

## Methodological Lessons from Census 2000 Coverage Error Measurement

Mary H. Mulry<sup>1</sup>

Statistical Research Division, U.S. Census Bureau, Washington, DC 20233

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### 1. Introduction and background

The U.S. Census Bureau conducted the Accuracy and Coverage Evaluation (A.C.E.) program to evaluate the coverage of Census 2000 and possibly adjust the census numbers for purposes other than the apportionment of the U. S. Congress. Neither the original A.C.E. estimates nor a revision of the A. C.E. estimates, known as A.C.E. Revision II, were used to adjust the census numbers for redistricting of the U.S. Congress or any other official purpose (U.S. Census Bureau 2003). However, the A.C.E. revealed surprises about Census 2000 and leaves a legacy that will influence census-taking methods for some time to come.

The original A.C.E. dual system estimates in March 2001 indicated a 1.18 percent undercount in the Census 2000 population size of 281,421,906. The Census Bureau followed a pre-specified decision process and decided not to adjust the census numbers for redistricting because of differences between the A.C.E. estimates and Demographic Analysis and other anomalies that could not be explained by the deadline of April 1, 2001. The Census Bureau continued evaluating the A.C.E. estimates throughout the summer of 2001 in preparation for a decision on whether to adjust other Census 2000 data products.

Through two separate evaluation studies, the Census Bureau discovered the A.C.E. failed to detect a large number of erroneous census enumerations. The Measurement Error Reinterview (Raglin and Kresja 2001) gave the initial indication that the A.C.E. processing did not detect a large number of erroneous enumerations. A more careful processing of a subsample found the estimate of correct enumerations was 1.4 million too high (Adams and Kresja 2001). In parallel, a computerized search of the census also provided evidence of a large number of duplicate census enumerations that the A.C.E. processing had not detected and estimated the number of correct enumerations was 2.9 million too high (Fay 2002a). The decision in October 2001 was to use the unadjusted

census for purposes other than redistricting because the evaluations of the A.C.E. found a large number of erroneous enumerations that the A.C.E. failed to detect. In October 2001, the Census Bureau produced the A.C.E. Revision Preliminary estimates, which indicated the net undercount was 0.06 percent (Thompson, Waite, Fay 2001). The estimates included adjustments to account for duplicate census enumerations and other measurement errors found in the sample of census enumerations (E-sample) detected by two evaluations, the Measurement Error Reinterview (Raglin and Kresja 2001) and the Matching Error Study (Bean 2001).

Because the A.C.E. Revision Preliminary estimates were only at the national level, the Census Bureau pursued a complete revision of the A.C.E. estimates, the A.C.E. Revision II, to provide census coverage estimates for geographic areas and for possible use in the Intercensal Population Estimates Program. These estimates which included an adjustment for correlation bias and improved adjustments for measurement error in the E-sample and in the independent sample of the population (P-sample) produced a revised estimate of -0.49 percent undercount (an overcount). Although the A.C.E. Revision II estimates were believed to be an improvement over the A.C.E. estimates, the Census Bureau also believed the revision contained troubling anomalies and unexplained results and decided to use the unadjusted census in the Intercensal Population Estimates Program (U.S. Census Bureau 2003).

This paper explores the lessons learned from the A.C.E. Revision II about census taking and about evaluating the coverage of censuses. Another source is Childers and Petroni (2003) who discuss A.C.E. data collection, data processing, and initial estimation.

### 2. Lessons about census-taking

The biggest surprise from A.C.E. Revision II was that duplicate enumerations occurred in the census much more frequently than previously observed or suspected in Census 2000 or other censuses. Studies of duplication as part of the A.C.E. Revision II program estimated 5.8 million duplicate enumerations in Census

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<sup>1</sup>This report is released to inform interested parties of (ongoing) research and to encourage discussion (of work in progress). The views expressed on (statistical, methodological, technical, or operational) issues are those of the author(s) and not necessarily those of the U.S. Census Bureau.

2000 (Mule 2002). The estimate of the number of duplicates in the census was validated in two evaluation studies. One found 6.7 million duplicates using only the census duplicates identified by administrative records (Mulry, Bean et al 2003). In the other study, an expert matching team clerically examined the duplicate enumerations and agreed that about 95 percent were duplicates (Byrne, Beaghen, Mulry 2003). Even more surprising is that this large amount of duplication remained in Census 2000 after 3.6 million enumerations were removed during the census data collection operations when the Census Bureau discovered and removed 1.5 million duplicate listings of housing units (Nash 2000, Miskura 2000).

Another surprise was the large number of duplicates where both enumerations were on mail-return forms. Conventional wisdom at the Census Bureau has been that questionnaires returned by mail contribute little to census error since they are self-responses. Of the 5.2 million duplicate enumerations where both were for people in housing units, 25 percent were both on mail returns while 10 percent had neither on mail returns, and the remaining 65 percent had one on a mail return and the other not on a mail return (Mule 2003).

