Census 2000 Accuracy and Coverage Evaluation Revision II

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Abstract: The estimates of Census 2000 coverage using the March 2001 Accuracy and Coverage Evaluation (A.C.E.) Survey were not acceptable because A.C.E. failed to measure significant numbers of erroneous census enumerations and there were suspicions that A.C.E. did not adequately measure residency status for the independent interview. While the Census 2000 data products will not be corrected, it was thought that possible improvements could be made to the post-censal population estimates. This was one of the Bureau's motivations for correcting errors in the A.C.E. data and developing improved estimates of the net undercount. We refer to these as A.C.E. Revision II estimates. A.C.E. Revision II estimates provide a better understanding of the sources of coverage error in Census 2000 which will help determine how they can be prevented or reduced for the 2010 Census. The A.C.E. Revision II estimates will also help in developing a better design and methodology for coverage measurement in 2010. This paper discusses the motivation and general approach and presents some A.C.E. Revision II results.[1]

Introduction

The work on A.C.E. Revision II has been completed and the results of this effort are available on the Census Bureau's web site. The A.C.E. Revision II results were not used to adjust intercensal estimates. The Bureau considered but rejected this adjustment because of methodological uncertainties. The details concerning this decision can be found in the document at the web site http://www.census.gov/dmd/www/dipe.html Also see the *Technical Assessment of A.C.E. Revision II* and other detailed information on methodology, limitations, and results at http://www.census.gov/dmd/www/ace2.html In general, the A.C.E. Revision II findings are dramatically different and substantially superior to the March 2001 A.C.E. results. They also represent our best and most detailed estimates of Census 2000 coverage error. Further limitations are associated with estimates for small areas. For a small number of very small counties and places, the A.C.E. Revision II estimates imply that there are some extreme overcounts. These extreme estimates may be inaccurate, since they may be caused by limitations associated with the A.C.E. Revision II methodology.

Background

The original March 2001 A.C.E. estimates were available in time to allow for the possibility of correcting Census 2000 redistricting files. At that time the Census Bureau's Executive Steering Committee for A.C.E. Policy (ESCAP) recommended **NOT** to correct the Census 2000 counts for purposes of redistricting (ESCAP, 2001). The Secretary of Commerce concurred. Given the information available at that time, this decision was not based on any clear evidence that the Census counts were more accurate, but rather concern that there was some yet undiscovered error in the March 2001 A.C.E. estimates. In particular, there were concerns about the inconsistency between the A.C.E. results and estimates from Demographic Analysis (DA). The A.C.E. estimate of a 3.3 million net undercount was very different from the DA estimate of a 1.8 million net *overcount*.[2] The ESCAP also noted concerns with the possibility of synthetic and balancing error.

Further evaluations were conducted over the next six months to examine the reasons for the discrepancy and to determine if Census 2000 data products, other than redistricting data, should be corrected. Two planned A.C.E. evaluation programs, the Matching Error Study (MES) (Bean 2001) and the Evaluation Followup (EFU) (Raglin and Krejsa 2001), identified some but not all of the errors in the A.C.E. The Person Duplication Study used computer matching techniques to identify large numbers of duplicate census enumerations that were not identified by the A.C.E. evaluation results (Fay 2001 2002). Additional evaluations were conducted to alleviate other concerns such as balancing, contamination, or missing data. Also, further research was done on the components of the DA estimates, resulting in some significant revisions to the components (particularly to the migration estimates), and a new set of DA estimates (Robinson 2001b).

In October 2001, the ESCAP again decided **NOT** to correct the census counts for other Census 2000 data products. Analysis of A.C.E. evaluation data and the results of the person duplication study revealed that the A.C.E. failed to measure large numbers of erroneous census enumerations, overstating the net undercount by at least 3 million persons (ESCAP II, 2001). This error alone was sufficient to call into question the quality of the A.C.E. estimates. Coupled with the revisions to the DA estimates, it provided an explanation for the previously observed inconsistency with DA. The earlier concerns with A.C.E. balancing, contamination, and biases due to missing data had also been resolved. The level of other errors was believed to be small by comparison and therefore was not a major factor in the second ESCAP

[1] 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.

