

Only samples are used for (2f) and (2e) and often also for (2d,c,b), although administrative sources (but not censuses as a rule) are also used for some purposes. In developing countries (1c), sample surveys, especially surveys in the household sector, tend to be the main source for the great variety of data needed. This is because of the lack of alternatives, as well as the small scale and "informal" nature of a great deal of social and economic activity of the population.

## 3. Samples Attached to Censuses

The mutually supportive role and combined uses of complete censuses and sample surveys can be discussed in terms of six major aspects:

1) Using sampling in connection with the census to assist in planning, testing, controlling and evaluating the census.
2) Sampling of census returns to make its results available in a timely and economical manner.
3) Attaching a sample enumeration to the census to supplement the relatively simple information collected in the census.
4) Conversely, using the census as a basis for sample surveys, in terms of providing impetus, experience, infrastructure and facilities, sampling frame, and baseline data for continuing survey operations (Section 4).
5) Combined use of census and sample data in providing postcensal and current estimates for local areas and small domains, including the possible use of rolling samples to obtain more detailed data (Sections 5 and 6).
6) Combined use of censuses and surveys for the development of statistical capability (Section 7).

In this section we discuss (1), (2) and (3), that is, samples attached to censuses. There is an extensive literature on these issues (for example, Steinberg and Waksberg (1956); Zarkovich (1965); Waksberg and Hansen (1965); Waksberg (1968); Majumdar (1975); Murthy (1980); and especially Kish (1979a) and United Nations (1971, 1980)). Our aim here is to provide a broad review.

### *3.1. Using samples to evaluate and control censuses*

*Pilot studies* are required to test the adequacy of census questionnaires, instructions, training programs, enumeration procedures, field organization, etc. They serve as practical training for the nuclear staff and supervisors, and provide information on operational aspects (costs, time) of enumeration. For pilots, it is usually difficult to insist on good samples of the entire country: the common practice is to choose areas which are convenient but also expected to yield a good test of questions and techniques in diverse circumstances. This approach assumes that the diverse circumstances, and especially areas of particular difficulty, are identifiable. Sometimes, but not usually, this approach is supplemented by a "micro-census" based on a large probability sample in advance of the actual census. In any case, to yield full benefits, tests should be carried out through all stages of collection, processing and examination of results. Since for a large undertaking such as the census, accurate operational information on conditions and requirements of enumeration is essential for proper planning and execution.

*Statistical quality control* techniques are sometimes used to assess and control the work of individual operators and operations. Various sampling plans have been developed

with the object of reducing the cost of verifying the operatives' work, and ensuring at the same time a specified quality level for the outcome. However, "quality assurance" with process control is a common alternative. It is important to emphasize that specific procedures should be developed in each situation, suited to actual field conditions and procedures of supervision.

As distinct from quality and operational control measures, *evaluation surveys* are designed to check the average quality of the census and its major components. In designing samples to check and evaluate census work (as well as to supplement census information on a sample basis), a number of options need to be considered; for example:

- the timing of the supplementary operation(s) in relation to the main census operations of pre-listing and enumeration – these may be all separate or may be combined in various ways;
- whether the test uses ordinary census enumerators or uses different, specially trained enumerators;
- whether the (more elaborate) test procedures are additional to or replace the ordinary census operations in the selected sample areas;
- in the former case, whether the test is conducted independently of or on the basis of the results already obtained;
- the size and design of the test sample;
- the relationship between samples for the different operations attached to the census.

Two types of census check operations may be distinguished: checks that help access *coverage errors* relating to duplication and omission of units, and checks that help access *content errors* relating to the accuracy of responses. Checks of completeness of coverage usually follow the ordinary census as a separate and additional operation, over a sample of EAs (enumeration areas) but enumerating all households, individuals or other ultimate units in each selected EA. They may or may not use special enumerators but do, in either case, use different enumerators for the same area. The standards of supervision in the test are usually more strict. Typically, check enumeration is carried out by referring to the first enumeration; i.e., enumerators are given previously prepared lists of units in the sample areas with the object of finding missed units. However, sample studies using "dual coverage techniques" (Marks et al. (1974)) for estimating undercoverage are also possible where lists of households (or other units) are available from entirely independent sources. For these reasons, benefits are derived from checks of censuses based on analytical, demographic, and statistical methods and models and on data from independent sources, registers and samples.

