Analysis of Variance Estimates from American Community Survey Multiyear Estimates

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Abstract

The American Community Survey (ACS) produced a series of three- and 5-year period estimates for 34 ACS counties using data from 1999-2005. This series of period estimates provided a large amount of information regarding the variance distributions for multiyear ACS estimates for the first time. The focus of this paper is on answering three questions: how much a new weighting methodology reduced variances at the place and census tract levels, what are the variance characteristics of estimates at the block group level (the smallest geographic level published in the ACS five-year products), and the relationship between the ACS tract level variances and corresponding variances from the Census 2000 Long Form.

KEY WORDS: American Community Survey, variance estimation

1. Introduction[1]

The American Community Survey (ACS) is a continuous monthly survey that collects the data historically collected by the decennial census "long form" sample. Full implementation of the ACS began in January 2005, with the first 2005 estimates published in August 2006. "Full implementation" entailed a full sample of approximately three million housing unit addresses, with sample in all counties and county equivalents in the 50 states, the District of Columbia, and Puerto Rico.

A single year's worth of sample in the ACS is not adequate to publish estimates for all geographic areas for which long form estimates were published in Census 2000. Instead, single-year estimates are published only for geographic areas with a population of at least 65,000. For smaller areas, several years' worth of ACS sample is pooled together to create "period" estimates. Areas with a population of at least 20,000 will be published using three years' worth of data. All areas, including Census tracts and block groups, will be published using five years' worth of pooled ACS sample. The first ACS multiyear estimates will be published in 2008 for the three year period 2005-2007, and five-year period estimates will be published in 2010 for 2005-2009.

The ACS Multiyear Estimates Study has produced the first sets of three- and five-year period estimates that use the weighting methodology we currently plan to implement for the first production multiyear estimates in 2008 and 2010. The estimates include an adjustment introduced specifically to address higher than expected variances at the tract level found in the ACS 1999-2001 and Census 2000 Comparison Project (Van Auken et al 2004; Starsinic 2005). Several aspects of the variances of these multiyear estimates need to be studied, including evaluating the current variance-reduction methods and examining the variance characteristics for previously unpublished geographic levels. Specifically, in this paper, we will provide preliminary results to the following questions:

1. What effect does the "g-weight" methodology have on variances of sub-county areas, such as places, tracts, and block groups?

2. What are "typical" variance characteristics for small sub-county areas, such as tracts, block groups, and zip code tabulation areas (ZCTAs)?

3. How do variances of tract-level estimates with g-weights compare to comparable Census 2000 Long Form variances?

2. ACS Multiyear Estimates Study – Sampling & Estimation

The ACS Multiyear Estimates Study was undertaken in late 2006 to produce multiple sets of multiyear ACS data using the available data from 1999-2005. The multiple purposes of this project included testing production methods that are planned for the 2008 release and helping data users begin to understand the characteristics of multiyear estimates. Data for 34 counties that had been in sample every year since 1999 with a sufficient sample size to support multiyear estimates were used for the study.(Tersine & Asiala 2007; U.S. Census Bureau 2007)

2.1 Sampling

From 1999 through 2005, the ACS systematically selected a sample of housing unit addresses in each

[1] This report is released to inform interested parties of ongoing research and to encourage discussion of work in progress. The views expressed on statistical and methodological issues are those of the authors and not necessarily those of the U.S. Census Bureau.

county from the Census Bureau's Master Address File (MAF). Note that these were samples of housing units only and did not include group quarters (such as college dorms, prisons, or military barracks).

For 1999 through 2001, the base sampling rate was 5 percent per year in 29 of the counties. Due to budget constraints, the base sampling rate was 3 percent per year in the remaining five counties (Bronx NY, Broward FL, Franklin OH, Lake IL, and San Francisco CA). After 2001, the base rate declined to 2.5 percent in 2002 and 2003, to 2.47 percent in 2004, and to 2.3 percent in 2005. Sampling rates within a county varied from the base rate by block, based on the size of the tract and the governmental units that each block was contained within.

