CENSUS COVERAGE MEASUREMENT METHODOLOGY RESEARCH:
PAST AND PRESENT

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KEY WORDS: Undercount, 2000 Census

1. Introduction

This paper provides a brief description of the coverage measurement methodologies which have been considered for research for possible application in a one-number census in the 2000 census. The term "one-number census" refers to a census process with an integrated coverage measurement program that would result in a single set of official population data by the mandated deadlines. In contrast, the 1990 methodology was designed to produce two sets of **official** population data, unadjusted counts by the legal deadlines and adjusted counts sometime later.

Although the remaining contenders are CensusPlus, SuperCensus, and Post Enumeration Survey, the paper provides the description, the advantages, the disadvantages, and Census Bureau experience for each coverage measurement method considered. For further reading, other resources that provide discussions of coverage measurement methodologies include Citro and Cohen (1985), Hogan (1989), and Mulry (1992) which includes a more extensive list of references.

2. Administrative Record Match

An administrative record match (ARM) is an evaluation procedure in which a sample from the administrative record file is matched to the census population. The percentage in the sample not matched is a measure of the census coverage error. In the Megalist methodology, several administrative lists are obtained and merged with unduplication. The composite list is matched to the census to identify persons missed by the census.

An advantage of using administrative lists is that they do not rely on a household survey or a previous census. Therefore, there is not the problem of surveys tending to miss many of the same people as censuses. Also, there is the possibility of focussing on the hard-to-enumerate segments of the population by obtaining lists such as those for Aid to Families with Dependent Children.

The disadvantage is that there is no guarantee that the lists would cover the entire population of sub-population of interest. This method also requires matching to the census with possible tracing or follow-up of nonmatches. An additional complication of the Megalist methodology is that the unduplication of the lists requires more matching which may be difficult because people use different names and addresses for different purposes. A crucial difficulty with using administrative records for coverage evaluation is identifying the target population for which these records constitute a frame. This creates problems in generalizing any results to the entire population.

The match of draft registration record to the 1940 census was the first ARM conducted at the Bureau of the Census. Surprisingly, there were more males registered for the draft than enumerated in the census (Price, 1947). Since then, the Census Bureau has conducted matches between other administrative lists and censuses, census dress rehearsals, and surveys. The matches to medicare records were with 1970 census records (U. S. Bureau of the Census, 1973) and the 1980 Post Enumeration Program (PEP) records, which included the April and August 1980 Current Population Survey (CPS) samples and a sample of census enumerations (U.S. Bureau of the Census, 1980). Social Security Administration records were matched with the 1980 PEP records (U.S. Bureau of the Census, 1980) and 1988 Dress Rehearsal records from St. Louis (Wolfgang, 1989). The matches to IRS record were with the 1978 February CPS sample (Cowan and Newbauer, 1980), the 1978 Census Dress Rehearsal (Muller, 1980), the 1980 PEP records (U.S. Bureau of the Census, 1980), and the 1980 Census (Childers, 1984).

Department of Motor Vehicles driver's license records were matched with 1970 census records in the District of Columbia (Novoa, 1971), 1980 Census records (Alberti, 1980), and 1988 Dress Rehearsal records in St. Louis (Wolfgang, 1989).

As part of the lawsuit over adjustment of the 1980 census, welfare records (U.S. Bureau of the Census, 1981) and several other unduplicated lists (U.S. Bureau of the Census, 1982) were matched to the census.

Veterans administration records for the St. Louis Dress Rehearsal site were matched to the census and to the PES (Wolfgang, 1989). Lists of names and addresses of parolees and probationers from parole officers were matched to the 1990 census (Wajer, 1992).

3. Reverse Record Check

A reverse record check (RRC) is a census evaluation program in which a sample of the population is drawn from records created prior to the census, traced forward to the time of the census, and matched to the census. The proportion of the sample which is unmatched provides an estimate of the proportion of the population which was missed in the census. The frame is usually composed of people enumerated in the previous census, persons missed in the previous census, births, and immigrants. Samples are selected from each group.

A RRC takes advantage of the phenomenon that the probability that a particular person can be found changes with time. For example, a child is easier to find than a young adult.

Even if hard-to-enumerate groups are easier to sample several years before the census, this advantage may be offset to some extent by another type of correlation bias. Correlation bias potentially arises if those people who were traced successfully are more likely to be counted in the census than those who were not traceable. A disadvantage is that the RRC has to be supplemented with a separate sample of census enumerations in order to measure erroneous enumerations.

