

Evaluation of the A.C.E. Revision II Estimates of Census 2000 Coverage Error

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1. Introduction

Evaluation studies examined the quality of the Census Bureau's revised estimates of coverage error in Census 2000 from the Accuracy and Coverage Evaluation Survey (A.C.E.), known as A.C.E. Revision II (U. S. Census Bureau 2003). The A.C.E. Revision II estimates of coverage error are subject to nonsampling error as well as sampling error. The discussion of the evaluations of the A.C.E. Revision II estimates includes an overview of the evaluations that focused on individual error components as well as comparisons of the relative error between the census and the A.C.E. Revision II.

The original A.C.E. dual system estimates (DSEs) in March 2001 indicated a 1.18 percent undercount in the Census 2000 population size of 281,421,906. The Census Bureau discovered that undetected duplicate enumerations in the census were a major source of error in the A.C.E. estimates and in October 2001 produced the A.C.E. Revision Preliminary estimates, which indicated the net undercount was 0.06 percent (Thompson, Waite, Fay 2001, Mule 2002). The latter estimates included adjustments to account for duplicate census enumerations and other enumeration sample (E-sample) measurement errors detected by the Measurement Error Reinterview (Raglin and Kresja 2001) and the Matching Error Study (Bean 2001). Subsequently, the Census Bureau developed the A.C.E. Revision II estimates, which included an adjustment for correlation bias and improved adjustments for measurement error in the E-sample and in the population sample (P-sample) and produced a revised estimate of -0.49 percent undercount (an overcount).

2. Error in the Identification of Duplicates

A.C.E. Revision II estimation used a computer match by the Further Study of Person Duplication (FSPD) (Mule 2002) to estimate duplication of E-sample cases to enumerations outside the search area around

the A.C.E. sample blocks where the A.C.E. matching operation considered enumerations correct. Although the processing for the original A.C.E. did not include people in housing units identified as potential duplicates by the Housing Unit Duplication Operation (HUDO) (Miskura 2000, Nash 2000), A.C.E. Revision II included links outside the A.C.E. search area to people in housing units reinstated in the census after HUDO and those deleted by HUDO. FSPD also estimated duplication within the A.C.E. search area, but A.C.E. Revision II used the A.C.E. clerical matching for these areas. FSPD matched the P-sample to census enumerations outside the search area to identify possible data collection error.

To save space, we restrict the discussion to the E-sample since the methodology and results for the P-sample are similar.

Two evaluations provided evidence that duplicate enumerations are present in the census and were not detected by the March 2001 A.C.E. estimation and evaluations. The evaluations also showed that estimation of duplicates has been greatly improved for A.C.E. Revision II. The Census and Administrative Records Duplication Study (CARDS) (Bean and Bauder 2002) used administrative records to evaluate FSPD while the Clerical Review of Census Duplicates (CRCD) (Byrne et al. 2002), used the Census Bureau's elite clerical matching team.

CARDS used the results of a previous Census Bureau match to identify links between the census and E-sample enumerations and P-sample people. CARDS first assigned a Protected Identification Key (PIK) (based on Social Security Numbers) to each census and P-Sample record. CARDS designated each FSPD duplicate as confirmed (same PIK), denied (different PIKs), or undetermined (PIK could not be assigned to at least one record). CARDS also identified duplicates that FSPD did not designate as duplicates.

In the Clerical Review of Census Duplicates (CRCD) (Byrne et al. 2002), the Census Bureau's elite matching team classified duplicates from FSPD statistical linking as confirmed, denied, or undetermined. They also reviewed the duplicates found only by CARDS and

¹This paper reports the results of research and analysis undertaken by Census Bureau staff. It has undergone a review more limited in scope than that given to official Census Bureau publications. This report is released to inform interested parties of research and to encourage discussion of work in progress. The views expressed are those of the authors and not necessarily those of the U. S. Census Bureau.

those found by both CARDS and the FSPD exact matching. CRCD reviewed data collected in the census and A.C.E. for E-sample cases linking to enumerations outside the surrounding blocks in a subsample of the A.C.E. block clusters known as the Evaluation Sample. CRCD did not review duplicates to enumerations in group quarters because the analysts would not have information from other household members to use in making decisions.