One substantive change to the sampling methodology which caused significant changes to the sample size in some counties occurred in 2003 with the inclusion of minor civil divisions (MCDs) in the list of governmental units used to determine the block sampling rates. Also, in 2005, the measure of size changed from an estimate of the total number of housing units to an estimate of the number of occupied housing units, based on the block's occupancy rate from Census 2000.

For addresses which do not respond to the ACS's mail questionnaire or the computer assisted-telephone interview (CATI), a subsample is selected for nonresponse follow-up using a computer-assisted personal interview (CAPI). The CAPI subsample was selected at a flat 1-in-3 rate for nonrespondents from 1999 through 2004. In 2005, a variable rate ranging from 1-in-3 to 1-in-2 was implemented based on the predicted rate of mail returns and CATI interviews for each tract. Unmailable forms were followed up at a 2-in-3 rate in all years.

See U.S. Census Bureau (2007) and U.S. Census Bureau (2006) for more information about ACS sampling from 1999-2005.

2.2 Estimation

The base weight for each housing unit was the inverse of the sampling rate. Weights for units subsampled for CAPI were also multiplied by the inverse of the CAPI sampling rate. A new step was introduced specifically for the multiyear estimates as a means to reduce variances for certain demographic characteristics at small areas. It was inserted into the weighting process after several ratio adjustments, including several for nonresponse, but before the first set of controls were applied. This step is described further in the next section.

County level housing unit and population estimates from the Census Bureau's official intercensal estimates program are used to control ACS estimates as both a coverage improvement and variance reduction tool. (For the multiyear estimates, the specific control used was the simple average of the controls for each of the individual years of the period.) In the first step, the estimate of total housing units was controlled to the intercensal estimates value. To this point, all persons in a housing unit have the housing unit's weight. Next, the weights for persons were adjusted to county-level totals by age, sex, race, and Hispanic origin (with collapsing where necessary). Occupied housing units were reweighted to match the household's "principal person" (the female spouse of the male householder if such a person exists, or the householder otherwise), and then the housing units were readjusted to match the county housing unit total.

All multiyear estimates used the geographic definitions of the final year of the period. All monetary values were inflation-adjusted to the December of the final year of the period.

See U.S. Census Bureau (2007) and U.S. Census Bureau (2006) for more information about ACS estimation from 1999-2005.

2.3 Variance Estimation and G-Weights

ACS variances are calculated using the successive differences replication method, which is currently in use by the Current Population Survey and was also used by the Census 2000 long form. (Fay and Train 1995) All published ACS estimates include some reliability measure, usually a 90 percent margin of error or a 90 percent confidence interval. Because of this, ACS variances are much more "in your face" to the user than the variances for the Census 2000 long form data, which the user must calculate for each estimate using design factors.

Data from these 34 counties had also been aggregated together for the ACS 1999-2001 and Census 2000 Comparison Project. The sample sizes in these 34 counties had been sufficiently large in that three-year period to allow tract-level estimates to be produced, which were compared against Census 2000 long form data in the corresponding tracts.

Research on the variances of the tract-level estimates (Van Auken et al 2004; Starsinic 2005) indicated that they were in general larger than expected when compared with corresponding Census 2000 long form variances. It was determined this was due in large part to the lack of ACS tract-level controls. Long form estimates were raked at the weighting area level (a collection of block groups, and

frequently equal to a tract) to a large matrix of Census 2000 100 percent (short form) data. The characteristics used included type of household, householder/ nonhouseholder, occupied/vacant, and tenure and race of the householder, in addition to age, sex, race, and Hispanic origin. Direct variances – upon which the long form's design factors were based – were zero or small for estimates of the matrix's many marginal totals. The ACS, on the other hand, is using controls at the county-level only, and for a much smaller set of characteristics. More detailed county-level controls are not available, nor are intercensal estimates that could be used as sub-county controls.