The Census Bureau used the 1960 RRC to estimate the number of persons omitted by the 1960 census (U. S. Bureau of the Census, 1964). The CPS-Census Retrospective Study traced CPS samples from 1976, '77, '78, '79, and '80 to the time of the 1980 decennial census and matched them to the census (Diffendal, 1986). In the Forward Trace Study, the people in the four samples were traced over the years 1980 to 1985. The estimates of the tracing rates were too low to merit a recommendation to use RRC to measure coverage in the 1990 census (Mulry and Dajani, 1989).

4. Demographic Analysis

Demographic analysis as a tool for census evaluation involves first developing estimates for the population in various categories, such as age, race, and sex groups, at Census Day by the combination of estimates based on various types of demographic data. The estimates for the groups are then added to yield an estimate of the nation as a whole.

The data used for demographic analysis estimates include: birth, death, and immigration statistics; sex ratios, life tables, etc.; historical series of census data; and data from sample surveys. The data are corrected for various types of known errors. The overall accuracy of the method depends on the quality of the demographic data and the corrections. The basic demographic accounting relationship is

$$\text{Population} = \text{Births} - \text{Deaths} + \text{Immigrants} - \text{Emigrants}.$$

The Census Bureau has experience with demographic analysis and knows that the estimates at the national level are comparable to those from a PES. Methodology for the evaluation of the demographic analysis estimates has been developed and implemented in a census environment. (Robinson, et al, 1993)

The primary advantage of demographic analysis is that it is completely independent of the census. The disadvantage is that the direct estimates of population size are available at the national level only. Another disadvantage is that the estimates are possible only for subgroups for which vital records are kept, Blacks and non-Blacks.

Demographic analysis methods were developed by Coale (1955) for the first time to evaluate the coverage error in the 1950 census. The 1960 census was the first census where demographic analysis was used as an evaluation tool (Seigel and Zelnick, 1966).

Many improvements were made in the demographic analysis methodology in 1970 (U. S. Bureau of the Census, 1974). Undocumented immigration surfaced as an issue for the 1980 demographic analysis estimates (Fay, Passel, Robinson, and Cowan, 1988). The coverage error methodology was applied to 1940 census in Fay, Passel, Robinson, and Cowan (1988). Demographic analysis was used as an evaluation tool for the 1990 Census. Estimates of the error distribution of the demographic analysis estimates were produced for the first time (Robinson, Ahmed, Das Gupta, and Woodrow, 1993).

5. Multiplicity

Multiplicity is an application of network sampling techniques during the census. Respondents are asked the names and addresses of their relatives, such as parents, siblings, and children. The census enumerations at the reported addresses are checked to determine if these people were enumerated. Undercount estimates are based on the number of people added. For further discussion of the methodology, see Sirken, Graubard, and La Valley, 1978).

An advantage for the one-number census is that the method may identify people who are hard-to-enumerate because they had loose ties to a household. A disadvantage is that implementation is troublesome because people often do not know the addresses of their relatives even if they know where they live.

In the 1978 Dress Rehearsal, multiplicity was used as a coverage measurement method in the 1978 Dress Rehearsal in Richmond and Durrango (Survey Design

Branch, 1978). A final report was never distributed. A telephone followup of 1990 mail returns was conducted in 10 district offices to assess the effectiveness of multiplicity questions for enumerations. The respondents were asked to list children who were not members of the household and to give their addresses and telephone numbers (Thompson, 1989).

6. Post Enumeration Survey

The Post Enumeration Survey (PES) is a survey conducted after the census for the purpose of measuring census coverage. The respondents are matched to the original enumeration on a case-by-case basis. Then dual system estimation may or may not used to give an estimate of the population size. A comparison of the census to the estimate of population size yields the net undercount rate. The methodology is described well in Sekar and Deming (1949) and Marks, Seltzer, and Krotki (1974).

The Census Bureau's PES is really two sample surveys, a sample of census enumerations, the E sample, and a sample of the population, the P sample. The E sample measures erroneous census enumerations, and the P sample measures census omissions.

Methodology for the evaluation of the estimates from a PES has been developed and implemented in a census environment. The Census Bureau has a large amount of experience with the PES and knows that the estimates at the national level are comparable to those from demographic analysis.

