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Subject: 2010 Census Coverage Measurement Estimation Report:
 Adjustment for Correlation Bias

This report is one of twelve documents providing estimation results from the 2010 Census Coverage Measurement program. This report focuses on the adjustment for correlation bias in the adult male dual system estimates.

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Census Coverage Measurement Estimation Report

Adjustment for Correlation Bias

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Executive Summary

Correlation bias results from the failure of the general independence assumption underlying dual system estimation. This form of bias tends to lead to underestimation by dual system estimates if persons missed in the census are more likely than those found in the census to also have been missed in the Census Coverage Measurement (CCM) survey. In the CCM, we made an adjustment for correlation bias in the United States adult male dual system estimates within age-race groups (Black or Non-Black) by applying national-level sex ratios from the Demographic Analysis (DA) program. As we assume no correlation bias in the adult female dual system estimates, we made no adjustment to females. This report presents the results of the adjustment for correlation bias.

Evidence of correlation bias comes from comparisons of the national-level CCM sex ratios (males to females) to sex ratios from DA. The DA sex ratios for Black adults significantly exceeded those sex ratios for CCM. This strongly suggests the presence of correlation bias in the adult Black male dual system estimates. The DA sex ratios for Non-Blacks aged 30 or older also exceeded those sex ratios for CCM, but to a lesser degree than for Black adults. This suggests a relatively small amount of correlation bias at the national level in the Non-Black male dual system estimates for these age groups. For Non-Blacks aged 18 to 29, the DA sex ratio was slightly less than the CCM sex ratio. Because of this, we did not make an adjustment for correlation bias for Non-Black males aged 18 to 29.

The impact of the adjustment for correlation bias was an increase in the national-level population estimate from 298.11 million to 300.67 million, an increase of 0.9%. This increase was entirely in the adult male estimates; the children and adult female estimates were not adjusted. The CCM estimate of the nation-level net undercount changed from -0.87% without the correlation bias adjustment to -0.01% with the adjustment.

The relative impact of the adjustment for correlation bias was greater for Blacks than for Non-Blacks. For Blacks, this adjustment resulted in an increase in the population estimate from 40.07 million to 41.00 million, an increase of 2.3%. For Non-Blacks, the population estimate increased from 258.04 million to 259.67 million, an increase of 0.6%.

In the 2000 Accuracy and Coverage Evaluation Revision II estimates, we also applied an adjustment for correlation bias. Compared to the Accuracy and Coverage Evaluation Revision II results, the relative impact of the correlation bias adjustment on the CCM adult Black male estimate was of a comparable magnitude. For the CCM adult Non-Black male estimate, the correlation bias adjustment had a larger relative impact than in 2000.

1. Introduction

The Census Coverage Measurement (CCM) estimation methodology included an adjustment for correlation bias in the adult male dual system estimates (DSEs). This report documents the results of the adjustment for correlation bias for the United States household population. The results are provided at the national level by age-race groups (Black or Non-Black). When appropriate, comparisons are made to the 2000 Accuracy and Coverage Evaluation (A.C.E.) Revision II estimates, which also contained an adjustment for correlation bias.

Correlation bias can result from either of two sources: (1) causal dependence, or (2) heterogeneity of inclusion probabilities (Griffin 2000). Causal dependence exists when the act of being included or excluded from the census makes an individual more or less likely to be included in the CCM survey. Heterogeneity exists when the census and CCM inclusion probabilities vary over individuals with identical estimated inclusion probabilities. Heterogeneity can exist even if the assumption of causal independence holds true for all individuals. Either source can result in correlation bias, which tends to lead to underestimation of the true population by the DSEs.

The CCM dual system estimation used logistic regression modeling to reduce bias due to heterogeneity in the capture probabilities. In previous post-enumeration surveys, post-stratification was used to reduce heterogeneity. The adjustment for correlation bias attempts to reduce the effect of heterogeneity that remains after the logistic regression modeling (Olson 2008).

2. Methods

The adult male DSEs from the 2010 CCM program were adjusted for correlation bias by comparing the CCM sex ratios (males to females) to Demographic Analysis (DA) sex ratios. The DA program uses demographic data and administrative statistics such as birth, death, migration, and other data sources that are independent of the census and the CCM survey to construct population estimates. The DA estimates are provided at the national level by age, sex, and Black or Non-Black race groups. For more information on the construction of the 2010 DA estimates, see Devine et al. (2012).