In order to reduce variances at sub-county levels, Bob Fay developed a model-assisted (generalized regression estimator) weighting step. This step incorporates linking administrative records data for all units in a county to the ACS sampling frame. The resulting "g-weights" are then input into the next step, the housing unit controls. For three-year estimates, the method targeted places and MCDs (in counties where MCDs were published), and for five-year estimates, tracts were targeted. For more information about the g-weighting methodology, please see Fay (2005), Fay (2006), and Fay (2007).

3. Analysis Results

The ACS Multiyear Estimates Study produced 14 sets of estimates for publication. These included three five-year period estimates (1999-2003, 2000-2004, and 2001-2005), five three-year period estimates (1999-2001 through 2003-2005), and six one-year period estimates (2000 through 2005; 1999 one-year estimates were not produced). Additionally, 2001-2005 and 2003-2005 period estimates were produced without g-weights for internal research.

The primary data product for each geographic area and period was the data profile, a collection of 454 estimates, broken up into four sub-tables by broad categories of estimates – demographic, social, economic, and housing. The profile used for this study was closely based on the data profiles published for the 2005 ACS data, and is similar to Census 2000's Quick Tables product. Duplicate estimates in the profile layout (19 of the 454), such as the multiple occurrences of total population, were removed from the analysis.

For this analysis, the 435 unique estimates were further grouped into 43 topics, whose constituent lines clearly have a common theme, such as age and sex, education, poverty rates, and housing value. Most of the results presented here are based on medians of the coefficient of variation (CV) – the standard error of an estimate divided by the estimate itself – or medians of ratios of CVs, as opposed to the analysis in Starsinic (2005), which was based on means and ratios of standard errors. Upon reflection, the medians and CVs were more appropriate for this analysis.

3.1 Research Question 1 – How Do G-Weights Affect Variances?

With both the "with g-weights" and "without g-weights" estimates and standard errors for 2001-2005 and 2003-2005, direct comparisons can be made, comparing the "with" and "without" CVs for each estimate and geographic area in a given geographic summary level. We focused on the ratio of the CV "with g-weights" to the CV "without g-weights". If the g-weights decreased the variance, then this ratio should be less than one, and the closer to zero, the larger the improvement.

Looking across all estimates in the profile, and across all tract level estimates within a county for the five-year period, the answer seems to be "not much".

Median CV ratios across all estimates and all tracts within a county ranged from 0.944 for Tulare County, California to 0.983 for Lake County, Montana. All the counties showed very modest improvement at this very high level. We were sure that some estimates saw major improvement, so we next looked at the topics across several different types of geographic areas.

Table 1 shows the median CV ratios, across all geographic areas, for a selection of topics and different geographic types (sorted by the values in the Tract column). For example, the median ratio of the CV "with" to the CV "without" for the estimate of total housing units, across all tracts in all 34 counties, was 0.298. Because tract is the targeted summary level for the five year estimates, we expected tracts to have the most improvement. By far the most improvement we see is in the three total estimates. Only a few other characteristics have a better than 0.9 median CV ratio. Ancestry, at 1.003, has the highest ratio for tracts. The "C"s for total population and total housing units in the County column indicates all estimates were controlled for both "with" and "without" g-weights, so the CV ratio was not defined.

Improvements for block groups, ZCTAs (except for the three totals), places and MCDs are very small, but there are still improvements. The county improvements are also small, but that is to be expected, as the improvements were targeted to areas much smaller than them.

