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STILL ROLLING: LESLIE KISH'S "ROLLING SAMPLES" AND THE AMERICAN COMMUNITY SURVEY

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ABSTRACT

Leslie Kish long advocated a "rolling sample" design, with non-overlapping monthly panels which can be cumulated over different lengths of time for domains of different sizes. This enables a single survey to serve multiple purposes. The Census Bureau's new American Community Survey uses such a rolling sample design, with annual averages to measure change at the state level, and three-year or five-year moving averages to describe progressively smaller domains. This paper traces Kish's influence on the development of the American Community Survey, and discusses some practical methodological issues that had to be addressed in implementing the design.

Key Words: Rolling Sample; Multi-year averages; Asymmetrical Cumulations

1. INTRODUCTION

A "rolling sample design", defined below, gives a single survey the flexibility to serve multiple purposes. The concept was developed by Leslie Kish in a series of papers (including Kish 1979a, 1979b, 1981, 1983, 1986, 1990, 1997, 1998 and Kish and Verma, 1983, 1986) in which he elaborated the principles of cumulating information over space and time from a rolling sample. Kish advocated its use for a variety of purposes (Kish, 1998), especially in developing countries (Kish, 1979b), but also in the context of the U.S. census (Kish, 1981). His personal use of rolling samples goes back at least to 1958, under the name "continuous sampling" (Kish, 1961); a still earlier project (Mooney, 1956) is cited in Kish (1998).

The American Community Survey (ACS), which is being developed as a replacement for the traditional "long form" survey conducted as part of the census, will use a form of the rolling sample design. This paper describes how the rolling sample concept is being implemented for the ACS, influenced by its specific objectives and operational considerations. The design decisions made for the ACS illustrate some issues that may arise for rolling samples in general. They also illustrate how Leslie Kish influenced survey development on multiple levels: philosophical, personal, and practical.

2. ROLLING SAMPLES

A "rolling sample" design jointly selects *k* non-overlapping probability samples (panels), each of which constitutes 1/F of the entire population. One panel is interviewed each time period until all the sample has been interviewed after *k* periods. Depending on the precision requirements, a single panel of 1/F may be sufficient

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to provide good estimates for the population as a whole, and possibly for some large domains. For smaller domains or for greater precision for large domains, cumulations of different numbers of consecutive panels can be used, up to k/F of the population. A rolling sample design with k=F is called a "rolling census". For a monthly rolling sample, it is natural to have *F* be a multiple of twelve, and natural cumulations are quarterly, semi-annual, annual, and multiple years.

"Domains" include both geographic areas and demographic subgroups. Kish (1987, section 2.3) presents a framework for the tradeoff between geographic and demographic detail, for a given required level of precision. Even more central to the idea of rolling samples was the idea of "asymmetrical cumulation" of data, over different lengths of time for different sizes of domain (Kish, 1990, 1998), which was later broadened into a view of the basic similarities of averaging over space and averaging over time (Kish, 1998), as well as averaging over different demographic domains. The flexibility of the rolling sample design comes from the opportunities it provides to make different tradeoffs between spatial, temporal, and demographic detail.

Leslie Kish left his colleagues with a challenge to extend these ideas into a "theory of combining populations" (Kish, 1999a, 2001). He organized a contributed paper session on "combining surveys" at the 1999 meetings of the International Statistical Institute, explaining to the presenters that we were all working on different aspects of the same problem, whether we knew it or not. The scope of this problem includes various forms of cumulation of data from rolling samples, as well as the question of how to combine data from different countries into statistics for larger entities such as the European Union. Kish (2001) suggests that these problems have fundamental features in common with the problem of combining information from different experiments (Cochran, 1937, 1954).