[2] The 1.8 million net overcount estimate is from the original "Base DA" estimates available in March 2001 (Robinson 2001a). Alternative estimates that allowed for a higher level of net undocumented immigration, "Alt DA," were also given by Robinson (2001a) for use in comparisons against the A.C.E. estimates. These yielded a net undercount estimate of 914,000. Revisions to the DA estimates (Robinson 2001b) ultimately changed these results to a net undercount estimate of about 340,000. All three DA estimates differ substantially from the March 2001 A.C.E. estimate of a 3.3 million net undercount.

decision. See Hogan et al. (2002) and Mulry and Petroni (2002) for further information.

In October 2001, the Census Bureau released approximations of the undercount for three race/Hispanic origin groups (Thompson et al. 2001). These "Revised Early Approximations" corrected estimates of erroneous enumerations for census duplicates and for other erroneous enumerations identified in the A.C.E. evaluations but not in the full A.C.E. E-Sample. The results were intended to be illustrative of the effects of these corrections on net undercount estimates and on possible coverage differences. The same methodology and data were later used to expand the calculations to seven race/Hispanic origin groups (Fay 2002, Mule 2002a). These preliminary estimates showed a very small net undercount. The data also indicated that the differential undercount has not been eliminated. These results were limited to the extent that they only provided information at the national level for broad population groups. Furthermore, these preliminary approximations were based on a small subset of A.C.E. data and only partially corrected for errors in measuring erroneous enumerations using Fay's lower bound (Fay 2001). Potential errors in measuring omissions were not accounted for.

A.C.E. Revision II Methodology

Even though the ESCAP recommended twice **NOT** to correct the census counts, they had concerns about differential coverage in Census 2000. The committee thought it possible that further research resulting in revised estimates of coverage could be used to improve the post-censal estimates. In addition, work on revised estimates would provide a better understanding of Census 2000 coverage error that could be used to improve census operations for 2010 and would help in developing better methodologies for the 2010 coverage measurement program. Hence, work began on revising the A.C.E. estimates to correct for detected errors in an effort now known as A.C.E. Revision II.

The major objective of A.C.E. Revision II was to produce improved estimates of net coverage error in Census 2000. Since the national net undercount, as indicated by both DA and the "Revised Early Approximations," was very small, and the census included large numbers of erroneous enumerations in the form of duplicates, it was imperative that the revised methodology carefully account for both overcounts and undercounts. This meant obtaining better estimates of erroneous census enumerations from the E-Sample and obtaining better estimates of census omissions from the P-Sample. Hogan (2002) summarized the major issues in the form of the following five challenges:

1. Improve estimates of erroneous enumerations
2. Improve estimates of census omissions
3. Develop new models for missing data
4. Enhance the estimation post-stratification
5. Consider adjustment for correlation bias.

There were no new field operations associated with the A.C.E. Revision II process. Because of the late date, it was not feasible (or practical) to revisit households for additional data collection. Consequently, the revisions were based on data that had already been collected. One aspect of the strategy for revising the coverage estimates involved correcting measurement errors using information from the A.C.E. evaluation data. This is referred to as the measurement correction study. Another aspect of these corrections involved conducting a more extensive duplicate study to provide results for correcting measurement error due to duplication that was not detected by the A.C.E. evaluations. This study is referred to as the Further Study of Person Duplication (FSPD) (Mule 2002b). The estimation method, discussed briefly below and more fully in Kostanich (2003a), is designed to handle overlap of errors detected by both of these studies and avoid overcorrecting for measurement error.

Measurement Correction Study

This study was designed to improve both estimates of erroneous census enumerations and census omissions by correcting for errors in the data collected by A.C.E. It used the original A.C.E. person interview (PI) and person followup (PFU) data, combined with data from the evaluation followup interview (EFU), the matching error study (MES), and the PFU/EFU review study[3] to correct for data collection error in enumeration status, residence status, mover status, and matching status. This effort involved extensive recoding of about 60,000 P-Sample cases and more than 70,000 E-Sample cases.[4] An automated computer algorithm was used to recode most of the cases, but others required a clerical review by experienced analysts at the National Processing Center (NPC). These analysts had access to the questionnaire responses as well as to interviewer notes which put them in a better position to resolve apparent discrepancies in the data collected. It was not possible to completely code all cases because of missing or conflicting information.