Generally, CARDS and CRCD agreed with FSPD on the identification of E-Sample records with duplicates in the census. The estimate of the number of duplicates in the census using only the duplicates identified by administrative records is 6,653,171 while the FSPD methodology estimated 5,826,478. In addition, CARDS found about 2.5 million links to enumerations deleted by HUDO while FSPD found about 2.9 million. CARDS found more duplicates that were geographically distant and more group quarters duplicates while the FSPD process was better at finding duplicates that were geographically close.

For discussion, we separate the three sources of duplicates, FSPD statistical matching, FSPD exact matching, and CARDS only. The CRCD looked for duplicates in household where FSPD or CARDS linked a member, but found very few additional duplicates.

The elite matching team agreed with 94.9 percent of the FSPD statistical matching E-sample duplicates in housing units eligible for the E-sample outside the search area, denied 3.8 percent, and found 1.3 percent undetermined. In fact, both CARDS and CRCD agreed with 73.4 percent (922,325 out of 1.25 million) of the duplicates in housing units eligible for the E-sample outside the search area. Also, some of the enumerations linked by FSPD statistical matching were not declared duplicates when their probability of being a duplicate was not above a cutoff. Both studies agreed with FSPD's decision that these cases were not duplicates 81.7 percent of the time (3.2 million out of 3.9 million). CRCD alone agreed that 93.8 percent were not duplicates, but found that 4.6 percent were duplicates with 1.6 percent undetermined.

For FSPD exact matching duplicates in the E-sample also found by CARDS, we have results for the elite matching team under the assumption that the probability of being a duplicate equals 1. Under this assumption, the elite matching team agreed with 79.9 percent of the FSPD exact matching E-sample duplicates in housing units eligible for the E-sample found outside the search area, denied 8.3 percent, and found 11.8 percent undetermined. However, all the duplicates identified by exact matching received a probability of being a duplicate that is less than 1 in the A.C.E. Revision II estimator.

Approximately 1.2 million of the duplicates CARDS found were not identified by FSPD statistical or exact matching. The matching team's review raises questions about the duplicates found only by CARDS. The matching team agreed on 37.3 percent, disagreed on 47.3 percent, and was undecided on 15.4 percent. The question is whether the matching team is correct for these cases because the reason given for 65.1 percent of the disagreements was 'household composition'. We have concerns about the accuracy of the coding for the cases based on 'household composition' because detecting a person who is truly a member of two different households is difficult.

CRCD did not review some categories of duplicates that were incorporated in the A.C.E. Revision II estimator. There were 86,883 FSPD exact matching duplicates that were not confirmed (i.e., denied or undetermined) by CARDS and not submitted for review by the matching team. CRCD did not review 297,164 FSPD duplicates to enumerations HUDO identified as potential duplicates, some of which were reinstated in the census and the rest were deleted. Also, 513,984 duplicates to enumerations in group quarters were not eligible for review in CRCD.

3. Error in Measurement Coding

Since the evaluations of the A.C.E. found errors in the assignment of enumeration and residence status codes for the E- and P- samples, respectively, the A.C.E. Revision II methodology included recoding a subsample of the A.C.E. sample and used the results in a double sampling ratio adjustment. In addition, there were a large number of cases coded "Conflicting" because the A.C.E. Person Followup (PFU) interview and Evaluation Followup (EFU) interview collected information that was contradictory regarding whether the person was a resident in the sample block on Census Day although the interviews appeared to be of comparable quality. The A.C.E. Revision II recoding operation strove to correct coding errors and to reduce the number of Conflicting cases by accurately coding as many of these as possible. The recoding operation assigned some of the E- and P-sample codes by a computer algorithm, with the rest assigned clerically by the Census Bureau's elite matching team (Adams and Kresja 2002a). Both the automated coding and the procedure for reducing the Conflicting cases were new methods and had the potential for introducing error into the estimates.

Although the strategy of combining automated and clerical coding permitted recoding of a larger sample in the time available, most likely reducing the variance of the A.C.E. Revision II, there was concern that the automated assignment of enumeration and residence status for some of the cases increased the possibility of

error in the A.C.E. Revision II dual system 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). While the assignment of the Conflicting codes may have been appropriate for evaluation purposes in the PFU/EFU Review (Adams and Kresja 2001), these codes were assigned too readily for the purpose of coding cases for their use in estimation. The recoding was able to successfully code many of the Conflicting cases in regard to their enumeration status or census day residency status. After the second coding of cases initially coded as Conflicting, very few remained coded as Conflicting and therefore, are believed to have a very small impact on the estimator.