Checks on content tend to be more varied in design. One may use a post-enumeration survey (PES) done after the census, or a sample of high-quality enumeration done simultaneously with the census. In the latter case, a sample of EAs is covered (possibly after subsampling within EAs) with better methods, better enumerators, longer questionnairs, etc., than those used elsewhere. With this arrangement the additional expense and respondent burden is less than that with double coverage of sample areas; however, only net differences at the aggregate level and with higher sampling variance are measured.

Whatever the method, it is generally preferable to use special and improved procedures to identify the nature and source of individual coverage and content errors so as to assess gross errors, including bias, and identify measures necessary to control these errors and minimize their effects. Furthermore, it is worth emphasizing that the objective(s) of the test should be clearly specified and be sufficiently modest to be attainable within given resources. Quality checks have frequently turned out to be of insufficient quality to yield

any useful information at all, in spite of the relatively high costs involved (United Nations (1982), Verma (1981)).

It is often difficult and expensive to use good samples of the entire country for quality checks. Inferences may have to be made from restricted areas of the population in the expectation that the results can be generalized. This requires carefully controlled sample selection; also, results will be convincing only if observed differences between different areas in the sample, or at least within major domains, are not too great. In any case, the samples will need to be larger and more objective than those typically required for the pre-census pilot surveys. Furthermore, the sampling requirements are more stringent when the objective is to adjust (improve) the census results, rather than merely to identify the nature and sources of major errors.

The results of the census check operations should be used, to the extent possible, in conjunction with alternative information available from other sources such as past censuses and surveys and administrative data, as well as substantive and analytical relationships.

### 3.2. *Sampling in census processing*

Sampling from census data may be resorted to in two situations:

(i) for quick tabulation of broad census results; and

(ii) for production of detailed tables.

The first situation arises from the need to release some broad results quickly, even in a rough form. The objective of introducing sampling for detailed tabulation is to save resources (Murthy (1980)).

For (ii), at least, the sample for processing can usually be selected at the household level from all the census EAs. (Sampling of individuals can be more cumbersome, and is often also unnecessary due to demographic heterogeneity within households.) However, confining the processing to a sample of EAs can still retain some operational convenience, especially for (i) which may need to be carried out well before the entire census data can be keyed in and edited.

For more complex analysis, as well as for release of micro-data for public use, it is usually desirable and possible to select samples from the entire census and avoid their clustering into basic units of enumeration. Random selection makes analysis simpler and facilitates prevention of identification of individuals in the sample.

For sampling of households, from EAs, and of individuals if applicable, systematic selection from ordered lists is probably the most convenient and efficient technique. The arrangement or ordering has to be operationally convenient, as well as suitable for a large number of characteristics for which estimations are required. For areas and households, ordering by administrative and geographical location is usually the most appropriate.

### 3.3. *Using sample enumeration to supplement complete censuses*

Censuses should be kept brief and simple, with precoded or easily coded items, to save costs of collection and tabulation. But increasingly more diverse data are being obtained with samples which are portions of the entire census. For example, it is generally accepted that in a population census it is "not necessary to gather all demographic and housing information on a 100 percent basis; a good deal of time and money can be saved through the use of sampling. Furthermore, in certain circumstances, only the sampling method yields data of acceptable accuracy" (United Nations (1971)).

Samples attached to the census differ from ordinary sample surveys in that their connection with censuses gives them special functions

and special advantages. They are often substantially larger than ordinary surveys and share the basic census objectives of providing detailed data for small domains. The large size is facilitated by the relative cost-effectiveness of these operations and the advantage they enjoy in availability of funds and resources as a result of their connection with the census. Sometimes, however, smaller and more concentrated samples may be used to cover more difficult topics for national statistics and large domains, often using special arrangements and enumerators.

For surveys attached to the census, the sample may be spread to all EAs or a sample of EAs may be selected for complete enumeration within EAs; sampling may also involve a two-stage selection of EAs and then of households. The choice of the design is influenced by a number of interrelated factors: size of the operation and required degree of detailed breakdown of the results; nature (complexity) of supplementary information to be collected; nature of EAs; travel conditions; type of enumerators available for the census and required for the attached survey; how often the households can be visited and the related considerations of time, cost and respondent burden; whether the attached survey replaces or is additional to the ordinary census operations in the sample areas, etc. When several samples are used to get different data, there is a conflict concerning spreading the samples over many different units versus concentrating them all in the same units. Spreading the schedules avoids the concentration of respondent burden, but concentrating them reduces costs and yields more information on relations between sets of variables.