We used the DA sex ratios to adjust for correlation bias in the adult male DSEs by implementing the Two-Group Model. This model is discussed in Bell (1999). The Two-Group Model was also used to adjust the 2000 A.C.E. Revision II adult male DSEs for correlation bias. To implement the Two-Group Model, we made the following assumptions:

- There was no correlation bias in the adult female DSEs.
- Relative correlation bias in the adult male DSEs was constant within the age-race groups formed for the correlation bias adjustment.
- Errors in the DA population estimates for a given age-race group were not vastly different for males and females so that the DA sex ratio for that age-race group was accurate.
- The census counts of the group quarters (GQ) and Remote Alaska populations (which are out of scope of the CCM survey) were accurate.

The 2010 DA population estimates consist of five separate series of estimates, reflecting uncertainty and differing assumptions in the DA estimation methodology. For the CCM correlation bias adjustment, we used the DA middle-series estimates.¹ For the purpose of the correlation bias adjustment and the results presented in this report, we defined Black in the DA and CCM estimates as Black alone-or-in-combination with other races.

The DA estimates and CCM DSEs prior to the correlation bias adjustment (PREDSEs) were aggregated into 12 age-sex-race groups defined by the cross-classification of 18 to 29, 30 to 49, and 50+ age groups; male and female; and Black and Non-Black. The DA estimates required an adjustment to account for universe differences between the DA and CCM programs. The DA universe is the national population, but the CCM universe is limited to the household population outside of Remote Alaska. For consistency, we subtracted the census counts of the GQ and Remote Alaska populations from the DA totals within each age-sex-race group. We call the resulting estimates the modified DA estimates.

A correlation bias adjustment factor was calculated for adult males in each age-race group. The male and female modified DA and PREDSE tallies for each age-race group were used to form a modified DA and PREDSE sex ratio (males to females) for that age-race group. The correlation bias adjustment factor c_k for the males in age-race group k was then calculated by

$$c_k = \frac{r_{DA,k}}{r_{PREDSE,k}}$$

where $r_{DA,k}$ and $r_{PREDSE,k}$ are the modified DA and PREDSE sex ratios, respectively, for age-race group k . The PREDSE for males in age-race group k was multiplied by the correlation bias adjustment factor to obtain the final DSE. As a result of this adjustment to the adult male DSEs, the final DSE sex ratio equals the modified DA sex ratio within each adult age-race group.

If the calculated adjustment factor was less than one, we set the adjustment factor to be equal to one. In age-race groups where this occurred, there was no adjustment to the male DSEs. The final DSE sex ratio equals the PREDSE sex ratio for these age-race groups.

There was no correlation bias adjustment for children aged 0 to 17. We do not have evidence from sex ratios to assume correlation bias only for male children. Also, this sex ratio adjustment cannot be used to adjust the DSEs for both male and female children.

3. Limitations

The adjustment for correlation bias in the adult male DSEs is subject to limitations due to the assumptions of the Two-Group Model and various aspects of the data used to perform the adjustment. This approach does not allow us to adjust for correlation bias in the adult female DSEs. The assumption of zero correlation bias in the adult female DSEs may not be correct. If

¹ For the CCM program, we use DA estimates provided in 2012. These estimates reflect adjustments made to the DA estimates that were released on December 6, 2010.

this assumption is incorrect, the correlation bias in the adult female DSEs might affect the adjustment made to the adult male DSEs.

The adjustment for correlation bias is subject to the quality of the DA estimates. Historically, sex ratios have been viewed as a strength of the DA program (Robinson et al. 1993). While the DA population estimates are subject to their own errors and limitations, it is believed that these errors generally do not differ by sex. It is for this reason that we use the DA sex ratios rather than the DA population estimates in the adjustment for correlation bias (Bell 1993). However if errors in the DA estimates disproportionately affect males or females, then our procedure may not correctly adjust for correlation bias in the adult male DSEs.

The correlation bias adjustment is also limited by the lack of detail in the DA estimates and the CCM DSEs. The DA estimates are available only at the national level, restricting the correlation bias adjustment to be calculated at the national level as well. Furthermore, the DA estimates are available in only Black and Non-Black race groups. This methodology does not allow us to calculate a separate correlation bias adjustment for other race/origin groups. By aggregating the DSEs into the high-level Black and Non-Black race groups, we may violate the assumption of constant relative correlation bias within these groups. For example, if the relative correlation bias is different for Non-Hispanic Whites and Non-Black Hispanics, then this assumption would not hold for the Non-Black race group. Similarly, the correlation bias adjustment is calculated within the broad age groups used to produce the CCM DSEs. This imposes artificial jumps in the magnitude of the correlation bias adjustment for the ages on the borders of these groups (Olson 2008). The assumption of constant relative correlation bias may not hold for all ages within an age group, especially when comparing the youngest and oldest ages in the group.