Another advantage of the PES is that it provides estimates for levels of geography below the national level and for race/ethnic groups. The advantage with regards to implementation is that since blocks are not released to the field staff until after the census, the risk of the lack of operational independence is alleviated.

One technical disadvantage of the PES is that the dual system estimates may be subject to correlation bias because people missed by the census may also tend to be missed by the PES. The poststratification may not describe all the heterogeneity of enumeration probabilities and thereby introduce correlation bias. However, some variations of the estimation methodology are designed to reduce the correlation bias. Another disadvantage is that the matching between two independent lists, the PES and the census, currently requires a substantial amount of time. The matching requires that the census enumeration files be available in addition to the PES files. Matching people who move between the census and the P-sample interview is complicated and is one reason so much time is necessary.

Estimates of the 1990 census undercount based on a PES were produced for a decision on July 15, 1991

to not use the estimates to adjust the census for undercount (Hogan, 1992a). The areas of technical concern were correlation bias, regression smoothing and the use of the assumption required for synthetic estimation for small areas.

Extensive evaluations of the 1991 estimates (Bateman, Clark, Mulry, and Thompson, 1991, Mulry and Spencer, 1993) were performed. The evaluations included measurements of nonsampling errors and estimation of the total error in the PES estimates. The total error estimates were used to in a loss function analysis as targets by which to compare the loss from using the adjusted and unadjusted numbers.

The PES estimates were revised in 1992 and were considered for use in the Census Bureau's Postcensal Estimates Program (Hogan, 1992b). Extensive evaluations and loss function analysis of the 1992 estimates were performed (Mulry and Spencer, 1992, Thompson, 1992, Fay, 1992).

The Census Bureau tested the 1990 PES design in test censuses conducted in 1985 (Jaro, 1989), 1986 (Wolter and Hogan, 1988), and 1987 (Anolik, 1989), and the 1988 Dress Rehearsal. The total error methodology was used to evaluate the PES estimates in 1986 (Mulry and Spencer, 1988) and in 1988 (Mulry and Spencer, 1991).

In 1980, the August P sample, or population sample, for Post Enumeration Program (PEP) was a PES. The E sample, or enumeration sample was an independent sample of census enumerations (Fay, Passel, Robinson, and Cowan, 1988).

6.1 Alternative Estimation

Alternative approaches to the estimation with data from a PES have also been explored. Some of these require an auxiliary data source while others do not.

Composite estimators which are weighted averages of the census and the PES estimates do not require an alternative source. Zaslavsky (1991) has developed composite estimators which use the census, the PES, and the PES Evaluation data in the estimation of the population size. For the decision on whether to incorporate the undercount estimates in the postcensal estimates program, an average of the census and the 1992 PES estimates and an average raked to national totals in eight categories defined by race and tenure have been investigate (Thompson, 1992).

Conditional logistic regression has been used to estimate probabilities of enumeration in the census and a PES. This method potentially permits every individual to have a different probability of enumeration, which is assumed to depend on a set of independent variables through a logistic regression model (Alho, Mulry, Wurdeman, and Kim, 1993).

Another way of addressing the problem of correlation bias in the dual system estimator is to replace the independence assumption by an alternative assumption which requires another data source. Wolter (1990) developed an estimator based on an assumption of known sex ratios and an assumption of independence for females only. Bell (1993) extended the methodology and applied it to estimating correlation bias in the 1990 PES using results from 1990 demographic analysis. An alternative method (O'Connell, 1991, O'Connell, Bloomfield, Pollock, 1992) describes the lack of independence in terms of internal and external constraints.

6.2 PES Variations: Dual System

A Simultaneous Enumeration Survey has the same methodology as a Post Enumeration Survey with the exception that the interviewing for the survey is conducted at the same time the census is in the field. A Pre Enumeration Survey (PrES) differs from a Post Enumeration Survey in that the survey is conducted before the census enumeration instead of afterwards.

The PrES and the Simultaneous Enumeration Survey take advantage of the Census Bureau's knowledge and experience with the PES operations and estimation. The advantage of the PrES is conducted before the census, there is more time for the preparing the PrES files for the matching operation than when the survey is conducted afterwards. The operational advantage of the Simultaneous Enumeration Survey is that since the census and the survey are conducted at the same time, fewer people will have moved.