For simpler items which can be combined with the basic census enumeration – during a single visit, using the ordinary census enumerators – the sample can be easily spread over all census areas. The more complex and specialized the inquiry, and especially if specialized enumerators are involved, the more it becomes preferable to concentrate the inquiry to a sample of EAs. This can be done more readily when the objective is to produce results at national or major domain levels, rather than at the level of small domains or local areas. Selection of complete (compact) EAs has the advantage of simplicity and lower cost; it is particularly appropriate when specialized procedures and enumerators are used, or when the survey replaces the ordinary census operations in the sample areas. However, this increases the variances of the estimates, and this would be most serious for small geographic domains, though it may not be critical for estimates for major domains and for cross-classes well distributed over different areas. Two-stage selection of households within EAs can bring effective compromises, and would be particularly suitable for samples which form the basis of a continuing program of post-censal surveys. However, subsampling of EAs may introduce serious selection biases, unless it is operationally separated from prelisting and is carefully controlled. The use of appropriate ratio estimates can overcome a part of the increase in variance due to clustering of the sample, and may remove some of the effects of selection biases when EAs are subsampled.

## 4. Censuses as Bases for Sample Surveys

The census forms the basis for subsequent surveys in a number of ways: by providing the sampling frame; by providing auxiliary information for improved estimation, especially estimation of population totals through regression and ratio estimates; and by mobilizing resources for the development of infrastructural facilities for conducting subsequent sample surveys. Samples attached to the census can also serve as the basis for a programe of continuing surveys.

### *4.1. Sampling frame*

Good samples need and are based on census data, especially in countries where alternative sources such as population registers are not available. The population census is the chief source of the sampling frame not only for household surveys covering a variety of demographic, social, and economic topics, including surveys of households and agriculture, but often also for establishment surveys, especially in sectors of small, informal businesses.

Careful consideration must be given to this function of the census during its planning and execution. The enumeration areas of the census have multiple functions: to partition the population into areas with clear, stable and identifiable boundaries, with maps and descriptions; to facilitate complete and unique coverage of the units in the population; to create reasonably equitable and feasible workloads; to facilitate organization and control of census operations; to provide a flexible basis for the production of area statistics at various levels of disaggregation; and to provide a basis for scientific and efficient sample selection for subsequent surveys. While these requirements cannot all be satisfied simultaneously, they point to certain desired characteristics of census EAs. EAs should be relatively small (say a few hundred people on the average) as well as reasonably uniform in size. However, the requirement of clear boundaries is more important than uniformity in size, though very large EAs should in any case be avoided. EAs should be proper areal units covering the entire country fully and should be mapped and described for clear identification of boundaries. They should not cut across administrative subdivisions, and should be geographically ordered with proper identification systems, to facilitate the production of results at different levels of aggregation. Information on size and other basic characteristics should be collected, coded and tabulated for individual areas (United Nations (1971, pp. 29–30)).

It should be noted that, generally, the census provides a frame only of *area* units for subsequent surveys. Lists of housing units, households and certainly of individuals from the census are usually not allowed because of confidentiality concerns. Also they are too difficult to arrange and too mobile and unstable to be used for subsequent surveys – with the possible exception of surveys attached to or conducted very shortly after the census.

### *4.2. Estimation*

Apart from the use of census data for stratification, determination of sample size requirements and sample allocation, PPS selection, etc., in order to achieve efficient sample design, census data are also useful in improving the precision of survey estimates. This applies in particular to the estimation of population totals and aggregates from relatively small samples. For example, more precise estimation can often be made by first obtaining sample proportions, means or ratios, and then inflating them with complete count figures from the census, updated from auxiliary information to the extent possible. Similarly, census (and other) information can be used to obtain more precise poststratified estimates, or "standardized" estimates where the achieved sample is weighted to correspond to a more precise estimation of the distribution of the population on some related characteristics (e.g., age and sex).

The estimation problem becomes more critical for small domains; special estimation procedures are required for these domains, as described in Section 5.