New missing data models were developed to reflect the different types of missing data now possible as a result of the recoding operation. There were three new types of missing data to deal with: (1) P-Sample households that were originally considered interviews but the recoding determined that there were no valid Census Day residents, (2) cases with unresolved match, enumeration, or residency status because of incomplete or ambiguous interview data, and (3) cases with conflicting enumeration or residency status due to contradictory information collected in the A.C.E. PFU and EFU interviews and it could not be determined which was valid. A household noninterview weighting adjustment using new cell definitions was used for (1). Imputation cells and donor

[3] The PFU/EFU review study was not a planned evaluation. It was a special study conducted in a subsample of the evaluation data to resolve discrepancies between enumeration status in the PFU and EFU.

[4] These are probability subsamples of the original A.C.E. P- and E- Samples and in the context of A.C.E. Revision II they are called "revision samples," but they are in fact equivalent to the evaluation followup samples.

pools were developed for the second type of missing data based on detailed responses to the questionnaires. For the conflicting cases in (3), there were no applicable donor pools, and probabilities of 0.5 were imputed for correct enumeration status and Census Day residency status. Fortunately, the measurement error corrections resulted in a relatively small number of these cases.

Further Study of Person Duplicates (FSPD)

The FSPD was designed to provide information to improve estimates of both erroneous census enumerations and census omissions. This study used computer matching and modeling techniques to identify E- and P-Sample cases which linked to (matched) another census enumeration anywhere across the entire country, including group quarters enumerations, and reinstated and deleted census cases. For the E-Sample links the study could not generally identify which enumeration was correct and which was the duplicate. For P-Sample links, the study could not identify whether the correct Census Day residence was at the P-Sample location or the census location. Rather, the information from the FSPD was used to model the probability that an E-Sample linked case was a correct enumeration or that a P-Sample case was a resident on Census Day.

Estimation Methodology

The revised estimates incorporate separate post-strata for estimating census omissions and erroneous census enumerations because the factors related to each of these were likely to be different. Our research efforts focused on determining variables related to explaining variations in rates of erroneous enumerations. This was because much of the previous work on developing post-strata focused on census omissions, and the same post-strata were simply applied to the estimation of erroneous inclusions. For the E-Sample, some of the original post-stratification variables were eliminated and other variables were added. Variables such as region, Metropolitan Statistical Area and type of enumeration area, and tract return rate were replaced by proxy status, type and date of census return, and household relationship and size. For the P-Sample, only the age variable was modified to define separate post-strata for children aged 0 to 9 and those 10 to 17. The same change to the age groups was made for the E-Sample. This change was made because the DA estimates suggested different coverage for younger versus older children. The estimated correct enumeration rates and estimated match rates were used to calculate Dual System Estimates (DSEs) for the cross-classification of the E- and P- Sample post-strata.

The A.C.E. Revision II DSEs include an adjustment for correlation bias. Correlation bias exists if (within P-Sample post-strata) people missed in the census were more likely (or less likely) to also be missed in the A.C.E. In the "more likely to be missed" scenario, correlation bias has a downward effect on estimates. In previous coverage measurement surveys, the erroneous inclusions were assumed to be much smaller than omissions. In this setting not adjusting estimates for correlation bias had the effect of understating the net undercount, which resulted in corrections to the census that were in the right direction but not large enough. In the presence of overcounts, it is possible that corrections without correlation bias might not even be in the right direction, and could actually increase errors relative to no adjustment.

Estimates of correlation bias in A.C.E. Revision II were calculated using the "two-group model" and sex ratios (number of males divided by the number of females) obtained from DA data. The correlation bias estimates are made only for adult males under the assumption of no correlation bias for adult females. Also, correlation bias is not estimated for children. The correlation bias adjustments were done separately for Blacks and NonBlacks within three age categories: 18-29, 30-49, and 50 and over, with the exception of NonBlack males 18 to 29 years of age, a group for which the data would not support estimation of correlation bias for males. The model used for the correlation bias adjustment was about the simplest possible, and assumed that relative correlation bias was constant over male post-strata within the age-race groups. See Shores (2002) for details.