The A.C.E. Revision II evaluation program did not include a further evaluation of the coding of match status, but used the coding of match status for the P-Sample from the Measurement Error Review (Raglin and Kresja 2001). The additional matches in the surrounding block discovered by the Matching Error Study also were incorporated for the A.C.E. Revision II match status (Bean 2001). Drawing from the results of these evaluations appeared to provide the best coding available, and any further recoding probably would not provide better codes. Therefore, the assumption is that the A.C.E. Revision II match status codes are error-free.

4. Other Errors in Census Omissions

We also examined errors in the estimates of census omissions due to inconsistent reporting of variables used in post-stratification and to using in-movers to estimate the out-movers in the A.C.E. Revision II PES-C version of dual system estimation.

4.1 Error Due to Inconsistent Poststratification Variables

A respondent's inconsistent reporting of characteristics in the census and the P-sample may be problematic because the respondent is categorized on a different basis for the match rate and the correct enumeration rate.

The basic approach of the evaluation was to estimate the inconsistency in the poststratification variables using the matches and then assume that the rates also held for the nonmatches. The evaluation then compared the A.C.E. Revision II estimates with and without the correction for the estimated bias in the match rate due to inconsistent reporting of poststratification variables. The comparison showed that the error due to inconsistent poststratification variables had very little effect on the A.C.E. Revision II estimates (Bench 2002).

4.2 Error Due to Using In-movers for Out-movers

The error due to using in-movers to estimate out-movers is unique to the PES-C model for dual system estimation used in the original A.C.E. and the A.C.E. Revision II. For the PES-C model, the members of the P-sample are the residents of the housing units on Census Day. The A.C.E. interview relies on the respondents to identify those who have moved out, the out-movers. Since the out-movers are identified by proxies, many of the out-movers are not recorded. Therefore, the estimate of out-movers is too low. To avoid a bias caused by an underestimate of the number of movers, PES-C uses the number of in-movers to estimate the number of out-movers. The in-movers are those who did not live in the sample blocks on Census Day, but moved in prior to the A.C.E. interview. Theoretically the number of in-movers in the whole country should equal the number of out-movers. However, the number of in-movers may not equal the number of out-movers in a poststratum.

The first step of the evaluation methodology consists of raking the number of out-movers to total in-movers. The distribution of the raked out-movers may better describe the out-movers than the distribution of the in-movers. Next is a comparison of the A.C.E. Revision II estimates formed by using the number of in-movers with the A.C.E. Revision II estimates calculated using the raked number. The comparison showed that the error due to using in-movers to estimate out-movers had very little effect on the A.C.E. Revision II estimates (Keathley 2002).

5. Sampling Error

Sampling error gives rise to random error, quantified by sampling variance. The sampling variance is present in any estimate based on a sample instead of the whole population. The variance estimation methodology is a simplified jackknife with the block clusters being the primary sampling unit. The effect of in-cluster subsampling is implicitly captured in the weighting.

The standard error of the A.C.E. Revision II estimated undercount rate of -0.49 percent was 0.20. This was higher than the standard error of 0.18 of the A.C.E. March 2001 estimated undercount rate of 1.18, but equal to the standard error of the 1990 Post Enumeration Survey estimate of a 1.61 undercount rate (U. S. Census Bureau 2003) .

6. Missing Data Models

The missing data models used for the March 2001 A.C.E. were not directly applicable to the Revision Sample used in the A.C.E. Revision II estimation because the recoding operation created new missing data. There

were three new types of missing data that required models for the Revision Sample: (1) P-sample households that were originally considered interviews but the recoding changed them to noninterviews, (2) cases with unresolved match, enumeration, or residency status because of incomplete or ambiguous EFU and PFU data, and (3) cases with conflicting enumeration or residency status. The A.C.E. Revision II missing data models are thought to be of higher quality than those used for the March 2001 A.C.E. estimates because the imputation cells rely on more information and more detailed questionnaire responses. (U. S. Census Bureau 2003)

All the imputation involves choosing a model. The choice of the imputation model may introduce error into the estimates. The evaluation of the March 2001 A.C.E. estimates included an analysis of reasonable alternative imputation models (Keathley et al. 2001). Time constraints did not permit the creation of alternative imputation models for the A.C.E. Revision II. However, an evaluation that was built on the alternative models created for the March 2001 A.C.E. estimated the variance due to the choice of the missing data model. The evaluation showed that the variance due to missing data was lower for A.C.E. Revision II than was observed for the A.C.E. (Kearney 2002).