An operational disadvantage of the PrES is that since the evaluation sample is interviewed before the census, the census field staff may be aware of the evaluation areas and treat them differently. This would confound any inferences about the areas not in the sample. An additional source of error may be a violation of an independence assumption because persons in the PrES may be more or less likely to participate in the census than persons not in the PrES. Another disadvantage is the substantial time requirement for tracing people in the PrES who do not match the census at the same address. The tracing causes the mover matching to require more time and resources than a PES. A contrasting disadvantage for the Simultaneous Enumeration Survey is that the operational independence between the survey and the census could not be assured since the two would be in the field at the same time. This would add a component of correlation bias not present in the PES or PrES methodology.

The Census Bureau conducted a PrES in 1986 to evaluate the Test Census in East Central Los Angeles

(Wolfgang, 1988). The April P sample for the 1980 Post Enumeration Program was a Simultaneous Enumeration Survey. The April estimates of 1980 census undercount tended to be lower than the August estimates (Fay, Passel, Robinson, and Cowan, 1988).

6.3 PES Variation: Triple System

The Triple System expands on a Post Enumeration Survey (PES) by adding a match to a third source such as administrative records. Then triple system estimation which has weaker independence assumptions may be used. A comparison of the census to the estimate of population size yields the net undercount rate.

The Triple System takes advantage of the Census Bureau's knowledge and experience with the PES. The methodology which has been developed for evaluating PES estimates may also be applied to estimates from triple system. The advantage of the triple system is that the alternative independence assumption reduces the potential problem of correlation bias.

The disadvantage is that the matching between three independent lists, the PES, the census, and a third source, adds complexity and increases the time and resource requirements to the currently substantial ones required for matching two lists.

As part of the 1988 PES, the Census Bureau conducted a three-way match between the census, the PES driver's license records. The estimated undercount rates were surprisingly high (Zaslavsky and Wolfgang, 1990). Another triple system estimator which allows for heterogeneous enumeration probabilities for individuals using a variant of the Rasch model from psychological measurement situations has been applied to the 1988 data (Darroch, Fienberg, Glonek, Junker, 1993).

As part of the 1980 PEP, a large triple system program was designed and implemented (Jones, 1980). The three systems were the 1980 Census, the PEP, and the IRS Individual Master File. A large number of cases in the census and the CPS could not be matched to the IRS file because of missing Social Security numbers.

7. CensusPlus

The CensusPlus selects a sample of blocks and continues enumeration in these blocks after the regular census is completed. The extended enumeration includes special methods that are too expensive to be conducted everywhere. The potential special methods include using administrative lists, participant observers, and highly trained interviewers. The additional enumerations in the CensusPlus sample areas are used to develop population estimates for the non-sample

areas by using methods such as ratio estimation.

The advantage of the CensusPlus is that erroneous enumerations may be identified. A disadvantage is that a type of correlation bias may be present in the CensusPlus estimates because the same people who are missed by the census may also tend to be missed by the CensusPlus methods.

In the 1950 Post Enumeration Survey, the Census Bureau measured coverage error by repetition of census enumeration methods, in a more thorough and refined form, on a sample basis (U.S. Bureau of the Census, 1960). During the 1990 Census, participant observers were placed in areas believed to be hard-to-enumerate (Ethnographic Exploratory Research Report Series, 1992)

8. SuperCensus

The SuperCensus is a new methodology which the Census Bureau has not attempted before. The SuperCensus selects a sample of blocks and conducts the enumeration with special methods too expensive to be used everywhere. The special methods are similar to those described for used in CensusPlus and include administrative records, participant observers, and highly trained interviewers. The population estimates are based on applying the ratio of people to housing units observed in the sample blocks to the total number of housing units.

The SuperCensus has the advantage that it can be completed quickly because it can be conducted simultaneously with the census. A disadvantage, as with CensusPlus, is that people missed by the regular enumeration methods may also tend to be missed by the SuperCensus methods. The variances of the population estimates tend to be high because the estimation cannot use ratios to the census results to reduce variance, but must rely instead on crude preliminary measures of size, such as prelist housing unit counts, to reduce variance (Wolter, 1986).

An intensified Nonresponse Followup(NRFU) was conducted in 10 district offices during the 1990 census. In five district offices, the duration of NRFU was decreased and the supervision was increased. In five other district offices, supervision was increased, supplemental questions were asked, quality assurance was expanded, and additional callbacks were allowed (Thompson, 1989).

* This paper reports the general results of research undertaken by the Census Bureau staff. The views expressed are attributable to the authors and do not necessarily reflect those of the Census Bureau.

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