The DSEs, adjusted for correlation bias, were used to produce coverage correction factors for each of the cross-classified post-strata (E-Sample post-strata cross-classified with the P-Sample post-strata). These factors were applied (carried down) within the post-strata to produce estimates for geographic areas such as places and counties. This process is referred to as synthetic estimation. The key assumption underlying this methodology is that the net census coverage, estimated by the coverage correction factor, is relatively uniform within the cross-classified post-strata. Failure of this assumption leads to synthetic error.

The specific form of the A.C.E. Revision II DSE is given in equation (1). For a detailed discussion of the estimator, see Kostanich (2003a) or Kostanich (2003b).

$$DSE_{ij} = Cen_{ij} \times r_{DD,ij} \times \frac{r_{CE,i}}{r_{M,j}} \times \phi \qquad (1)$$

where:

i and j denote the E- and P- Sample post-strata used to estimate the correct enumeration and match rates, respectively.

Cen_{ij} is the census count of the household population for the cross-classification of post-strata i and j. Includes the reinstated cases.

$r_{DD,ij}$ is the data-defined rate for the cross-classification of post-strata i and j. The reinstated cases are included in the denominator but not in the numerator.

$r_{CE,i}$ is the estimated correct enumeration rate for E-Sample post-stratum i.

$r_{M,j}$ is the estimated match rate for P-Sample post-

stratum *j*.

ϕ is the correlation bias adjustment factor (for adult males, distinct for a given age-race group)

The numerator of the data-defined rate, $r_{DD,ij}$, is the count of census data-defined persons, which is the census count excluding whole person imputations and all "reinstated" persons (those who were removed from the census but then reinstated as part of the Housing Unit Duplication Operation.) The denominator of $r_{DD,ij}$, is the census count, so that the product, $Cen_{ij} \times r_{DD,ij}$, at the level of the *ij* post-strata is the count of data-defined persons that were eligible for A.C.E. matching. The correct enumeration rate, $r_{CE,i}$, is the ratio of the E-Sample estimated correct enumerations to the weighted estimate of data-defined persons for E-Sample post-stratum *i*. The product, $Cen_{ij} \times r_{DD,ij} \times r_{CE,i}$, effectively estimates correct enumerations for the detailed *ij* post-stratum under the synthetic assumption that correct enumeration rates are constant over persons within E-Sample post-stratum *i*.

The match rate, $r_{M,j}$, is the ratio of estimated matches to estimated Census Day residents for P-Sample post-stratum *j*. Under the traditional DSE independence assumption (no correlation bias), these match rates would estimate the probabilities of persons being included in the census, so that dividing the estimated correct enumerations $(Cen_{ij} \times r_{DD,ij} \times r_{CE,i})$ by $r_{M,j}$ would appropriately inflate them to account for census omissions (under the synthetic assumption that census inclusion probabilities are constant over persons within P-Sample post-stratum *j*). In the presence of correlation bias the $r_{M,j}$ tend to overestimate the census inclusion probabilities so that dividing by them does not sufficiently inflate the estimate of correct enumerations. Demographic Analysis sex ratios provide evidence of such correlation bias and permit its estimation for adult males (assuming no correlation bias for adult females) at the national level for age-race (Black versus NonBlack) groups. These estimates can be expressed as multiplicative factors ϕ which correct the adult male DSEs for this estimated correlation bias. Note this includes a synthetic assumption that correlation bias for adult males is constant over persons within the age-race groups. For children and adult females the factors ϕ are 1.

The results of the A.C.E. Revision II Measurement Correction Study and the Further Study of Person Duplication affect the estimates of correct enumerations that are the numerators of the correct enumeration rates, $r_{CE,i}$. The denominators of the correct enumeration rates are not affected. For example, E-Sample cases with duplicates that were originally coded as correct enumerations are given reduced correct enumeration probabilities, which reduces tabulated estimates of correct enumerations. The A.C.E. Revision II Measurement Correction Study and the Further Study of Person Duplication also affected both the estimates of matches and the estimates of P-Sample residents that are the numerators and denominators of the match rates, $r_{M,j}$. The specifics are complicated; see Kostanich (2003a) or Kostanich (2003b).