7. Synthetic Error Evaluation

The A.C.E. Revision II has several potential sources of synthetic error. One source involves correcting the individual poststratum estimates for error estimated at more aggregate levels, such as corrections for correlation bias and measurement coding errors. However, the evaluation examined error from synthetic estimation within poststrata rather than across poststrata. This study focused on the synthetic estimation bias that arises when the census from different areas but in the same poststratum have different coverage error rates but have the same census coverage correction factors.

The evaluation followed the methodology of an evaluation of synthetic error in the A.C.E. estimates (Griffin and Malec 2001) and attempted to estimate synthetic estimation bias in undercount estimates from analysis of “artificial populations” or “surrogate” variables whose geographic distributions are known. These surrogate variables are constructed as best as possible to have patterns similar to coverage error. Sensitivity analyses of four artificial populations generally did not change the overall loss function findings described in Section 9 (Griffin 2002), though we recognize that the analyses were not conclusive.

Any limitations of the loss functions regarding synthetic error are expected to be more important when comparing small places or counties than for large places or counties. The use of different poststrata by the E-

and P-samples may have reduced synthetic error for small areas that is present when the E- and P-samples use the same poststrata as in the Census Bureau’s previous applications of dual system estimation. However, the use of different E- and P-sample poststrata has increased concern for synthetic error in the areas affected by some extreme coverage correction factors for some combined E- and P-sample poststrata.

8. Consistency between the A.C.E. Revision II Estimator and HUCS

The study examined the validity of the A.C.E. Revision II estimates by assessing the consistency in the results from the A.C.E. Revision II estimates and the Housing Unit Coverage Study (HUCS) (Barrett, et al 2001). The A.C.E. Revision II estimates of population coverage agree with the HUCS results on housing coverage in the measurement of coverage patterns by region, type of area, and tenure. Both estimates show little statistically significant variation in coverage between regions or between types of areas. Both estimates measure a higher net census undercount of renter-occupied units than owner-occupied units. (Robinson and Wolfgang 2002)

9. Relative Accuracy Measured Using Demographic Analysis

Demographic Analysis (DA) uses vital records, immigration statistics, and Medicare data to obtain an estimate of the population size. Since the methods are somewhat independent of the census, DA provides a method for assessing the relative quality of the Census and the A.C.E. Revision II. The A.C.E. Revision II estimates of net undercount rates are broadly consistent with the DA estimates (Robinson and Adlahka 2002). The A.C.E. Revision II estimate of 280.1 million is 1.7 million below the revised DA estimate. The A.C.E. Revision II estimate implies a net census overcount of 1.3 million. The A.C.E. Revision II undercount estimates for Black adult males are in line with the measured differentials with DA. This is basically a consequence of using the DA sex ratios to remove the correlation bias. The A.C.E. Revision II estimates for females (especially NonBlack females) are generally consistent with the DA estimates for ages 10 and over, even though they did not receive an adjustment for correlation bias.

A major concern is the inconsistency between the A.C.E. Revision II and the DA estimates of coverage rates for children aged 0-9. In contrast to DA results which show a net undercount rate of 2.6 percent for children aged 0 to 9, the A.C.E. Revision II estimates show a small net overcount of children 0-9 although it is not statistically significant. When we examine children aged 0-9 by race, DA finds a net undercount rate of 2.4 percent and 3.4 percent for NonBlack and Black children,

respectively. A.C.E Revision II estimated a net undercount rate of 0.7 percent for Black children aged 0-9 and -0.7 percent for NonBlacks. The source of the inconsistency of the DA and A.C.E. Revision II results for young children has not been identified.

