

**P-SAMPLE MATCH RATE CORRECTED FOR ERROR DUE TO INCONSISTENT
POST-STRATIFICATION VARIABLES**

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1. BACKGROUND¹

To measure the overall and differential coverage of the U.S. population in Census 2000, the U.S. Census Bureau conducted the Accuracy and Coverage Evaluation (A.C.E.). The A.C.E. enumerated the persons living in sampled housing units, and tried to determine their Census day residency status. That is, whether they lived at the sample address on both Census day and at the time of the A.C.E. person interview (non-movers), moved into the sample address after Census day (in-movers), or lived at the sample address on census day but lived elsewhere at the time of the A.C.E. Person Interview (out-movers) (Childers and Fenstermaker, 2000).

The A.C.E. used the dual-system estimation (DSE) method to measure coverage error. The DSE method assumes there are two independent lists of the population. The first list consists of data-defined persons (a person who has two or more of the following items answered on their census form: name, age, sex, race, Hispanic Origin, or relationship) in the A.C.E. sample area who were enumerated in the Census (E-sample), and the second list is people enumerated in the A.C.E. (P-sample). These two lists were matched to produce an estimate of the number of people missed in the Census, and an estimate of the number of people correctly enumerated in the Census. The coverage error was then calculated using these two estimates (Childers and Fenstermaker, 2000).

These estimates of coverage error were found to contain errors. The main errors resulted from failure of the A.C.E. to measure a large number of erroneous enumerations. Subsequently, the U.S. Census Bureau produced the A.C.E. Revision II

¹ This paper reports the results of research and analysis undertaken by U.S. 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. The views expressed are those of the authors and not necessarily those of the U.S. Census Bureau.

estimates of coverage error that incorporated corrections for errors (Kostanich, 2003).

Both the original A.C.E. DSEs and the A.C.E. Revision II DSEs can be affected by inconsistent post-stratification bias, which affects estimates of the P-sample match rate (rate of P-sample people who matched to E-sample people). Such bias occurs when the coverage factors for gross undercount are derived for post-strata based on the P-sample responses and then applied to the post-strata based on responses to Census enumerations (Haberman and Spencer, 2001). The inconsistent reporting sometimes is caused by the census and A.C.E. interviews for a household having different respondents who do not provide exactly the same information about family members.

This study measures the impact of inconsistency bias on the original A.C.E. DSE and the A.C.E. Revision II DSE.

2. METHODS

The basic form of the DSE is:

$$DSE = (Cen - II) * \left(\frac{r_{ce}}{r_m} \right)$$

where,

Cen = the census count excluding late adds (people in housing units added to the census after the E-sample was identified. These people were ineligible for A.C.E. matching.)

II = the insufficient information cases (persons in the census for whom there is insufficient information for inclusion in the E-sample including non-data-defined persons and persons in whole household imputations) excluding late adds.

r_{ce} = the E-sample correct enumeration rate

r_m = the P-sample match rate

In this study, we calculated P-sample match rates corrected for the error due to inconsistent post-stratification variables (see section 2.2 for list of these variables), and used the corrected P-sample match rates to compute an A.C.E. DSE estimate and an A.C.E. Revision II DSE estimate adjusted for inconsistency bias. The DSE adjusted for inconsistency bias was then compared to the unadjusted DSE to see if statistically significant differences exist. The inconsistency bias in the P-sample match rate was calculated using models produced by Shelby Haberman.

The basic approach used in Shelby Haberman's models is to estimate the inconsistency rates in the post-stratification variables using the matches and then assume that the rates also hold for the non-matches. The models used for the inconsistency of the post-strata (Haberman and Spencer, 2001) were fitted in two steps, first (i) models for inconsistency of post-stratification variables, and then (ii) derivation of inconsistency probabilities for post-stratification variables given the inconsistency probabilities of the post-stratification variables. The inconsistency probabilities led to an estimate of the bias in the P-sample match rate that was used to estimate the bias in the DSE (Bench, #PP-12, 2002).

2.1 Variance Estimation

Shelby Haberman's program does not estimate variances for the corrected P-sample match rates. So, we used the simple jackknife method based on 32 replicates to estimate variances for the A.C.E. and A.C.E. Revision II DSE and DSE corrected for inconsistency bias.