Since there were 205.3 million enumerations of people in housing units on mail returns and 64.9 million on non-mail returns (Treat 2004), the duplicate enumerations do not negate the conventional wisdom that mail returns are of higher quality. The percentage of enumerations on mail returns that have a duplicate is 2.2 percent with 0.6 percent having the duplicate on another mail return and 1.7 percent having a duplicate on a non-mail return. For non-mail returns, 6.0 percent have a duplicate with 0.8 percent on another non-mail return and 5.2 percent on a mail return (Mule 2003).

Interestingly, the duplicates occur disproportionately among the population under 30 years of age. The group under 30 years of age is 42.2 percent of the census population while they are 53.6 percent of the estimated 5.8 million duplicates between enumerations in housing units and those in housing units or group quarters. The group aged 18-29 is 16.5 percent of the census population but 24.0 percent of the duplicates (Mule 2002). The causes of duplicate enumerations within a block cluster appear to arise from operational errors, such as a dwelling having two different addresses on the address list. Early indications are that the causes of duplicate enumerations in different states or counties include moving situations, people visiting family/friends, people with vacation/seasonal homes, college students, and children in shared custody (Smith 2004).

The innovation that allowed discovery of the duplicate enumerations was the scanning of census forms by optical character and mark recognition technologies that converted the names and other information on the census questionnaires into electronic format. The duplicates were identified by a computerized search of the census. The nationwide search methodology could not have been used in previous censuses because names on enumerations were not converted to an electronic format that permitted using computers.

### 3. Lessons about census coverage measurement

The A.C.E. Revision II estimates were the first coverage error estimates for any U. S. census that found an overcount for the nation as a whole. Although coverage measurement surveys found erroneous enumerations in previous censuses, the estimated omissions always were larger. Consequently, the design of census operations focused on avoiding omissions as much as possible with the belief that procedures for avoiding duplication were adequate.

A.C.E. Revision II used data collected for A.C.E. along with additional data collected and processed in subsequent evaluations and research. Both A.C.E. and A.C.E. Revision II used dual system estimation, but A.C.E. Revision II incorporated additional data as explained in this section. The components are a sample of census enumerations, the E-sample, and an independent sample of the population, the P-sample. There is case-by-case matching based on personal characteristics to determine whether the enumerations in the E-sample are correct or erroneous and the rate at which people in the P-sample were included in the census, the match rate.

#### 3.1 Survey Design

Every coverage measurement survey must decide how to treat people who move between Census Day and the survey interview. The 2000 A.C.E. implemented a different treatment of movers in the population sample (P-sample) than used by the coverage measurement surveys in 1990 and 1980. Although the A.C.E.'s treatment of movers in 2000 was successful, the 1990 and 1980 treatment appears to be a better choice whenever possible because there is less reliance on proxy responses (Beaghen 2004, Martin, Fay, and Krejsa 2002 ).

The 1990 and 1980 surveys defined the P-sample with the PES-B model as the residents of the sample blocks on the day of the P-sample interview. This means movers into the sample blocks after Census Day, the in-movers, are included and people who move

out, the outmovers, are not. For 2000, the members of the P-sample were defined using PES-C where the sample members are the residents of the housing units on Census Day. The A.C.E. interview relied on the respondents to identify the outmovers. Since proxy respondents, such as landlords, neighbors, and others, identify the outmovers, many of the outmovers are not recorded. Therefore, the estimate of outmovers is too low. The A.C.E. estimated 13.3 million in-movers and 8.8 million out-movers (Liu, Byrne, and Imel 2001), and the A.C.E. Revision II showed similar results. To avoid a bias caused by an underestimate of the number of movers, the A.C.E. used the number of in-movers to estimate the number of out-movers. However, the rate at which movers are included in the census, the match rate, was based on the out-movers. The disadvantage of PES-B is that the search for the P-sample person's census enumeration has to look at the Census Day address. Computerized geocoding of Census Day addresses and computerized search for enumerations will reduce the processing burden for 2010.

A totally separate design issue is that more coordination between the processing for housing unit coverage estimates (Barrett, Beaghen, Smith 2001) and person coverage estimates would improve the ability to assess the quality of both. Separate matching operations for housing unit coverage and person coverage data led to difficulties in interpreting results because the coding of a housing unit and the people in it was not always consistent. Coordinating the coding of erroneous housing units and enumerations would facilitate assessing the validity of results.