### *4.3. The census as a basis for statistical development and continuing postcensus surveys*

The census is a major operation which can provide great impetus to the development of national statistical organizations (Section 7). In addition, large-scale surveys attached to the census can provide a convenient and

efficient basis for launching continuing survey programs. Later surveys can be smaller in scale but more varied and complex in content, or they can be specially designed to monitor changes, as for example in multi-round demographic surveys. The larger baseline survey can provide a master sample for more efficient and convenient subsampling for and estimation from the subsequent, smaller surveys. We hope that greater attention will be paid to these possibilities in future rounds of population censuses.

## 5. Postcensal Estimates

The need for detailed statistical data has been augmented by increased mobility and diversity in both modern and in rapidly developing societies. Even more varied, rich and current data for local areas and for other small domains are required for planning reforms, for welfare and for administration in many fields. Furthermore, the demands for data have become sharper and more critical because they are used directly for apportioning funds and resources to local areas. Census data have been used where available but, as noted earlier, they tend to be obsolete and limited in content. Population registers and other administrative records supply the needed data only in rare cases, and sample surveys cannot generally be made on a large enough scale to yield data for small domains, especially for small administrative areas (Kish (1980)).

Only recently do we find the development of postcensal and small domain estimates. They are stimulated both by demand and by the emergence of new data bases, new methods, and especially of higher-speed computers. Table 2 lists the various methods and sources of data for postcensal estimates. The first two methods use data from censuses and registers but not from samples; methods 3 and 4 do not need registers. The remaining methods have been developed for the combined use of all three sources, but can also be used without data from registers, and are hence denoted with (*). The last method is most flexible and may use any two or all three of the sources. These methods have been described with a list of references by Purcell and Kish (1979a, 1980).

*Table 2. Sources of Data for Postcensal Estimates*

| Methods | Census | Sample | Register |
|---|---|---|---|
| 1. Symptomatic Accounting | * | | * |
| 2. Regression-Symptomatic | * | | * |
| 3. Synthetic (Ratio) Estimates | * | * | |
| 4. James-Stein, Bayesian, Shrinkage | (*) | * | |
| 5. Sample-Regression | * | * | (*) |
| 6. Synthetic-Regression | * | * | (*) |
| 7. Base Unit Methods | * | * | (*) |
| 8. Categorical Data Analysis | (*) | (*) | (*) |

The symptomatic accounting techniques use current demographic "symptomatic" data (births, deaths, school enrollment, housing units, income tax returns, etc.) for local areas along with empirical demographic relationships to update census population totals (U.S. Bureau of the Census (1975)). The regression-symptomatic methods are based on fitting linear regression functions between the symptomatic variables and the census data to predict current population counts, but the approach can be used to predict other variables also (Schmitt and Crosetti (1954)). The sample-regression method (method 5) is an extension

of the above; it corrects for the obsolescence of the structural relations by using current data from samples (Ericksen (1973, 1974), Cohen and Kalsbeek (1977), and Tam (1982)). As in all methods using sample data, these are subject to sampling variation both between local areas and within them. (Note that these data need to be collected only for a *sample* of the local areas; from the relationships computed there, predictions are made to all local areas.) Hence, the gains depend on the balance between obsolescence and sampling error. Gains are greater where samples are larger, more widespread and more relevant; also where data from registers are poor, less relevant or lacking.

Synthetic estimates (3) are essentially ratio estimates that relate current sample data for subclasses for large domains to less current census data from the same subclasses in local areas. Current local-area estimates are computed as weighted sums over subclasses of large-domain sample estimates, with the weights based on census local-area estimates (Gonzalez and Hoza (1978)). Synthetic regression estimates (6) combine linear regression from registers with census and sample data for synthetic estimators (ibid.).

James-Stein, Bayesian and "shrinkage" estimates (4) refer to several proposals for using a weighted sum of the unstable sample means for small domains, and a sum of some more stable auxiliary estimators. The latter may be obtained from the sample itself (for the total sample or from large domains), or from small-domain but less current census data (Fay and Herriot (1977)).