Equation (1) shows how the A.C.E. Revision II estimates are constructed for the cross-classified *ij* post-strata. To produce estimates for specific areas or population subgroups we first define coverage correction factors (CCFs) by dividing the DSEs from equation (1) by the corresponding census counts, i.e.,

$$CCF_{ij} = DSE_{ij} / Cen_{ij} = r_{DD,ij} \times \frac{r_{CE,i}}{r_{M,j}} \times \phi \qquad (2)$$

To produce the estimate for any area or population subgroup *a*, the CCFs from equation (2) are applied synthetically:

$$\sum_{ij} Cen_{a,ij} \times CCF_{ij} = \sum_{ij} Cen_{a,ij} \times r_{DD,ij} \times \frac{r_{CE,i}}{r_{M,j}} \times \phi$$

where the summation is over all the cross-classified *ij* post-strata and $Cen_{a,ij}$ is the census count in post-stratum *ij* for area or subgroup *a*.

The A.C.E. Revision II DSE can be thought of as incorporating the following enhancements to a traditional DSE:

- New post-stratification to reflect different factors related to erroneous inclusions and omissions.
- Corrections to the correct enumeration rate from the Further Study of Person Duplication.
- Corrections to the correct enumeration rate from the A.C.E. Revision II Measurement Correction Study.
- Corrections to the match rate from the Further Study of Person Duplication.
- Corrections to the match rate from the A.C.E. Revision II Measurement Correction Study.
- Adjustment for correlation bias.

The impact of these revisions can best be seen by looking at the numerical effects of incorporating one change at a time to the DSE. Consider Table 1 below which shows the impact of each change relative to the March 2001 A.C.E. estimates of national net undercount.

Table 1: Change in Estimated Net Undercount (Household Population in millions)

		Net Undercount	Change* Undercount	Cumulative Undercount
March 2001 A.C.E. Estimate		3.26		
New Post-Stratification			0.04	3.30
E Sample:	Person Duplication Study		-2.81	0.49
	Measurement Correction Study		-2.43	-1.94
P Sample:	Person Duplication Study		-1.10	-3.04
	Measurement Correction Study		0.01	-3.03
Correlation Bias			1.70	-1.33
A.C.E. Revision II Estimate		-1.33	-4.59	

* Shows the effect of adding in one revision at a time. A different

ordering of the revisions would result in slightly different intermediate effects, but yield the same overall net undercount estimate. Estimated change in the net undercount is not the same as estimated additional erroneous enumerations or additional census omissions.

This table starts with the March 2001 A.C.E. estimate of a national net undercount of just under 3.3 million persons. Each row shows the effect on the net undercount estimate of making one of the specific revisions. Using only the new post-stratification and not making any other corrections would increase the estimated net undercount to 3.3 million, an increase of less than 39,000. Though the effect of the new post-stratification is small at the national level, it has considerably more impact on subnational estimates, particularly for small areas. When corrections are made to the correct enumeration rate, we see that if we first correct for those identified by the person duplication study the estimated net undercount is reduced by 2.8 million. Next, adding in the corrections identified by the measurement correction study reduces the estimated net undercount by another 2.4 million, resulting in an estimated net overcount of 1.9 million. Next we incorporate corrections into the match rate. First, adding in the corrections based on the person duplication study reduces the estimated net undercount by another 1.1 million. Adding in the corrections from the measurement correction study causes the estimated net undercount to increase slightly by only 11,000. Making the final correction for correlation bias increases the estimated net undercount by 1.7 million, yielding the A.C.E. Revision II estimate of a 1.3 million net overcount. See Mule (2003) for further information on how these revisions impact race/ethnic groups.