3. THE CENSUS LONG FORM AND INTERCENSAL ALTERNATIVES

The decennial census "long form" survey is the main source of subnational data about the *characteristics* of the U.S. population and housing. Estimates of the *number* of people and housing units come from the "short form" part of census administered to all households. With an overall sampling rate of one-in-six, the long form survey provides precise, detailed[2] estimates of a variety of demographic and economic characteristics for individual states, large cities, and large counties or groups of counties. It provides useful, though less precise and less detailed, estimates for even very small areas such as small towns and Indian Reservations, as well as census tracts, which average about 4,000 population. For the smallest governmental units, higher sampling rates are used, as high as one-in-two for the smallest places, so that there are usable estimates for these areas. To compensate for the higher sampling rates in these areas, the rate is one-in-eight in the largest tracts.

Between the censuses, the federal government's statistical programs provide relatively little information about the characteristics of the population below the national level. The basic census counts are updated by an intercensal demographic estimates program, but other demographic and economic characteristics are available mainly from national surveys. The Current Population Survey (CPS), the U.S. monthly labor form survey, has about a one-in-1000 sampling rate with substantial overlap in the sample units from one month to the next so that the sample cannot be profitably cumulated over time as a rolling sample can. A March Supplement to the CPS collects additional information once a year, providing estimates for income and poverty at the state level, but with limited precision and demographic detail. There are programs which use modeling methods based on administrative records to make small-area estimates for unemployment, and for income and poverty, but not for a variety of characteristics.

The need for more frequent information for smaller domains (or "communities") has long been recognized

[2] "Precise" refers to the sampling error, and "detailed" means that estimates are given for many demographic domains within the geographic domain.

(Hauser, 1941; Eckler, 1972, p. 212; Bounpane, 1986). Leslie gave credit to his friend, Philip Hauser, for proposing an "annual sample census" in 1941. Kish (1981) proposed a rolling sample as a way to meet this need, presenting several options including a rolling sample for the CPS. Instead a mid-decade census was authorized for 1985, but it was never funded. Nor was a proposal to double the size of the CPS (Tupek, et al, 1990).

Interest at the Census Bureau in intercensal information about population characteristics was revived by a proposal for a "Decade Census Program" advanced by Herriot, et al (1989). This program would have collected data in different states in different years; ultimately this proposal did not gain acceptance. However, Roger Herriot's energetic and eloquent advocacy of the importance and potential value of intercensal subnational data created awareness in federal statistical agencies of the possibility of a "new paradigm" for the decennial cycle of data collection. Awareness of Kish's rolling sample proposal was definitely a factor during this period, as the Bureau considered new approaches for the 2000 census (see Bounpane, 1986).

There was renewed Congressional interest in intercensal characteristics data (Melnick, 1990; Sawyer, 1993), and a "continuous measurement" alternative to the census long form was considered as part of the research for Census 2000, starting in 1992. Kish's rolling sample design was eventually proposed for this purpose because it provided flexibility in making estimates, as well as the potential for efficient data collection (Alexander, 1993, 1997; National Academy of Sciences, 1994, 1995). My recollection is that the most influential articles were Kish (1981, 1990), and that Kish and Verma (1983, 1986) were also consulted. "Continuous Measurement" was later renamed the "American Community Survey (ACS)".

The proposed ACS was not adopted for Census 2000, but after limited testing during 1996-1998, the ACS methodology was implemented in 36 counties for the years 1999-2001, so that ACS results could be compared to the 2000 census long form data. There was also a large-scale test in 2000, for a state-representative annual sample of about 700,000 addresses called the Census 2000 Supplementary Survey, of collecting long-form data separately from the census, using the ACS questionnaire. In 2001 and 2002, the Supplementary Survey is being continued, as part of the transition to the ACS.

4. THE PLANNED AMERICAN COMMUNITY SURVEY

The ACS will start in 2003, if funded by Congress, with a monthly sample of about 250,000 addresses, a new panel of addresses starting each month. This corresponds to a monthly rolling sample with an average rate of approximately $F = 480$ or an annual sample with $F = 40$. The survey will use $k = 60$, with the shortest published cumulation being calendar year estimates. The ACS will be conducted by mail, with nonresponse followup by telephone. A random sample of one-third of the remaining nonrespondents will be selected for followup in person.