### 3.2 Sample Design

The sample design for the 2000 A.C.E. was successful in using proportional allocation and double sampling to achieve a reasonable range in the sample weights. The 1990 Post Enumeration Survey used differential sampling that resulted in a wide range in the weights that led to larger than desired variances for estimates for some subpopulations. The double sampling scheme used in the selection of small block clusters was particularly effective in keeping the range of weights small enough to not increase the variance estimate (ZuWallack, et al 2000)

### 3.3 Data Collection

The independent list of the housing units in the sample blocks for the P-sample was thought to be accurate since it was created specifically for the coverage measurement survey. However, the 2000 A.C.E. P-sample listing was found to have geocoding error. In 2000, the error caused a large difference in the

weighted number of matches to enumerations in the surrounding blocks and the weighted number of correct enumerations in the surrounding blocks. Fortunately, most of the geocoding error was within the blocks surrounding the A.C.E. sample blocks, called the extended search area (Adams and Liu 2001). Since P-sample geocoding error may be present but not detected, searching the surrounding blocks to find correct enumerations and matches for all the A.C.E. sample blocks is preferable to selecting a subsample.

Previously, the assumption for coverage measurement surveys had been that the combination of questionnaire probes about usual residence and moves asked by high quality interviewers could obtain accurate information about residency. However, the research for A.C.E. Revision II found that for P-Sample people who were not movers and who said their usual residence was in the A.C.E. sample blocks on Census Day, an estimated 6.1 million linked to census enumerations outside the A.C.E. search area surrounding the sample blocks. Of the 6.1 million, 3.2 million also matched to enumerations within the A.C.E. search area and 2.9 million were non-matches (Mule 2002). These links raised doubts about whether the P-Sample persons actually were Census Day residents at their given address (U.S. Census Bureau 2003b). Reviews of the questionnaires found unreliable identification of moves, second homes, and stays in group quarters residences. These reviews concluded that there were fundamental problems with how the questionnaires asked about the usual residence of a person and that improving the quality of data collected would require intensive questionnaire design and testing. (Martin, Fay, Krejsa 2002).

Interviewers used notes to describe more complicated cases (Adams and Kresja 2002a, Martin, Fay, Krejsa 2002). Since the questions on the questionnaire could not be used to capture the complicated cases, evaluation of ambiguities could not be made without a clerical review of all the cases. Designing a questionnaire with improved questions about residency that does not rely so much on interviewer notes is a subject of research for 2010 (Kostanich, Whitford, and Bell 2004).

The degree of inconsistency in reporting the sex of E- and P-sample cases that matched was surprisingly high (Farber 2001). Further investigation found that the inconsistency might have been related to laptop data entry design. The keys for entering sex were "1" and "2" which by their close proximity led to errors. A better choice would have used keys further apart on the keyboard, such as "1" and "5" or with meaning such as "M" and "F" (Love and Byrne 2004).

### 3.4. Data Processing

A.C.E. Revision II demonstrated that automated coding with the data collected on the followup questionnaire is possible for a large number of cases. The recoding operation assigned some of the E- and P-sample codes by a computer algorithm using keyed data from the followup form, with the rest assigned clerically by the Census Bureau's elite matching team (Adams and Kresja 2002a). Concerns arose that the automated assignment of enumeration and residence status for some of the cases increased the possibility of error in the estimates. An evaluation based on a subsample of cases coded both ways showed that the potential error from the automated coding was very small (Adams and Kresja 2002b).

Providing clerical matchers with all the data collected can identify ambiguities in time to resolve them in the followup. The 2000 A.C.E. matchers did not have access to the in-movers because in-movers did not receive match codes. However, the Measurement Error Review found that 37 percent of the in-movers reported they were non-movers in the reinterview. Of those, 40 percent matched to census enumerations and 10 percent were duplicates of other non-movers (Raglin and Kresja 2001). If the A.C.E. matching operation had looked for E-sample matches to in-movers and duplicates between in-movers and non-movers and out-movers, then more information about the residency of these in-movers could have been collected in the A.C.E. followup.

Using clerical searching to augment automated searching within block clusters increases the number of duplicates found. Within the A.C.E. block clusters, the A.C.E. Revision II computerized matching found 1.2 million duplicates, but the combination of A.C.E. computer and clerical matching found 1.9 million duplicates (Mule 2002). However, when clerical matchers looked for additional duplicates in households where a member linked to someone outside the A.C.E. sample block cluster, they found very few (Byrne, Beaghen, Mulry 2003).