There are four main steps to estimating these variances. First, we formed the 32 replicates. Second, we ran Haberman's bias program for the whole sample and the 32 replicates to correct the appropriate P-sample match rate components for inconsistency bias. Third, we calculate the inconsistency bias corrected DSE for the whole sample and each of the 32 replicates. Fourth, we calculate the variance of the DSE and the inconsistency bias corrected DSE using the estimates calculated for the 32 replicates.

Note that these variances are based on only 32 replicates instead of on a replicate for each A.C.E. cluster. In addition, the variance is a simple jackknife estimate, which does not take into account the strata used when identifying the A.C.E. sample.

2.2 Significance Tests

To detect significant inconsistency bias, we calculated a t-statistic for the difference between the DSE and the inconsistency corrected DSE for each of the A.C.E. post-strata and A.C.E. Revision II crossed E-sample and P-sample post-strata. We also calculated the difference between the DSE and the inconsistency corrected DSE for the following five aggregate groups: sex, age, age by sex, race/Hispanic ethnicity domain, and domain by age by sex. We then calculated the relative error for these groups, where the relative error equals the difference divided by the DSE. However, no variances were calculated for the aggregate group

estimates. The differences between the following DSEs were calculated.

- The A.C.E. DSE and the inconsistency corrected A.C.E. DSE.
- The A.C.E. Revision II DSE and the inconsistency corrected A.C.E. Revision II DSE.

To determine which A.C.E. and A.C.E. Revision II t-statistics were significant, we used a Bonferoni multiple comparison procedure to adjust the overall alpha value (α_N). We used $\alpha_R = \alpha_N/m$, where α_R is the significance level adjusted for multiple comparisons, and m is the number of comparisons. For the A.C.E., there were 416 post-strata. So, α_N equals 0.10, m equals 416, and α_R equals 0.000240384. For the A.C.E. Revision II, there were 7584 crossed E-sample and P-sample post-strata. So, α_N equals 0.10, m equals 7584, and α_R equals 0.000013185.

It should be noted that for the A.C.E. the E-sample and P-sample post-strata were defined the same. That is, the 416 E-sample post-strata were defined the same way as the 416 P-sample post-strata, which resulted in the 416 A.C.E. post-strata. The A.C.E. E-sample and P-sample post-strata consisted of 64 post-stratum groups broken out by age/sex groups. For 56 of the 64 post-stratum groups there were 7 age/sex groups. For the remaining 8 post-stratum groups these 7 age/sex groups were collapsed to 3 because the combined number of nonmovers and outmovers in the pre-collapsed post-strata was less than 100. The age/sex groups can be found in Table 1. The 64 post-stratum groups were defined by the following variables: race/Hispanic origin, tenure, metropolitan statistical area and type of enumeration area, return rate, and region of country.

For the A.C.E. Revision II, the E-sample and P-sample post-strata were defined differently. That is, there was a set of E-sample post-strata, and a completely different set of P-sample post-strata. The E-sample and P-sample post-strata were then cross classified to get the 7584 crossed A.C.E. Revision II post-strata. The A.C.E. Revision II P-sample post-strata consisted of the same 64 post-stratum groups as the A.C.E., but were instead broken out by 8 age/sex groups. The A.C.E. Revision II E-sample post-strata consisted of 93 post-stratum groups broken out by the 8 age/sex groups. So, once the E-sample and P-sample post-strata were cross classified there were 948 A.C.E. Revision II post-strata groups per age/sex group. The 8 age/sex groups can be found in Table 3. The E-sample post-stratum groups were defined by the following variables: race/Hispanic origin, tenure,

relationship, household size, early/late mail return, early/late non-mail return, and proxy/non-proxy interview.