Categorical data analysis (8) provides a framework for using the power of modern computers for increased flexibility in data resources and for freedom from the structural assumptions of linear regressions and ratio estimators of the other methods. It has yielded remarkable gains in precision in limited tests (Purcell (1979) and Purcell and Kish (1980)). This approach utilizes relationships between the estimand (say rates of employment) and some associated variables (for example age, sex, race). A detailed but less current source such as the census (possibly in combination with registers) may provide these relationships at the small-domain or local-area level. Samples may provide more current relationships, but only at the level of large domains. The procedure is to iteratively adjust the former relationships (termed the "association structure") to conform to the latter (the "allocation structure"), and then to use the adjusted results to produce current estimates for small domains.

Thus several methods have become available recently and are being developed for providing estimates detailed both in time and in space (or for other small domains) by combining the spatial details of censuses with the timeliness of sample data and/or with registers when available. The postcensal estimates are useful, but they have errors. Measuring those errors is difficult because, beyond their sampling variations, they also suffer from biases that must be assessed against outside standards, such as past censuses. Making a choice among the methods has to be based on empirical research or on the research of others in similar situations. The relative advantages of the methods depend on several circumstances, first of all on the quantity and quality of available data. Where large and good samples are available the synthetic and sample-regression methods may be best and the synthetic may be simpler. Where samples are lacking but registers are available, symptomatic accounting or regression-symptomatic methods may be used, and the regression is probably more robust and more general. The choice among all of them also depends on what variables need estimation, since either the sample or registers may be better. Categorical data analysis will probably prove the most flexible and accurate in view of the fewer structural assumptions involved.

## 6. Sample Designs for More Detailed Data

Increasing needs for statistics for local areas and lack of adequate techniques and data lead to suggestions for periodic surveys designed so that their results can be efficiently cumulated over time to provide greater geographic detail. Other objectives of such surveys, for example to monitor trends, perhaps with lesser geographic detail. We propose that periodic surveys be designed deliberately for cumulating data to be used for postcensal estimates, for local areas and for other small domains, either in combination with data from censuses and registers or instead of them, where these are lacking. For example, periodic labor force surveys or health surveys may be redesigned in order to cover each local area over the nation for each year, and cover it even better over the decennial period.

We may term such a design a "rolling sample," (we know of no actual examples as yet, alas) (Kish (1981, 1986)). The approach is as follows. First design a sample to cover all local areas (small domains) in say 10 years with a sampling rate of $p$ (e.g., from 0.1 to 1). Then subdivide this master sample into yearly samples of $p/10$, then into quarterly samples of $p/40$, monthly samples of $p/120$, or even weekly samples of $p/520$. These subdivisions should be compromises between the aim of greater spread for better local statistics and the need for economy in field work. This type of design has been used on relatively small populations and described (Kish, Lovejoy and Rackow (1961)) and discussed before (Kish (1965, sec. 12.5D, 1979b, 1981)).

The closest example of a national sample may be that of the U.S. National Center for Health Statistics that covers 1 000 dwellings weekly, which are cumulated to 52 000 dwellings yearly. However, this is too small for small domains, and was not "rolled" (designed) to cover all small local areas (NCHS (1958)).

A number of problems must be faced in the use of rolling sample designs. First, to produce small area estimates over a reasonably short period of time, the size of the sample (and subsamples) may have to be very large and the sample widely spread. This problem is less serious when one uses a moderate sample size that can be sustained to produce more precise estimates for main administrative subdivisions, as in many developing countries.

Second, efficient cumulation favors little or no overlap between subsamples, or at least prohibits large overlaps. This can involve high costs and considerable administrative difficulties, especially in situations where, due to difficult and expensive travel and to linguistic and cultural diversity, enumerators have to be locally recruited and stationed within fixed sample areas. Indeed, developing countries have experienced difficulties, particularly at the initial stages of their survey programs, in introducing the desired level of rotation of sample areas (Rao and Verma (1982)). This difficulty may be somewhat alleviated by reducing the periodicity of surveys and using large, more heterogeneous PSUs so that the sample may be rotated (rolled) to an extent within fixed PSUs.

Third, an overlap (as distinct from rolling) design serves to reduce the variance of change. These reductions are important for "stable" variables that have high individual correlations (R), like poverty, but not for less stable characteristics, like unemployment, with low R. Reducing the overlap should be decided in accordance with balancing the purposes best served by overlapping versus cumulating. Technical considerations may also affect this decision: for instance, it is possible (with weighted estimation) to obtain much of the gains with overlaps as small as 1/3 or even 1/10. The rolling samples can be designed to include small overlaps and still obtain most of the desired cumulation.