Table 1. Five-Year Median CV Ratios for Selected Topics and Geographic Types
SOURCE: ACS Multiyear Estimates Study (U.S. Census Bureau 2007)

Topic	Lines in Topic	Tract	Block Group	ZCTA	County	Place	MCD
Total Housing Units	1	0.298	0.881	0.619	C	0.839	0.731
Total Households	1	0.544	0.915	0.766	0.938	0.883	0.851
Total Population	1	0.625	0.922	0.772	C	0.885	0.840
Age & Sex	34	0.815	0.965	0.900	0.987	0.942	0.923
Place of Birth	6	0.833	0.967	0.915	0.977	0.947	0.935
Tenure	2	0.837	0.964	0.907	0.958	0.948	0.933
Relationship	6	0.893	0.974	0.935	0.964	0.959	0.952
Occupied/Vacant	4	0.926	0.963	0.953	0.975	0.966	0.958
Hispanic	6	0.935	0.979	0.955	0.981	0.966	0.961
Marital Status	10	0.952	0.991	0.965	0.980	0.980	0.973
Education	15	0.956	0.992	0.965	0.978	0.980	0.977
Language at Home	11	0.960	0.988	0.964	0.979	0.977	0.979
Units in Structure	9	0.964	0.987	0.967	0.976	0.979	0.974
Race	42	0.973	0.989	0.980	0.995	0.986	0.981
Income	43	0.974	0.994	0.979	0.980	0.992	0.986
Poverty	19	0.987	0.993	0.983	0.965	0.993	0.991
Ancestry	27	1.003	1.009	1.002	0.993	1.006	1.001
# of Areas (2001-2005)		2270	6889	531	34	500	373

Table 2. Three-Year Median CV Ratios for Selected Topics and Geographic Types
SOURCE: ACS Multiyear Estimates Study (U.S. Census Bureau 2007)

Topic	Place	MCD	County
Total HUs	0.381	0.478	C
Total Pop	0.640	0.695	C
Total HHs	0.644	0.699	0.976
Age & Sex	0.832	0.878	0.997
Place of Birth	0.850	0.914	0.994
Tenure	0.860	0.909	0.980
Relationship	0.927	0.945	0.983
Hispanic	0.941	0.952	0.994
Language at Home	0.950	0.961	0.992
Marital Status	0.961	0.972	0.989
Education	0.967	0.974	0.993
Occupied/Vacant	0.967	0.977	0.985
Units in Structure	0.979	0.985	0.996
Race	0.980	0.986	0.999
Income	0.983	0.986	0.993
Poverty	0.994	0.994	0.992
Ancestry	0.997	0.998	0.999
# of Areas (2003-2005)	71	74	30

Table 3. Percent CVs Improved, "With" versus "Without", 2001-2005 Period
SOURCE: ACS Multiyear Estimates Study (U.S. Census Bureau 2007)

Topic	Tract	County	Block Group	Place
Total HUs	99.0%	NA	83.1%	77.5%
Total HHs	98.5%	88.2%	76.6%	73.7%
Total Pop	98.2%	NA	73.8%	77.4%
Tenure	87.7%	82.4%	63.9%	67.4%
Age & Sex	87.5%	56.5%	64.6%	70.4%
Place of Birth	83.2%	67.2%	63.1%	68.7%
Occupied/ Vacant	82.3%	74.3%	71.3%	69.2%
Relationship	79.2%	73.5%	61.3%	66.2%
Hispanic	70.3%	60.2%	59.7%	63.5%
Marital Status	69.6%	65.3%	54.8%	59.5%
Education	68.2%	67.3%	54.0%	60.1%
Units in Structure	66.1%	67.5%	56.6%	62.4%
Language	65.4%	61.2%	55.9%	59.9%
Income	61.6%	65.5%	52.7%	54.1%
Race	61.3%	52.4%	55.2%	56.7%
Poverty	57.7%	74.9%	53.7%	54.1%
Ancestry	48.0%	55.2%	44.9%	46.5%

Table 2 is similar to Table 1, except here we are looking at data for the three-year profiles, where the g-weight process targeted places and MCDs. As before, the improvements to the totals for the targeted summary levels are impressive, while improvements elsewhere are generally modest.

The next table looks at the percent of estimates where the CV improves, that is the CV for the "with" estimate is less than the CV for the "without" estimate.