2.3 A.C.E. DSE Match Rate

The formula for the A.C.E. DSE P-sample match rate, r_m , for post-stratum j is as follows (see Haines, 2001):

For P-sample out-mover sample size greater than or equal to 10:

$$r_{m,j} = \frac{M_{nm,j} + \frac{M_{om,j}}{N_{om,j}} * N_{im,j}}{N_{nm,j} + N_{im,j}}$$

For P-sample out-mover sample size less than 10:

$$r_{m,j} = \frac{M_{nm,j} + M_{om,j}}{N_{nm,j} + N_{om,j}}$$

where

$N_{nm,j}$ = weighted number of P-sample non-movers in post-stratum j

$N_{im,j}$ = weighted number of P-sample in-movers in post-stratum j

$N_{om,j}$ = weighted number of P-sample out-movers in post-stratum j

$M_{nm,j}$ = weighted number of P-sample non-mover matches in post-stratum j

$M_{om,j}$ = weighted number of P-sample out-mover matches in post-stratum j

2.3.1 A.C.E. DSE Match Rate Corrected for Inconsistent Post-stratification Variables

To define a match rate corrected for inconsistent post-stratification, we need to define:

$f_G(j,k)$ = the proportion of group G persons enumerated in P-sample post-stratum k who belong to E-sample post-stratum j . The estimation of this proportion is based on the matched P-sample persons in group G . In this application, group G may be non-movers, out-movers, or in-movers. Next we need to define the following:

$$N_{nm,j,l} = \sum f_{nm}(j,k)N_{nm,k}$$

$$N_{im,j,l} = \sum f_{im}(j,k)N_{im,k}$$

$$N_{om,j,l} = \sum f_{om}(j,k)N_{om,k}$$

$$M_{nm,j,l} = \sum f_{nm}(j,k)M_{nm,k}$$

$$M_{om,j,l} = \sum f_{om}(j,k)M_{om,k}$$

Then we define the match rate corrected for inconsistent post-stratification variables, assuming no other errors are present, by the following:

For P-sample out-mover sample size greater than or equal to 10:

$$r_{m,j,l} = \frac{M_{nm,j,l} + \frac{M_{om,j,l}}{N_{om,j,l}} * N_{im,j,l}}{N_{nm,j,l} + N_{im,j,l}}$$

For P-sample out-mover sample size less than 10:

$$r_{m,j,l} = \frac{M_{nm,j,l} + M_{om,j,l}}{N_{nm,j,l} + N_{om,j,l}}$$

2.3.2 Calculation of Error in the A.C.E. DSE

The A.C.E. DSE for post-stratum j is

$$DSE_j = (Cen_j - II_j) * \left(\frac{r_{ce,j}}{r_{m,j}} \right)$$

Then the A.C.E. DSE that incorporates a correction for the error due to inconsistent post-stratification variables for post-stratum j is given by

$$DSE_{j,l} = (Cen_j - II_j) * \left(\frac{r_{ce,j}}{r_{m,j,l}} \right)$$

The bias due to inconsistent post-stratification variables is

$$DSE_j - DSE_{j,l}$$

2.4 A.C.E. Revision II DSE Match Rate

The formula for the A.C.E. Revision II DSE P-sample match rate, r_m , for post-stratum j is as follows (see Kostanich, 2003):

$$r_{m,j} = \frac{WTMATCH}{WTPTOTAL}$$

For full P-sample out-mover sample size greater than or equal to 10:

$$WTMATCH = M_{nm,j}^{ND} * f_{2,j'} + \tilde{M}_{nm,j}^D + \left[\frac{M_{om,j} * f_{3,j'}}{P_{om,j} * f_{4,j'}} \right] * \left(P_{im,j} * f_{5,j'} + g(P_{nm,j}^D - \tilde{P}_{nm,j}^D) \right)$$

$$WTPTOTAL = P_{nm,j}^{ND} * f_{6,j'} + \tilde{P}_{nm,j}^D +$$

$$P_{im,j} * f_{5,j'} + g(P_{nm,j}^D - \tilde{P}_{nm,j}^D)$$

For full P-sample out-mover sample size less than 10:

$$WTMATCH = M_{nm,j}^{ND} * f_{2,j'} + \tilde{M}_{nm,j}^D +$$

$$M_{om,j} * f_{3,j'} + g(M_{nm,j}^D - \tilde{M}_{nm,j}^D)$$

$$WTPTOTAL = P_{nm,j}^{ND} * f_{6,j'} + \tilde{P}_{nm,j}^D +$$

$$P_{om,j} * f_{4,j'} + g(P_{nm,j}^D - \tilde{P}_{nm,j}^D)$$

where

$P_{nm,j}^{ND}$ = weighted number of non-mover residents without duplicate links (P-sample and Census enumerations appearing two or more times are linked) in post-stratum j