Fourth, the conceptual obstacle of movers during the cumulation strikes some observers on first sight. However, this can be handled by accepting all persons when their segments are selected. Only a small portion will appear (in unbiased manner) more than once in any cumulation.

Fifth, there seem to be conceptual and philosophical obstacles to accepting the validity of data cumulated and averaged over periods subject to secular, cyclical, and haphazard variations. Whereas data collected at a specific time are good for that specific time, inferences beyond it are subject to bias and to judgmental inference. Tradition and familiarity have blinded us to the dubious nature of those inferences from judgment samples of time. There is much more to be said for the advantages of averaging over seasonal and haphazard variations instead of simple projections from one instant into the future. These issues and the preceding have been discussed elsewhere (Kish (1965, 1979a, 1981)).

## 7. Combined Role in Promoting Statistical Development

We have noted that undertaking the census can provide a great impetus to the development of national statistical organizations. This applies especially to developing countries. The census involves large-scale mobilization of resources and provides opportunities for unusually close collaboration of statistical and administrative infrastructures and of users and producers of statistical data. It also provides opportunities for significant upgrading of experience, technical expertise, and facilities for field work, data processing and dissemination (transport, core of trained supervisory staff, new and enlarged computer hardware and software, printing facilities, etc.) (Gil and Ghansah (1968)). This makes it particularly opportune – both more feasible and more necessary – to consolidate this capability, to upgrade census results and to expand them to many more topics through ongoing sample surveys. The 1970 African Census Programme has, for example, been an important factor in the launching of continuing programmes of household surveys in many countries in Africa, and subsequently elsewhere (United Nations (1981, 1983)). This also applies in reverse. Sample surveys – if undertaken with proper planning and in parallel with the establishment and gradual improvement of skills and facilities to carry them out on a regular and continuing basis – can make a major contribution towards the upgrading of statistical capability, and hence the capability to conduct better censuses. Indeed, the establishment of infrastructural facilities for surveys and the actual undertaking of survey programmes "constitute[s] in many situations the leading or dynamic component in the process of overall statistical development" (Rao and Verma (1982)). This is because properly planned and executed programs of surveys "can generate interconnected data of a great variety, broadening the range of users which the statistical organization can satisfy and enhancing the uses of data collected through censuses and other means" (ibid.).

## 8. References

Cohen, S.B. and Kalsbeek, W.D. (1977): An Alternative Strategy for Estimating the Parameters of Local Areas. Proceedings of the Social Statistics Section, American Statistical Association, pp. 781–785.

Ericksen, E.P. (1973): A Method for Combining Sample Survey Data and Symptomatic Indicators to Obtain Population Estimates for Local Areas. Demography (10), pp. 137–160.

Ericksen, E.P. (1974): A Regression Method for Estimating Population Changes in Local Areas. Journal of the American Statistical Association, (69), pp. 867–875.

Fay, R.E. and Herriot, R. (1977): Estimates of Income for Small Places: An Application of James-Stein Procedures to Census Data. Journal of the American Statistical Association (74), pp. 269–277.

Gil, B. and Ghansah, D.K. (1968): Design and Concepts of Population Censuses and Sample Surveys in a Developing Country – Ghana. In Caldwell, J.C. and Okonjo, C., eds., The Population of Tropical Africa. Longmans, London.

Gonzalez, M.E. and Hoza, C. (1978): Small Area Estimation with Application to Unemployment and Housing Estimators. Journal of the American Statistical Association (73), pp. 7–15.

Hansen, M.H., Hurwitz, W.N., and Bershad, M.A. (1961): Measurement Errors in Censuses and Surveys. Bulletin of the International Statistical Institute 38(2), pp. 359–374.

Khamis, S.H. and Alonzo, D.C. (1975): Changes in Methods, Scope and Concepts of the 1980 World Census of Agriculture. Bulletin of the International Statistical Institute 45(2), pp. 54–82.

Kish, L. (1965): Survey Sampling. New York: John Wiley. Section 1.3, 13.1–13.6.

Kish, L. (1979a): Samples and Censuses. International Statistical Review, (47), pp. 99–109.

Kish, L. (1979b): Rotating Samples Instead of Censuses. Asian and Pacific Census Forum, (6), pp. 1–2, 12–13.