Another issue is the reconciliation of race assignments in DA with the reporting of race in the census and CCM survey. For example, in the birth registration system, the race of the mother and father is reported rather than the race of the child. The census and CCM survey allow people to self-report their race and to report multiple races. Due to these differences in race assignments, the Black and Non-Black race groups may not be entirely consistent between the DA and CCM estimates. The extent to which these inconsistencies exist will affect the accuracy of the adjustment for correlation bias.

The accuracy of the correlation bias adjustment is also subject to the census coverage of the GQ and Remote Alaska populations. Coverage errors in these census counts can result in modified DA sex ratios that do not accurately describe the true household population outside of Remote Alaska. The correlation bias adjusted adult male DSEs would then reflect this inaccurate modified DA sex ratio.

Differences between the 2000 A.C.E. Revision II and the 2010 CCM estimation methodologies limit the ability to make comparisons of the impact of the correlation bias adjustment between these two programs. The A.C.E. Revision II program used post-stratification to calculate the DSEs. This limited the number of factors that can be included in the calculation of the DSEs because each factor added to the post-stratification can crudely be thought of as cutting the post-stratum sample size in half (Mule 2008). The use of logistic regression modeling in the CCM program allows a greater number of variables to be used and eliminates many high-order

interactions that are implicit in a post-stratification. This should help to reduce heterogeneity in the CCM DSEs. Therefore, differences in the relative impact of the correlation bias adjustment between the CCM and A.C.E Revision II DSEs could be partially attributable to the use of logistic regression modeling versus post-stratification.

When making comparisons between years, it is important to note that the definition of Black that we use for the CCM correlation bias adjustment differs from the definition used for A.C.E. Revision II. The A.C.E. Revision II correlation bias adjustment used the race/origin domains and adjusted the 2000 DA estimates for Black Hispanics (Shores 2002). For race/origin domains, each person is classified into one and only one of seven race/origin domains as described in Mulligan and Davis (2012). For the CCM correlation bias adjustment, we define Black as Black alone-or-in-combination with other races. This is a broader definition of Black than what was used for A.C.E. Revision II. Therefore, the adjustment factors for Blacks are applied to a greater portion of the population than if the race/origin domains were used. Note that this change in definition has negligible impact on the sex ratios and the calculated correlation bias adjustment factors.

Finally, there are no measures of error provided for the DA population estimates, and standard errors are not available for the 2000 A.C.E. Revision II estimates included in this report. The standard errors provided for the 2010 CCM estimates reflect mainly sampling error and do not in general account for nonsampling errors. Nonsampling errors include matching error, modeling error, synthetic error, and classification error. Unlike sampling error, nonsampling error is difficult to quantify. Therefore, statements of comparison between the CCM estimates and the A.C.E. Revision II or 2010 DA estimates only reflect the sampling error of the CCM estimates.

4. Discussion of Results

This section presents the results of the adjustment for correlation bias that was made to the 2010 CCM adult male DSEs. Statements of comparison are statistically significant at the 90% confidence level using a two-sided test. In this section, the term DA refers to the modified DA estimates; that is, the DA estimates modified for consistency with the CCM universe.²

4.1. Sex Ratios Prior to Correlation Bias Adjustment

Evidence of correlation bias is seen when comparing the CCM sex ratios prior to the correlation bias adjustment to the DA sex ratios. These sex ratios are given in Table 1 along with those from the A.C.E. Revision II and 2000 DA programs.

The 2010 DA sex ratios for adult Blacks greatly exceeded the CCM sex ratios in all three age groups. This relationship strongly suggests correlation bias in the DSEs for adult Black males. A similar relationship was seen between the 2000 DA and A.C.E. Revision II sex ratios for adult Blacks.

² For the 2000 A.C.E. Revision II correlation bias adjustment, the census counts of the Remote Alaska population were not subtracted from the DA estimates. Because the Remote Alaska population is so small, this modification has negligible effects on the on the modified DA sex ratios (Bell, 2001).

The DA sex ratios for Non-Blacks aged 30 to 49 and 50+ slightly exceeded the CCM sex ratios, suggesting small amounts of correlation bias at the national level for males in these groups. A similar relationship was seen between the 2000 DA and A.C.E. Revision II sex ratios for Non-Blacks in these age groups.

For Non-Blacks aged 18 to 29, the DA sex ratio was slightly less than the CCM sex ratio (expressed to more decimal places, the DA and CCM sex ratios for this group were 1.02998 and 1.03286, respectively). The same anomaly was seen in the comparison of the 2000 DA and A.C.E. Revision II sex ratios for this group (Shores, 2002). For the CCM population estimates, we did not make an adjustment for correlation bias for Non-Black males aged 18 to 29. This procedure is consistent with what was done in 2000.