$M_{nm,j}^{ND}$ = weighted number of matched non-movers without duplicate links in post-stratum j

$P_{om,j}$ = weighted number of out-movers in post-stratum j

$M_{om,j}$ = weighted number of matched out-movers in post-stratum j

$P_{im,j}$ = weighted number of in-movers in post-stratum j

$P_{nm,j}^D$ = weighted number of non-mover residents with duplicate links in post-stratum j

$\tilde{P}_{nm,j}^D$ = corrected number of non-mover residents with duplicate links in post-stratum j

$M_{nm,j}^D$ = weighted number of matched non-movers with duplicate links in post-stratum j

$\tilde{M}_{nm,j}^D$ = corrected number of matched non-movers with duplicate links in post-stratum j

$f_{2,j'}$ = double sampling ratio adjustment for non-duplicate non-mover matches in A.C.E. Revision II Sample post-stratum j'. The A.C.E. Revision II Sample post-strata are collapsed A.C.E. sample post-strata.

$f_{3,j'}$ = double sampling ratio adjustment for out-mover matches in A.C.E. Revision II Sample post-stratum j'.

$f_{4,j'}$ = double sampling ratio adjustment for out-movers in A.C.E. Revision II Sample post-stratum j'.

$f_{5,j'}$ = double sampling ratio adjustment for in-movers in A.C.E. Revision II Sample post-stratum j'.

$f_{6,j'}$ = double sampling ratio adjustment for non-duplicate non-movers in A.C.E. Revision II Sample post-stratum j'.

g = estimated proportion of P-sample persons with census duplicates outside the search area (the sample block, or for a sample of blocks the sample block and one ring of blocks surrounding the sample block) who are not retained as resident non-movers by the duplicate study because they should have been coded as in-movers.

2.4.1 A.C.E. Revision II DSE Match Rate Corrected for Inconsistent Post-stratification Variables

To define a match rate corrected for inconsistent post-stratification, we need to define:

$f_G(j, k)$ = the proportion of group G persons enumerated in P-sample post-stratum k who belong to P-sample post-stratum j, based on their E-sample variables. The estimation of this proportion is based on the matched P-sample persons in group G. In this application, group G may be non-movers, out-movers, or in-movers.

Next we need to define the following:

$$P_{nm,j,l}^{ND} = \sum f_{nm}(j, k) P_{nm,k}^{ND}$$

$$M_{nm,j,l}^{ND} = \sum f_{nm}(j, k) M_{nm,k}^{ND}$$

$$P_{G,j,l} = \sum f_G(j, k) P_{G,k}, \text{ for } G = \text{im or om}$$

$$M_{om,j,l} = \sum f_{om}(j, k) M_{om,k}$$

$$P_{nm,j,l}^D = \sum f_{nm}(j, k) P_{nm,k}^D$$

$$M_{nm,j,l}^D = \sum f_{nm}(j, k) M_{nm,k}^D$$

$$\tilde{P}_{nm,j,l}^D = \sum f_{nm}(j, k) \tilde{P}_{nm,k}^D$$

$$\tilde{M}_{nm,j,l}^D = \sum f_{nm}(j, k) \tilde{M}_{nm,k}^D$$

Then we define the match rate corrected for inconsistent post-stratification variables, assuming no other errors are present, by the following:

$$r_{m,j,l} = \frac{WTMATCH_l}{WTPTOTAL_l}$$

For full P-sample out-mover sample size greater than or equal to 10:

$$WTMATCH_l = M_{nm,j,l}^{ND} * f_{2,j'} + \tilde{M}_{nm,j,l}^D +$$

$$\left[\frac{M_{om,j,l} * f_{3,j'}}{P_{om,j,l} * f_{4,j'}} \right] * \left(P_{im,j,l} * f_{5,j'} + g(P_{nm,j,l}^D - \tilde{P}_{nm,j,l}^D) \right)$$