Kish, L. (1980): Design and Estimation for Domains. The Statistician, 29(4), pp. 209–222.

Kish, L. (1981): Using Cumulated Rolling Samples. U.S. Government Printing Office, No. 80–52810, 78 pages.

Kish, L. (1986): Timing of Surveys for Public Policy. Australian Journal of Statistics, pp. 1–12.

Kish, L. and Verma, V. (1983): Censuses plus Samples: Combined Uses and Designs. Bulletin of the International Statistical Institute 50(1), pp. 66–82.

Kish, L., Lovejoy, W., and Rackow, P. (1961): A Multistage Probability Sample for Continuous Traffic Surveys. Proceedings of the Social Statistics Section, American Statistical Association, pp. 227–230.

Majumdar, H. (1975): Analytical Studies Relating to the Sampling Procedure Adopted in 1971 Census. Data Base of Indian Economy (ed. Dandekar and Venkataramaiah). Statistical Publishing Society, Calcutta, pp. 315–321.

Marks, E.S. (1973): Different Roles of Population Censuses and Interview Surveys, Particularly in the U.K. Context (discussion of paper by Redfern, P.). Bulletin of the International Statistical Institute (41), p. 212.

Marks, E.S., Seltzer, W., and Krotki, K.J. (1974): Population Growth Estimation. Population Council, New York.

Murthy, M.N. (1980): Use of Sampling in Population Census with a Reference to the Experience of Some Countries of Asia and the Pacific. Paper presented at SIAP Workshop on Sampling, Jakarta, 12–14 May.

National Center for Health Statistics (1958): Statistical Design of the Health Household-Interview Survey, Public Health Service, 584-A2, pp. 15–18.

Purcell, N.J. (1979): Efficient Small Domain Estimation: A Categorical Data Analysis Approach. Unpublished PhD thesis, University of Michigan, Ann Arbor, Michigan.

Purcell, N.J. and Kish, L. (1979): Estimation for Small Domains. Biometrics (35).

Purcell, N.J. and Kish, L. (1980): Postcensal Estimates for Local Areas (or Domains). International Statistical Review (48), pp. 3–18.

Rao, V.R. and Verma, V. (1982): The United Nations' National Household Survey Capability Programme. Presented at the American Statistical Association Joint Statistical Meetings, Cincinnati, USA. (Unpublished)

Schmitt, R.C. and Crosetti, A.H. (1954): Accuracy of the Ratio Method of Estimating Postcensal Population. Land Economics (30), pp. 279–280.

Steinberg, J. and Waksberg, J. (1956): Sampling in the 1950 Census of Population and Housing. Working Paper No. 4, U.S. Bureau of the Census, Washington, D.C.

United Nations (1971): Handbook of Population and Housing Census Methods. Part VI: Sampling in Connexion with Population and Housing Censuses. Studies in Methods, Series F No. 16 (Sales E.70.XVII.9).

United Nations (1980): Principles and Recommendations for Population and Housing Censuses. Series M No. 67 (Sales E.80.XVII.8).

United Nations (1981): The National Household Survey Capability Programme: Prospectus. (DP/UN-INT-79-020/1).

United Nations (1982): Nonsampling Errors in Household Surveys: Sources, Assessment and Control. (DP/UN/INT-81-041/2).

United Nations Statistical Office (1983): National Household Survey Capability Programme: Selected Issues of Design and Implementation. Bulletin of the International Statistical Institute 50(2), pp. 1363–1380.

U.S. Bureau of the Census (1975): Population Estimates and Projection. Current Population Reports, Series P-25 No. 580. U.S. Government Printing Office, Washington, D.C.

Verma, V. (1981): Assessment of Errors in Household Surveys. Bulletin of the International Statistical Institute 49(2), pp. 905–919.

Waksberg, J. (1968): The Role of Sampling in Population Censuses: Its Effect on Timeliness and Accuracy. Demography (3), pp. 362–373.

Waksberg, J. and Hanson, R.H. (1965): Sampling Applications in Censuses of Population and Housing. Washington: U.S. Bureau of the Census, Technical Paper No. 13.

Zarkovich, S.S. (1965): Sampling Methods and Censuses. Rome: FAO, Chapters 1–6.

Received January 1986
Revised August 1986