Table 1. Sex Ratios Prior to Correlation Bias Adjustment

Age Group	2010				2000			
	Black		Non-Black		Black		Non-Black	
	CCM	DA	CCM	DA	A.C.E. Revision II	DA	A.C.E. Revision II	DA
18-29	0.89 (0.012)	0.94	1.03 (0.006)	1.03	0.83	0.90	1.05	1.04
30-49	0.81 (0.006)	0.91	0.99 (0.002)	1.02	0.81	0.89	0.99	1.01
50+	0.76 (0.004)	0.80	0.88 (0.002)	0.89	0.72	0.76	0.85	0.86

2000 data source: Shores (2002).

Standard errors for the CCM sex ratios are in parentheses below the estimate. Standard errors are not available for the A.C.E. Revision II estimates.

The CCM and A.C.E. Revision II sex ratios are those prior to the correlation bias adjustment.

The DA sex ratios were calculated using the modified DA estimates, as described in the text.

4.2. Estimates of Relative Correlation Bias

Table 2 gives the Two-Group Model estimates of the relative correlation bias in the 2010 CCM and 2000 A.C.E. Revision II adult male DSEs. Recall that we assumed no correlation bias for adult females and children. The estimate of the relative correlation bias in the DSEs for adult males, expressed as a percent, was calculated as

$$100 \times \left(\frac{r_{\text{PRELSE},k}}{r_{\text{DA},k}} - 1 \right)$$

where $r_{\text{PRELSE},k}$ and $r_{\text{DA},k}$ are the PRELSE and modified DA sex ratios for age-race group k . The estimates of relative correlation bias in Table 2 may not follow from the sex ratios in Table 1 due to rounding.

The Two-Group Model estimate of relative correlation bias for Black males aged 18 to 29 for CCM implied an underestimation by the DSEs of 4.9%. In 2000, the estimate of relative correlation bias for this group implied an underestimation by the DSEs of 7.5%. The estimates

of relative correlation bias for Black males aged 30 to 49 (-10.0%) and 50+ (-5.2%) were similar to the analogous estimates from 2000 (-9.2% and -5.2%, respectively).

The estimates of the relative correlation bias for Non-Black males aged 30 to 49 (-2.7%) and 50+ (-1.6%) were small in magnitude relative to the estimates for Black males. The estimates for Non-Black males in these age groups were greater in magnitude than the analogous estimates from 2000 (-1.5% and -1.0%, respectively).

For Non-Black males aged 18 to 29, the estimate of the relative correlation bias was 0.3%. This positive estimate is difficult to explain as correlation bias. The estimate of relative correlation bias for this group in 2000 was also positive (0.4%). As stated before, we proceeded by making no adjustment for correlation bias for Non-Black males aged 18 to 29.

Table 2. Relative Correlation Bias Estimates (expressed as a percent)

Age Group	2010 CCM		2000 A.C.E. Revision II	
	Black Males	Non-Black Males	Black Males	Non-Black Males
18-29	-4.9 (1.2)	0.3 (0.5)	-7.5	0.4
30-49	-10.0 (0.7)	-2.7 (0.2)	-9.2	-1.5
50+	-5.2 (0.6)	-1.6 (0.2)	-5.2	-1.0

2000 data source: Shores (2002).

Results may not follow from the sex ratios in Table 1 due to rounding.

Standard errors for the CCM estimates are in parentheses below the estimate. Standard errors are not available for the A.C.E. Revision II estimates.

4.3. Effect of the Correlation Bias Adjustment on the CCM Population Estimates

This section presents the effect of the correlation bias adjustment on the 2010 CCM DSEs. Section 4.3.1 presents the results for the national-level population by race groups. Section 4.3.2 presents the results for adult males by age-race groups. Recall that the correlation bias adjustment only impacted the adult male DSEs; the children and adult female DSEs were unchanged by the adjustment.

Tables 3 and 4 in this section present the national-level 2010 CCM DSEs before and after the correlation bias adjustment. The tables also present the absolute and percent differences between the DSE totals before and after the correlation bias adjustment. The percent difference was calculated as

$$100 \times \left(\frac{ADJDSE_k - PREDSE_k}{PREDSE_k} \right)$$

where $PREDSE_k$ is the DSE total for group k before the correlation bias adjustment and $ADJDSE_k$ is the DSE total for group k after the correlation bias adjustment.