Summary of Results

Table 2 below shows A.C.E. Revision II estimates of percent net undercount in Census 2000 for the household population and major demographic groups. For comparison, Table 2 also shows results from the March 2001 A.C.E. estimates. A.C.E. Revision II estimates a negative net undercount, or overcount, of the Census 2000 household population. The estimated percent net undercount of -0.49 with a standard error of 0.20 is significantly different from zero at the 10-percent significance level. This differs sharply from the March 2001 A.C.E. estimate of a 1.18 percent net undercount (standard error of 0.13), an estimate which was corrupted by undetected duplicates and the effects of data collection error on residency status.

Among the A.C.E. Revision II coverage estimates by race/Hispanic origin domains, only those for the Non-Hispanic White and Non-Hispanic Black domains show estimated net undercounts that differ significantly from zero. The Non-Hispanic White domain has a negative estimated net undercount of -1.13 percent, reflecting an overcount, while the Non-Hispanic Black domain has an estimated net undercount of 1.84 percent.

Table 2 also shows differential coverage estimates with respect to tenure. Nationally, A.C.E. Revision II estimates owners to have a net undercount of -1.25 percent and non-owners a net undercount of 1.14 percent. These estimated net undercount rates are statistically different from zero, and their difference is also statistically significant.

The A.C.E. Revision II estimates show coverage differentials by age and sex. In particular, statistically significant net overcounts were estimated for children age 10-17 and for adult females 18-29, 30-49, and 50 and over, as well as for males 50 and over. In contrast, statistically significant net undercounts were estimated for males 18-29 and 30-49, and the net undercount estimate for children 0-9 was not significantly different from zero. The coverage differences by sex are affected by the correlation bias adjustments that increase the undercount estimates for adult males.

Table 2: Percent Net Undercount for Major Groups

Characteristic		A.C.E. Revision II		A.C.E. March 2001	
		Est (%)	SE (%)	Est (%)	SE (%)
Total		-0.49	0.20	1.18	0.13
Race/Hispanic Origin Domain					
	Non-Hispanic White	-1.13	0.20	0.67	0.14
	Non-Hispanic Black	1.84	0.43	2.17	0.35
	Hispanic	0.71	0.44	2.85	0.38
	Non-Hispanic Asian	-0.75	0.68	0.96	0.64
	Hawaiian or Pacific Isl	2.12	2.73	4.60	2.77
	AI on Reservation	-0.88	1.53	4.74	1.20
	AI off Reservation	0.62	1.35	3.28	1.33
Tenure					
	Owner	-1.25	0.20	0.44	0.14
	Non-Owner	1.14	0.36	2.75	0.26
Age/Sex					
	0 - 9*	-0.46	0.33	1.54	0.19
	10 - 17*	-1.32	0.41	1.54	0.19
	18 - 29 Male	1.12	0.63	3.77	0.32
	18 - 29 Female	-1.39	0.52	2.23	0.29
	30 - 49 Male	2.01	0.25	1.86	0.19
	30 - 49 Female	-0.60	0.25	0.96	0.17
	50+ Male	-0.80	0.27	-0.25	0.18
	50+ Female	-2.53	0.27	-0.79	0.17

* For March 2001, the "0 - 17" Age/Sex group was a single group. Therefore, the net undercount and standard error for children "0 - 9" and "10 - 17" are identical.
A negative net undercount denotes a net overcount.

Implications for 2010

These improved coverage estimates have already enhanced our understanding about Census 2000 errors. They will also help us to develop better methodologies for designing the 2010 Census and associated coverage measurement programs. Several areas of additional research and possible testing are immediately suggested:

- Develop better methods to detect, correct and

evaluate or measure census erroneous enumerations, particularly duplicates. Clearly efforts should be made in the direction of preventing duplicates from occurring, as well as investigating ways to determine which member of a duplicate pair is correct.

- The need for research into the Census Bureau's residence rules. Cognitive research and testing of simplified, more understandable residence rules should be researched and tested. Research should focus not only on clarifying the rules, but also on ways to improve questionnaires for both the census enumeration and coverage measurement. Research should pay particular attention to difficult enumeration situations involving college students, children in joint custody, and individuals with more than one residence.
- Significant research and testing should be devoted to minimizing error caused by proxy data. Clearly census operations should be designed to limit the introduction of proxy data in the first place, and systems should be developed to improve the quality of the proxy data when proxy data must be used.

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