$$WTPTOTAL_l = P_{nm,j,l}^{ND} * f_{6,j'} + \tilde{P}_{nm,j,l}^D$$

$$P_{im,j,l} * f_{5,j'} + g(P_{nm,j,l}^D - \tilde{P}_{nm,j,l}^D)$$

For full P-sample out-mover sample size less than 10:

$$WTMATCH_l = M_{nm,j,l}^{ND} * f_{2,j'} + \tilde{M}_{nm,j,l}^D +$$

$$M_{om,j,l} * f_{3,j'} + g(M_{nm,j,l}^D - \tilde{M}_{nm,j,l}^D)$$

$$WTPTOTAL_I = P_{nm,j,I}^{ND} * f_{6,j'} + \tilde{P}_{nm,j,I}^D + P_{om,j,I} * f_{4,j'} + g(P_{nm,j,I}^D - \tilde{P}_{nm,j,I}^D)$$

2.4.2 Calculation of Error in the A.C.E. Revision II DSE

The A.C.E. Revision II DSE for estimation cell ij formed by the intersection of E-sample post-stratum i and P-sample post-stratum j is

$$DSE_{ij} = cb * (Cen_{ij} - II_{ij}) * \left(\frac{r_{ce,i}}{r_{m,j}} \right)$$

cb = the correlation bias adjustment. The A.C.E. Revision II DSEs for Black and Nonblack male post-strata were adjusted for correlation bias by dividing the summation of the A.C.E. Revision II DSEs for female Black or Nonblack post-strata by the summation of the A.C.E. Revision II DSEs for male Black or Nonblack post-strata, and then multiplying this quotient by a demographic analysis sex ratio for Blacks or Nonblacks.

Then the A.C.E. Revision II DSE that incorporates a correction for the error due to inconsistent post-stratification variables for the estimation cell ij is given by

$$DSE_{ij,I} = cb * (Cen_{ij} - II_{ij}) * \left(\frac{r_{ce,i}}{r_{m,j,I}} \right)$$

The bias due to inconsistent post-stratification variables is DSE_{ij} - DSE_{ij,I}

3. A.C.E. RESULTS

Twenty-six out of the 416 A.C.E. post-strata or 6.25 percent have significant differences. Twenty-three of these significant differences are from one of the 264 Non-Hispanic white post-strata, two are from one of the 52 Hispanic post-strata, and one is from one of the 52 Non-Hispanic black post-strata. So, 8.71 percent of the Non-Hispanic white post-strata, 3.85 percent of the Hispanic post-strata, and 1.92 percent of the Non-Hispanic black post-strata are significant. In addition, 0 to 17 year olds and females 30 to 49 years old are the age and sex groups most affected by inconsistency. They both account for more than 5 significant differences. Each of the remaining seven age and sex groups only account for 0 to 4 significant differences. The absolute values of the significant differences for the 416 A.C.E. post-strata range from 1240.32 to 9484.64, and all but two of the significant differences are negative. These differences seemed relatively small when compared to the actual DSE estimates. Table 1 below lists the number of significant differences for each age and sex group.

Table 1. Number of A.C.E. Significant Differences by Age/Sex Group

Age/Sex Group	Number of Significant Post-strata	Number of Post-strata	Percent of Post-strata Significant
0-17	9	64	14.06
18-29 M	1	56	1.79
18-29 F	2	56	3.13
30-49 M	3	56	5.36
30-49 F	6	56	10.71
50+ M	4	56	7.14
50+ F	1	56	1.79
18+ M ¹	0	8	0
18+ F ¹	0	8	0
Total	26	416	6.25

1: The 7 age/sex groups for 8 of the 64 A.C.E. post-strata groups were collapsed to 3 age/sex groups. These were 0-17, 18+M, 18+F.