For domains with average response rates, with a monthly $F = 480$, the standard errors for a 5-year average estimate from the ACS will be somewhat larger than for a corresponding estimate from the census long form, typically on the order of 1.33 times as large. This was judged to be "sufficiently close" for most purposes, given the advantage of timeliness and the expected lower missing data rates due to having a permanent staff of interviewers. In areas with lower-than-average mail response rates, the subsampling for nonresponse follow-up will reduce the effective sample size. This happens not only because the number of interviews is reduced, but also because the unequal weights typically lead to a higher design effect (Kish, 1965, pp. 429-431). To compensate for this, the ACS will probably use a higher nonresponse subsampling rate in low-response areas, balanced by a lower sampling rate in areas with higher-than-average mail response. The details of this are still being determined. There also will be an oversample of addresses in small governmental units, as with the census long form sample.

An important development in the last decade, that made the ACS possible[3], is the Census Bureau's program to maintain an ongoing Master Address File (MAF), linked to our TIGER geographic database. The main source of address updates throughout the decade is the Postal Service's Delivery Sequence File (DSF). The Bureau is implementing a MAF/TIGER modernization program that will augment the DSF updates with data files from local governments and other administrative sources, and by targeting new addresses in more rural areas by interviewers from the ACS and other surveys. The monthly samples are actually generated by selecting an annual sample from the MAF in the previous September, and dividing it into 12 monthly panels. In February, there is a supplemental sample of new units from the DSF, spread across the remaining months of the year.

Replacing the 2010 census long form, by the ACS, is one component of a program to re-engineer the 2010 census. This also includes the modernization of MAF/TIGER, as well as a program of early research and testing to automate, streamline, and improve the census operations for 2010. This combination of improvements is expected to have a budgetary cost for the full 10-year cycle that is less than the cost of repeating the Census 2000 methods in 2010. This is a quite different plan than the vision of ACS described in National Academy of Sciences (1994, Chapter 6; 1995, Chapter 6), where I expressed hopes that eliminating the long form by itself, without other fundamental improvements, might save enough to pay for the ACS.

5. SOME VARIATIONS ON THE BASIC DESIGN, AND SOME ISSUES

5.1 Multi-stage Cluster Samples

The ACS uses an unclustered one-stage systematic sample, because the goals include providing data for all small geographic domains, such as tracts or block groups, each year. From discussions in Kish (1981, 1998), it is clear that rolling samples can also use cluster samples and multiple stages of selection, as well as varying probabilities of selection. However, to qualify as a "rolling sample", the primary sampling units themselves must be a rolling sample. A design with a fixed set of primary sampling units (PSUs), with a rolling sample within each PSU, is a "cumulated representative sample" (Kish, 1998).

Leslie was emphatic that the proposal by Herriot, et al (1989), was not what he meant by "rolling sample". However, it would seem to fit the definition if the states are considered as PSUs. I think this demonstrates that there is an implicit requirement that a rolling sample must yield a useful representative probability sample in each time period, for each geographic domain of interest; this is not true if the PSUs are states. This means that the clusters or PSUs need to be substantially smaller than the smallest domain of interest. (See Kish, 1998, p. 38.)

5.2 Differential Sampling Rates

Kish (1998, Section 4) notes that a rolling sample can use different sampling fractions in different strata. This can get complicated, especially if the sampling fractions change over time, because the conditional probability of selecting a unit (without replacement) for the j^{th} panel in the h^{th} stratum depends on the sampling rates used in the previous panels in that stratum. This is even more complicated if the strata change over time, for example as the boundaries of governmental units change.

To simplify this for the ACS, we select the sample in two stages. The first stage selects a rolling "super sample" using a constant sampling rate for each panel and each year, equal to the largest sampling rate required in any stratum. The second stage subsamples the initial sample, to give the desired sampling rate for each

[3] Kish (1981) suggests an alternative approach of "cumulative rolling listings", but this would be quite expensive for making regular estimates for all of the smallest domains, such as census tracts.

stratum for that year. The selection of subsequent samples, which avoids overlap with the entire previous supersamples, needs only to keep track of the sampling rate for the first stage.