Table 3 shows that the CV is improving in nearly every case for some topics for tracts. Even at other levels, a strong majority of CVs are improving for most of these topics. Even for ancestry, about half of all estimates have an improved CV.

Median CV ratios and the percent improved were generally consistent when looking at individual counties versus across all counties. Similar results were seen with the three-year period data.

We believe the g-weights proved their worth with some significant improvements for certain characteristics at the tract level for the five-year estimates and at the place and MCD levels for three-year estimates.

3.2 Research Question 2 – What Are the Variance Characteristics for Small Areas?

This study was the first time that we had been able to produce ACS estimates and variances for some of the smallest geographic levels that the Census Bureau produces data for – tracts, block groups, and ZCTAs. All three of these levels will only be published with the five-year products.

Table 4 gives the median CVs over all estimates in the profiles and all tracts (or block groups, or ZCTAs) within each county for the 2001-2005 period estimates with the g-weights. There was not much difference between counties for tracts and block groups, but the median CVs for block groups was much higher than that for tracts in all the counties. The county median CV for tracts ranged from 0.181 to 0.325, and the county median CV for block groups ranged from 0.308 to 0.492. The estimates for ZCTAs were quite variable across counties, because the size of ZCTAs tends to be influenced by the population of the county. Counties with larger populations, like San Francisco and the Bronx, have ZCTAs that tend to be large, and the larger sample size leads to smaller CVs.

The median CVs for the block groups seemed very high, and we went a little further looking for some better news. Looking at topics for tracts across counties, we broke each down into four groups by the total population of the tract or block group.

Table 4. Median CVs for Tracts, Block Groups, and ZCTAs, by County
SOURCE: ACS Multiyear Estimates Study (U.S. Census Bureau 2007)

County	Tract	Block Group	ZCTA	County	Tract	Block Group	ZCTA
Pima, AZ	0.285	0.438	0.166	Lake, MT	0.316	0.492	0.416
Jefferson, AR	0.296	0.448	0.504	Douglas, NE	0.298	0.435	0.163
San Francisco, CA	0.296	0.447	0.142	Otero, NM	0.290	0.441	0.418
Tulare, CA	0.274	0.447	0.275	Bronx, NY	0.325	0.466	0.111
Broward, FL	0.266	0.390	0.138	Rockland, NY	0.266	0.413	0.222
Upson, GA	0.264	0.416	0.120	Franklin, OH	0.292	0.435	0.148
Lake, IL	0.282	0.401	0.168	Multnomah, OR	0.289	0.432	0.157
Miami, IN	0.285	0.437	0.530	Fulton, PA	0.181	0.308	0.384
Black Hawk, IA	0.274	0.387	0.207	Schuylkill, PA	0.246	0.395	0.320
De Soto, LA	0.260	0.405	0.382	Sevier, TN	0.256	0.409	0.239
Calvert, MD	0.285	0.377	0.291	Starr, TX	0.255	0.412	0.285
Hampden, MA	0.255	0.421	0.203	Zapata, TX	0.305	0.450	0.412
Madison, MS	0.294	0.423	0.205	Petersburg, VA	0.304	0.420	0.255
Iron, MO	0.241	0.347	0.415	Yakima, WA	0.246	0.430	0.331
Reynolds, MO	0.216	0.344	0.400	Ohio, WV	0.306	0.408	0.324
Washington, MO	0.239	0.404	0.314	Oneida, WI	0.261	0.376	0.451
Flathead, MT	0.266	0.450	0.388	Vilas, WI	0.256	0.385	0.166

Table 5. Median CVs for Selected Topics by Population of Geographic Area
SOURCE: ACS Multiyear Estimates Study (U.S. Census Bureau 2007)

Tract Pop Size	Age & Sex	Number of Bedrooms	Citizen-ship	Labor Force
Less than 1000	0.394	0.559	0.707	0.403
1000 to 2999	0.165	0.288	0.465	0.143
3000 to 4999	0.127	0.236	0.334	0.104
5000 or more	0.111	0.213	0.235	0.089