The differences of all five aggregate groups are relatively small when compared to the aggregated A.C.E. DSEs and inconsistency bias corrected A.C.E. DSEs. In addition, only a few of the aggregate groups have any relative errors greater than 1 percent. The relative error is less than 1 percent for all of the aggregate sex, age, and age by sex groups. For the aggregate domain groups, only one of the seven domains has a relative error greater than 1 percent. This group is the Native Hawaiian or Pacific Islander domain, which has a relative error of 1.31 percent. For the aggregate domain by age by sex groups, 7 of the 51 groups (13.73 percent) have relative errors greater than 1 percent. All of these are less than 3 percent. The relative errors for these seven groups are shown in Table 2.

Table 2. A.C.E. Domain by Age by Sex Groups with Relative Errors Greater than 1 Percent

Domain	Age/Sex Group	Relative Error
American Indians or Alaska Natives Off Reservation	0-17	1.05%
Hispanic	18-29 F	2.23%
	30-49 F	1.95%
Hispanic	18+ M ¹	2.76%
	18+ F ¹	2.50%
Native Hawaiians or Pacific Islanders	0-17	1.73%
	18+ M	1.72%

1: This aggregate consists of only one post-strata group.

4. A.C.E. REVISION II RESULTS

Two hundred sixty of the 7584 crossed E-sample and P-sample post-strata or 3.43 percent have significant differences. All of these significant differences are from one of the 5952 Non-Hispanic white post-strata. So, 4.37 percent of the Non-Hispanic white post-strata are significant. In

addition, males 30 to 49 years old, 10 to 17 year olds, and females 30 to 49 years old are the age and sex groups most affected by inconsistency. They each account for more than 40 significant differences. Each of the remaining five age and sex groups only account for 0 to 32 significant differences. The absolute values of the differences range from 0.01 to 1728.50. These differences seem relatively small when compared to the actual DSE estimates. Table 3 below lists the number of significant differences for each age and sex group.

Table 3. Number of A.C.E. Revision II Significant Differences by Age/Sex Group

Age/ Sex Group	Number of Significant Post-strata	Number of Post- strata	Percent of Post-strata Significant
0-9	0	948	0
10-17	63	948	6.65
18-29 M	0	948	0
18-29 F	7	948	0.74
30-49 M	99	948	10.44
30-49 F	44	948	4.64
50+ M	32	948	3.38
50+ F	15	948	1.58
Total	260	7584	3.43

The differences of all five aggregate groups are relatively small when compared to the aggregated A.C.E. Revision II DSE and inconsistency bias corrected A.C.E. Revision II DSE estimates. In addition, only a few of the aggregate groups have any relative errors greater than 1 percent. The relative error is less than 1 percent for all of the aggregate sex, age, and age by sex groups. For the aggregate domain groups, only one of the seven domains has a relative error greater than 1 percent. This group is the Native Hawaiian or Pacific Islander domain, which has relative errors of 1.24 percent. For the aggregate domain by age by sex groups, 8 of the 56 groups (14.29 percent) have relative errors greater than 1 percent. All of these are less than 2.5 percent. The relative errors for these eight groups are listed in Table 4.

Table 4. A.C.E. Revision II Domain by Age by Sex Groups with Relative Errors Greater than 1 Percent

Domain	Age/Sex Group	Relative Error
American Indians or Alaska Natives Off Reservation	10-17	1.45%
	18-29 F	2.30%
	30-49 F	1.85%
Native Hawaiians or Pacific Islanders	0-9	1.26%
	10-17	2.17%
	18-29 M	1.20%
	30-49 M	1.63%
	50+ M	2.26%

5. CONCLUSIONS

The 26 significant A.C.E. differences show that inconsistency bias had the most affect on Non-Hispanic white post-strata, 0 to 17 year old, and female 30 to 49 year old post-strata. However, the statistically significant differences for the 416 A.C.E. post-strata, and the relative errors for the aggregate groups are relatively small. This suggests that overall inconsistency bias is not an issue for the A.C.E.

The 260 significant A.C.E. Revision II differences show that inconsistency bias had the most affect on Non-Hispanic white post-strata, and more specifically male 30 to 49 year old Non-Hispanic white post-strata. However, the statistically significant differences for the 7584 A.C.E. Revision II crossed E-sample and P-sample post-strata, and the relative errors for the aggregate groups are relatively small. This suggests that overall inconsistency bias is not an issue for the A.C.E. Revision II.

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