10. Relative Accuracy Measured by Confidence Intervals and Loss Function Analysis

Evaluations of the A.C.E. Revision II estimates provided data to estimate bias (systematic error) and variance (random error) for use in constructing bias-corrected confidence intervals and in a loss function analysis (Mulry and ZuWallack 2002). 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 March 2001 A.C.E. estimates. Although the evaluations do account for the variance arising from the corrections for bias, the corrections for bias in the A.C.E. Revision II estimates may themselves be subject to bias, the magnitude of which has not been quantified. This is particularly true for the corrections for correlation bias and for P-sample cases that linked to census enumerations outside the A.C.E. search area since several models fit the data, and no information was available to enable selecting among the models on the basis of bias. Other criteria, such as variance, had to be used.

The loss function analysis accounted for some but not all error components that could be identified in the A.C.E. Revision II estimates. More specifically, the bias estimate included error components for inconsistency of post-stratification assignments based on census versus A.C.E. data, for error from estimating the numbers of outmovers by the numbers of inmovers, and most importantly, for error in the estimates of census duplicates although evaluations indicate that this error may have been misestimated. The variance estimate included sampling error components from both phases of sampling in A.C.E. Revision II estimates, and also random nonsampling error components from choice of imputation models and for models used to account for P-Sample cases that matched census enumerations outside the search area.

On the other hand, the loss function analysis did not account for the following errors: synthetic estimation error; bias from response error and coding error in P-Sample residency status, match status, and mover status; bias from response error and coding error in E-Sample correct enumeration status; bias in correlation bias adjustments to the estimates due to error in the Demographic Analysis sex ratios and to the choice of model used to implement the adjustments; and bias

due to the choice of model used to adjust the DSE for E-Sample cases with duplicate links. Though not included in the loss functions, Section 7 describes a partial evaluation of synthetic error.

The evaluations detected a small amount of bias in the A.C.E. Revision II estimate of the net undercount rate at the national level, only - 0.16 percent. Based on the bias-corrected 95-percent confidence intervals, both the census and the A.C.E. Revision II estimates are too low for Non-Hispanic Blacks and both Non-Hispanic Black Owners and Renters. The intervals show the census is too high for Non-Hispanic Whites, Owners, White Owners, and Hispanic Owners. All other census and A.C.E. Revision II estimates are covered by their bias-corrected 95-percent confidence intervals. The source of most of the bias estimate is the CARDS evaluation of the identification of duplicates.

The loss function analysis examines the relative accuracy by using the estimates of sampling variance and nonsampling bias and variance to estimate the aggregate expected loss for the census and the A.C.E. Revision II for population levels and shares for counties and places across the nation and within state. The measure of accuracy used by the loss functions is the weighted mean squared error with the weights set to the reciprocal of the census count for levels and the reciprocal of census share for shares. The analyses indicated that the A.C.E. Revision II is more accurate than the census for every loss function considered with the exception of levels for places with population of at least 100,000. The bulk of the error in the A.C.E. Revision II for places with population of at least 100,000 appears to lie in the nine (9) places with population of at least 1 million. More research is needed to understand the one exceptional result. The validity of the loss function analysis depends on the quality of the estimates of components of error in the A.C.E. Revision II, and some of those components are not accurately quantified.

In general, we cannot be certain whether omitted biases will tend to make any given loss function analysis overstate or understate the comparative accuracy of the A.C.E. Revision II estimates relative to the census. Whether omitted biases cause the loss function to favor the census or the A.C.E. Revision II depends on the signs of the correlations between the omitted biases and the expected undercount rate for the areas considered. While the loss function evaluations suggest the superiority of the A.C.E. Revision II estimates, concerns do remain about whether the bias estimates used in the loss function analysis are of sufficient quality to assure the correctness of the results.

11. Summary

Evaluations of the estimates of the census coverage error have provided valuable information about the quality of the census as well as the undercount estimates themselves. The evaluations of the original A.C.E. estimates detected that duplicate enumerations were a much larger problem in Census 2000 than observed or suspected in previous censuses (Thompson, Waite, Fay 2001). The evaluations of the A.C.E. Revision II estimates of census coverage error confirmed the presence of the large number of census duplicates as well as gave insight to the quality of the A.C.E. Revision II estimates themselves.

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