### 3.5 Estimation

The estimation of a net overcount by A.C.E. Revision II created a new perspective on the issue of adjusting estimates of census coverage error for correlation bias. Coverage error estimates for past censuses always had shown a net undercount. Therefore not adjusting for correlation bias meant the estimates understated the coverage error, but were in the right direction. However, in the presence of a net overcount, not including an adjustment for correlation bias may have meant the estimates of coverage error

were not even in the correct direction (U.S. Census Bureau 2003). The weakness of relying on Demographic Analysis sex ratios for use in estimating the amount of correlation bias became very apparent. Demographic Analysis (Robinson and Adlahka 2002) is available only for Blacks and NonBlacks since that is what was collected for the historical vital records used in Demographic Analysis estimation. No comparable data are available for estimating correlation bias separately for Hispanics, Asians, or Native Americans. The lack of data by race and Hispanic ethnicity is problematic since the expectation is that the correlation bias rates in these groups are different. (U.S. Census Bureau 2003)

The A.C.E. Revision II produced the first coverage estimates to use different poststratification variables for the E- and P-samples although there was some overlapping (U.S. Census Bureau 2003). All previous estimation of census coverage error for Census 2000 and prior censuses and test censuses used the same poststratification variables for the E- and P-samples. Large variation in the coverage error rate for places, particularly extreme overcount estimates for some small places, has raised questions about the choice of poststratification variables and the use of different variables for the E- and P-samples. Also, synthetic estimation for small area estimation may be problematic when there is a large variation in net coverage rates (U.S. Census Bureau 2003).

The P-sample cases that linked to a census enumeration outside the A.C.E. search area around the sample block posed a challenge for the estimation. The data did not include which was correct. For the E-sample, the estimation of the probability of being correct assumed one and only one of the pair was a correct enumeration. (Bell 2003). However, such an assumption was not appropriate for the P-sample cases. The method for assigning a probability of being a resident in the sample block to the P-sample cases borrowed from the E-sample estimation. The E-sample people who linked to an enumeration outside the search area had an overall probability of 0.45 of being correctly enumerated while the P-sample people with links had a probability of 0.51 of being resident. Children aged 0-17 years in the E-sample who linked to an enumeration outside the search area had an overall probability of 0.50 of being correctly enumerated while the P-sample children with links had a probability of 0.48 of being a resident (Fenstermaker and Davis 2002). As the method was implemented, the probability of a census enumeration with a duplicate being correct was higher for children than for the population on average. However, for the comparable group in the P-sample, the

people that linked to census enumerations outside the search area, the probability of being a resident was lower for children than for the population on average. The relative difference has not been explained. Being able to identify the members of duplicate pairs that are correct is preferable for the estimation of coverage error.

The strategy of forming the A.C.E. Revision II estimates using a dual system estimator with a double sampling ratio adjustment estimated from recoding a subsample proved effective in moderating the increase in variance. The standard error of the A.C.E. Revision II estimated undercount rate of -0.49 percent was 0.20, based on a simple jackknife estimation method. This was higher than the standard error of 0.18 of the A.C.E. estimated undercount rate of 1.18, but equal to the standard error of the 1990 Post Enumeration Survey estimate of a 1.61 percent net undercount rate (U.S. Census Bureau 2003).

#### 4. Evaluation of Coverage Measurement

The evaluations of the A.C.E. estimates of census coverage error proved to be very important because they provided valuable information about the quality of the census as well as the coverage measurement operation and estimates. The evaluations of the original A.C.E. estimates detected erroneous enumerations that the A.C.E. failed to detect. The evaluations of the A.C.E. Revision II estimates of census coverage error confirmed the presence of census duplicates and provided insight to the quality of the A.C.E. Revision II estimates themselves (Mulry and Petroni 2003).

One of the evaluations, the Census and Administrative Records Study (Mulry, Bean et al 2003) demonstrated how administrative records could provide a good evaluation tool in some circumstances when fieldwork is not practical or affordable. The Statistical Administrative Records System, created with newly developed administrative records database methodology (Leggieri, Pistiner, Farber 2002, Judson 2000), provided a means of evaluating the estimates of duplicate enumerations when it was too late for fieldwork. The evaluation coincided with the estimation of duplicate enumerations and generally agreed with A.C.E. Revision II estimates of duplicate enumerations, validating their use in the A.C.E. Revision II estimates (U.S. Census Bureau 2003).

The evaluations of the A.C.E. Revision II estimates illustrated the difficulty of assessing the quality of estimates when most of the data intended for evaluations is incorporated into the estimator (U.S. Census Bureau 2003). The evaluations of bias were relatively limited because data that previously were

used to estimate bias were incorporated into the A.C.E. Revision II estimates in order to correct for major errors discovered in the A.C.E. estimates (Mulry, ZuWallack, and Spencer 2003).

#### 5. Summary

The current planning for the 2010 Census is drawing on the wealth of information about the census and coverage measurement that A.C.E., A.C.E. Revision II, and their evaluations provided. The development of methodology to detect and avoid duplication during the census process is a topic of research. The planning for the 2006 Census Test includes a test of coverage measurement methodology with a new focus on obtaining estimates of erroneous enumerations and census omissions that provide information useful for designing improvements in future censuses (Kostanich, Whitford, and Bell 2004).

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