5.3 Updates to the Frame

In practice, the population is a little different for each panel. New addresses are added to the frame. Some old addresses cease to exist; they may be removed from the address list, or they may stay on the list and be deleted only after attempts to contact them. This presents no fundamental conceptual problem. It does mean that a "rolling census" would not necessarily contact every population unit that ever exists, since some units may go in and out of existence too quickly to fall into sample.

To avoid record-keeping of different conditional sampling rates for different "cohorts" of addresses which were added during Master Address File updates at different times, we have found it convenient to assign artificial "back samples" by selecting addresses from each set of new addresses not only for the current panel, but for past panels. These units are not interviewed, since the times for their assigned panels are past, but they are avoided during the without-replacement selection of future panels.

5.4 What happens after Panel k?

One question Leslie did not address explicitly, as far as I know, is how to draw the sample for panel k+1. I think he assumed that panel k + 1 would be the same as panel 1, panel k + 2 repeats panel 2, and so forth. This works fine for a simple random sample, but not so well for a systematic sample intended to spread the sample over a geographically sorted list, because as the frame changes over time, panel 1 doesn't keep its even spacing.

Our plan is to select panel k + 1, and future panels, as a fresh systematic sample. Each one will avoid overlap with the previous k - 1 panels, so there will always be k consecutive non-overlapping panels, but we won't worry about overlapping with panels before that.

5.5 Questionnaire Reference Date, Given an Extended Interview Period

The interviews from each monthly ACS panel take place over a three-month period, allowing two months for mail returns and telephone followup before starting the more expensive personal visits in the third month. Thus, the data actually collected in June consist of early mail returns from the June panel, late mail returns and telephone interviews from the May panel, and personal-visit followup cases from the April panel. This raises the issue of whether to ask the survey questions as of the time the survey was mailed out–the best choice as far as sampling bias–or as of the time the questions are asked–the best choice as far as response error and other nonsampling errors, especially for people who have moved from the address.

Taking these quality tradeoffs into account, we chose to use a "current" reference date, collecting the characteristics of the household members at the time of interview. One reason for this decision is that we think the nonsampling errors will be harder to evaluate than the sampling bias. Also the sampling biases in the monthly estimates will tend to cancel over the course of the year. This is one reason for limiting the ACS to annual and multiple-year estimates.

5.6 Use of Intercensal Population Estimates as Survey Weighting Controls

The Census Bureau has a program of "intercensal"[4] demographic estimates, based on demographic models. These models update the previous census, using vital records and other administrative records information.

[4] Leslie would call these "post-censal" estimates, reserving "intercensal" for estimates between two censuses that have been completed.

These estimates are used as independent weighting controls, or "post-stratification factors", for most national household surveys (see Kish, 1965, pp. 90-92). Adjusting the survey weights to agree with controls can reduce the variances of survey estimates, adjust for differences in coverage by age, sex, race, or Hispanic origin, and improve consistency across surveys. The census long form similarly uses the census counts as controls in its weighting.

The weighting controls have traditionally not been available for the smallest geographic domains, at least not with the demographic detail available for larger areas. Plans to produce more detailed controls for use in ACS weighting are described in Alexander and Wetrogan (2000). Some improvements will come from improved sources of administrative data, but in addition the ACS itself will provide information on changes in the population, which can be incorporated into the demographic models. The problem is complicated by the differences between the "current resident rule" used in the ACS and the "usual resident rule" used in the census; the ACS includes a question about part-year residents to help in adjusting for this difference. To facilitate this integration of survey data and demographic models, and especially to develop error measures for the resulting estimates, the Census Bureau is trying to develop "statistical" versions of the demographic models used in producing the intercensal population estimates. The inspiration for this effort to blend the statistical and demographic approaches is Purcell and Kish (1979).