4.3.1. National Population by Race Groups

Table 3 gives the CCM DSEs for the national-level population by race groups. A total of 2.6 million adult males were added to the total DSE, resulting in a 0.9% increase in the CCM national-level population estimate. The difference was mostly in the Non-Black population. About 1.63 million adult males were added to the Non-Black population estimate while less than one million adult males were added to the Black population estimate. The relative impact of the correlation bias adjustment was greater for the Black population (2.3% increase) than the Non-Black population (0.6% increase).

Table 3. Effect of Correlation Bias Adjustment for the CCM Total Population Estimates

Race Group	Before Adjustment (Thousands)	After Adjustment (Thousands)	Difference (Thousands)	Percent Difference
Total	298,111 (420)	300,667 (429)	2,556 (119)	0.9 (<0.1)
Black	40,073 (193)	40,999 (209)	927 (64)	2.3 (0.2)
Non-Black	258,038 (374)	259,668 (372)	1,630 (102)	0.6 (<0.1)

Standard errors are in parentheses below the estimate.
Estimates may not add due to rounding.

4.3.2. Adult Male Population by Age-Race Groups

Table 4 shows the impact of the correlation bias adjustment on the CCM and A.C.E. Revision II DSEs for adult males by age-race groups. The percent difference between the DSEs for the total adult male population before and after the correlation bias adjustment was larger for the 2010 CCM estimates (2.4%) than for the 2000 A.C.E. Revision II estimates (1.8%). This was due to a greater impact of the correlation bias adjustment on the adult Non-Black male DSE in 2010 (1.7%) as compared to 2000 (1.0%). For the adult Black male population, the percent increase in the DSE for 2010 (7.6%) was not statistically different from 2000 (8.3%).

The correlation bias adjustment resulted in a 5.1% increase in the CCM DSE for Black males aged 18 to 29. The increase in the DSE for this group in 2000 was 8.1%. For Black males aged 30 to 49 and 50+, the increases in the CCM DSEs (11.1% and 5.4%, respectively) were similar to the A.C.E. Revision II results (10.2% and 5.5%, respectively).

For Non-Black males, the correlation bias adjustment resulted in a 2.8% increase in the DSE for the 30 to 49 age group and a 1.6% increase in the DSE for the 50+ age group. In 2000, the increases in the DSEs for these groups were 1.6% and 1.1%, respectively.

For Non-Black males aged 18 to 29, the correlation bias adjustment factor was forced to have a value of one. Therefore, there was no change in the DSE for this group. Similarly, the correlation bias adjustment was not implemented for this group for the A.C.E. Revision II estimates.

Table 4. Effect of Correlation Bias Adjustment for the 2010 and 2000 Adult Male Population Estimates

Age-Race Group	2010 CCM				2000 A.C.E. Revision II	
	Before Adjustment (Thousands)	After Adjustment (Thousands)	Difference (Thousands)	Percent Difference	Difference (Thousands)	Percent Difference
Total Males 18+	108,210 (195)	110,767 (179)	2,556 (119)	2.4 (0.1)	1,702	1.8
18-29	24,103 (115)	24,274 (111)	171 (44)	0.7 (0.2)	208	1.0
30-49	40,235 (101)	41,748 (86)	1,513 (98)	3.8 (0.2)	1,024	2.5
50+	43,872 (66)	44,744 (63)	872 (74)	2.0 (0.2)	470	1.4
Black Males 18+	12,262 (72)	13,188 (69)	927 (64)	7.6 (0.5)	805	8.3
18-29	3,348 (43)	3,519 (38)	171 (44)	5.1 (1.4)	208	8.1
30-49	4,764 (36)	5,293 (30)	529 (39)	11.1 (0.9)	447	10.2
50+	4,150 (27)	4,376 (23)	226 (25)	5.4 (0.6)	150	5.5
Non-Black Males 18+	95,949 (179)	97,578 (164)	1,630 (102)	1.7 (0.1)	897	1.0
18-29	20,755 (105)	20,755 (105)	0 (0)	0.0 (0.0)	0	0.0
30-49	35,472 (92)	36,455 (80)	983 (88)	2.8 (0.3)	577	1.6
50+	39,722 (64)	40,368 (60)	646 (70)	1.6 (0.2)	321	1.1

2000 data source: Shores (2002).

Standard errors for the CCM estimates are in parentheses below the estimate. Standard errors are not available for the A.C.E. Revision II estimates.

Estimates may not add due to rounding.

For both 2010 and 2000, the correlation bias adjustment factor for Non-Black males aged 18 to 29 was forced to have a value of one.

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