6. DIFFERENT CUMULATIONS FOR DIFFERENT PURPOSES

For the main ACS objective, to replace the census long form as a source of detailed descriptive statistics, we plan to use 5-year ACS cumulations, for a data product similar to traditional long form "summary files". This is the shortest time period for which the ACS sampling error is judged to be reasonably close to that of the census long form. All sizes and types of geographic areas would be included on these 5-year data files. For allocating government funds based on an assessment of current need for the funds, simulations suggest that 3-year cumulations may be preferable to the 5-year, sacrificing precision for greater recency (Alexander, 1998).

For individual areas, the most prominently published data will be one-year averages for areas greater than 65,000 population, and 3-year averages for areas greater than 20,000, in addition to the 5-year averages for all areas. Annual average estimates for areas below these thresholds will be available for more "sophisticated" uses to use in time series models, and to indicate large variations within the multi-year averages, but will not be as prominently displayed in our publications or on our websites.

These planned published ACS data products are designed to encourage analysts to use the same length of cumulation when comparing areas of different sizes, on the grounds that to do otherwise may be perceived as unfair to smaller jurisdictions. In doing this, we have accepted the notion of "asymmetrical cumulations" as far as levels of geography, but not necessarily within the same level of geography. For example, we would use one year for comparing states, but would recommend 5 years for all the counties in a table comparing large and small counties. In this latter recommendation, we differ somewhat from Kish (1998, pp 42-43) which would let us use tables of counties with one-year estimates for large counties, 3-year averages for medium-sized ones, and 5-year averages for small ones. It will be interesting to see what practices data users will adopt in this regard.

7. WEIGHTING THE YEARS IN MULTI-YEAR CUMULATIONS

Kish (1998) points out that there are a number of choices for weighting multi-year cumulations. If there are ten yearly means $\bar{y}_i$, then there are many choices of $\bar{y} = \sum w_i \bar{y}_i$, with $\sum w_i = 1$, to use as the ten-year cumulations.

For the ACS 5-year and other multi-year cumulations, discussed in Section 6, our plans are to give the years equal weights in the standard published data products, e.g., $w_i = .2$ for the 5-year average. This was an area of disagreement with Kish (1998), which gently urges us to consider of alternatives, in particular weights of the form $w_{i+1} = Cw_i$, with $C > 1$.

An underlying issue in thinking about unequal weights is what statistical problem we are trying to solve. Using the 2003 - 2007 cumulation as an example, is the goal:

- to provide a "direct design based" estimate for the 2003-2007 historical average;
- to provide a "model-based" estimate for the 2007 value; or
- to provide a "direct, design-based" estimate for a weighted 2003-2007 historical average, with more weight on recent years?

To interpret the 2003-2007 estimate as an estimate for 2007 requires a model or assumptions about the time series for the area. The problem may be viewed as combining a direct estimate for 2007 with a forecast for 2007 based on the years 2003, ..., 2006, with the requirement that the same formula be used for all areas and all characteristics to preserve additivity in the tables and comparability across tables.

I have previously interpreted the decision as a choice between the first two goals, and have shied away from the second approach for the ACS, ultimately because of the concerns expressed in Hansen, et al (1983, Sections 3 and 5.5) about using model-based estimates for general-purpose "official statistics". With the variety of statistics and geographic areas covered by the ACS, there inevitably will be some where the compromise model fails badly; a data user may be unaware of this failure, or may be very aware. In what sense can the compromise average be viewed as a valid estimate for 2007 when the compromise model clearly fails, and what measure of error would be associated with it? With this view of the issue, we have recommended using the unweighted multi-year averages as the standard general-purpose data product, with the time series of annual estimates being available for use in time series models for specific applications, and for interpreting the multi-year averages when there is variation within the 5-year period.

However, upon rereading Kish (1998), I now interpret his view of the weighted average to be the third formulation, a design-based estimator of a more up-to-date population parameter. This avoids the concerns about model fit for general-purpose uses, although there is still the question of how to justify and achieve a consensus solution. Also, the unequal weights tend to increase the standard errors of the multi-year averages. But Kish (1998, p. 40) will get the last word on the subject:

> *"Important questions remain for further discussions and research. Perhaps forever, and this can become a 'growth industry.' "*

8. NOT COMBINING THE CPS AND THE ACS

Leslie often said he was pleased to see his idea being implemented in the ACS, but I think he was disappointed that we did not try to replace both the census long form and the CPS with one survey. By contrast with some other issues where we had lively discussions, Leslie took a "hands off" stance on this issue. I think he viewed this as a decision about quality tradeoffs, which the government agencies had to work out for ourselves. There were two main reasons for our decision:

We cannot adequately measure the monthly unemployment rate with a mail survey. Correct measurement of the unemployment rate requires complex questions that would not be feasible to ask by mail, for example, to probe to be sure that someone who is "looking for work" did conduct an active job search. (See Butani, et al, 1999). The Census 2000 Supplementary Survey, using the ACS procedures, dramatically overestimated the 2000 national unemployment rate (5.3 percent versus 4.0 percent in the CPS). A similar difference was seen in the 1990 census.

A mail survey would lag substantially in producing monthly rates, compared to the CPS. In addition, the impossibility of completing all the mail interviews for a panel in the designated month introduces biases in monthly estimates (see section 5.5 above). These problems would be reduced somewhat for quarterly moving averages instead of monthly estimates, which Leslie frequently suggested (for example Kish 1999), but the monthly unemployment report is an indispensable economic indicator in the U.S.

It is too expensive to replace the long form without using mail. A rolling sample survey, conducted in person with a large enough sample to replace the long form, would have to be 3 or 4 times as large as the CPS. This is a function of the size of the U.S. population, and the number of tract-sized domains for which estimates are required from the long form. Such a survey would be much more expensive per case than the CPS, because it could not use a cluster sample or telephone interviews for repeated interviews of the same households, as does the CPS. The total cost of such a survey would be several times as great as the combined cost of the proposed ACS and the CPS.

Because it is designed so narrowly as a long form replacement, the ACS does not illustrate the full range of flexibility that Leslie envisioned from a rolling sample. Under different circumstances, for a smaller population, with less need for very small domains from the "long form survey", or less strict requirements for timing and questions for the labor force survey, it might be possible for a labor force survey with a rolling sample to meet the demands for small domain data. With the further addition of a split panel or other components (Kish, 1998, pp. 40-41) an even wider range of objectives could be met.

9. CONTRIBUTIONS: PHILOSOPHICAL, PERSONAL, AND PRACTICAL

The long list of articles by Leslie Kish on the subject of rolling samples clearly demonstrates the intensity and tenacity of his campaign for what he understood as an important idea. The evolution of the idea over the course of these papers also illustrates the depth of his attention to "philosophical" questions about the fundamental quality objectives for a survey: What are we trying to do? How does the choice of survey design relate to what we are trying to do, and why? This kind of guidance is crucial at the start of a survey program, when the "big questions" are being addressed, and makes the difference between ideas that quickly fall by the wayside and those that are "still rolling".

Leslie's personal support of other statisticians went far beyond his papers. Though I was by no means one of his closest colleagues, he regularly provided personal advice or encouragement when he sensed it was needed. The "still rolling" in this paper's title was the title I used in e-mail messages to him when I had news about the ACS's perilous passage through the annual budget cycle, which was most of the time. He would respond briefly by e-mail, but important messages always came in the form of handwritten letters.

Finally, based on these papers, it is clear that Leslie was always a practical person, even at his most philosophical, and that his papers cannot be fully appreciated without knowing what was going on in the survey world when he wrote them. Looking back over his rolling sample papers, I can see many comments, about both details and general principles, that were aimed at enlightening specific decisions that the Census Bureau needed to make at the time. I would guess that throughout his work, there are specific messages to help out someone somewhere in the world who faced a practical design decision at the time.

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This paper reports the results of research and analysis undertaken by Census Bureau staff. It has undergone a Census Bureau review more limited in scope than that given to official Census Bureau publications. This report is released to inform interested parties of ongoing research and to encourage discussion of work in progress.