BG Pop Size	Age & Sex	Number of Bedrooms	Citizen-ship	Labor Force
Less than 500	0.455	0.601	0.896	0.444
500 to 999	0.314	0.451	0.705	0.270
1000 to 2999	0.243	0.377	0.490	0.206
3000 or more	0.147	0.250	0.292	0.125

Table 6. Median CVs for Selected Topics by Population of Geographic Area and Excluding Small Estimates
SOURCE: ACS Multiyear Estimates Study (U.S. Census Bureau 2007)

Topic	Tract Pop Size	All Estimates	Estimates >100 only
Ancestry	Less than 1000	0.919	0.332
Ancestry	1000 to 2999	0.627	0.305
Ancestry	3000 to 4999	0.564	0.303
Ancestry	5000 or more	0.536	0.305
Heating Fuel	Less than 1000	0.567	0.241
Heating Fuel	1000 to 2999	0.381	0.145
Heating Fuel	3000 to 4999	0.395	0.119
Heating Fuel	5000 or more	0.407	0.105
Race	Less than 1000	0.678	0.289
Race	1000 to 2999	0.630	0.171
Race	3000 to 4999	0.606	0.202
Race	5000 or more	0.560	0.268

The median CVs in the smallest size category for tracts and block groups mean that many estimates in that group simply are not useful – a CV of 0.61 or greater indicates the estimate isn't significantly different from zero at a 90 percent confidence level.

However, most tracts and block groups in the 34 counties *are not* in those two smallest groups – only 3 percent of tracts have total population less than 1000, and only 8 percent of block groups have total population less than 500. The median CVs for the other size groups are generally much more reasonable.

This reinforces a statistical truism – estimates from really small sample sizes will always have really large variances. With that in mind, it is possible we have been maligning some topics which may not be as bad as they initially seem.

Some topics, such as these three in Table 6, have a number of categories which will almost always have a small number of people. By excluding instances where the estimate is less than 100 persons (or 100 housing units, as appropriate), the median CVs drop dramatically. There is nothing that can be done to significantly improve the standard errors of the very smallest estimates that are based on a tiny number of sample cases. For categories where these small estimates are prevalent, they are giving an overly pessimistic view of the performance of the variances.

3.3 Research Question 3 – Comparisons to Long Form Variances

For the 1999-2001 ACS/Census Long Form Comparison project, Census 2000 long form data was tabulated at the tract level using only persons in households (excluding those in group quarters) to allow direct comparisons to ACS estimates. The data profiles created for that project had about 300 lines which were exact matches to the multiyear estimate study profiles, so CVs for with and without g-weight estimates can be directly compared to Census 2000 long form CVs.

Table 7. Tract Median CVs, Comparing With and Without G-Weights to Long Form
SOURCE: ACS Multiyear Estimates Study (U.S. Census Bureau 2007)

	All Estimates			Estimates > 100 Only		
Topic	Median CV With	Median CV Without	Median CV LF	Median CV With	Median CV Without	Median CV LF
Total Housing Units	1.9%	6.6%	C	1.9%	6.6%	C
Total Households	3.7%	6.9%	1.3%	3.7%	6.9%	1.2%
Total Population	5.4%	8.9%	C	5.4%	8.8%	C
Tenure	10.0%	12.4%	6.4%	9.3%	11.7%	5.9%
Age & Sex	16.8%	19.8%	11.8%	14.5%	17.5%	10.1%
Hispanic	39.6%	41.9%	30.9%	19.2%	24.2%	13.0%
Heating Fuel	39.9%	39.7%	28.2%	12.0%	13.9%	7.5%
Ancestry	57.0%	56.8%	53.3%	29.8%	30.1%	23.7%

The first three columns in Table 7 show the median CVs of all estimates in eight selected categories. The median CV for the with g-weight estimates are generally less than the without g-weight median CV, but both are higher than the long form median CV. (Total housing units and total population are not necessarily controlled at the tract level for the 2000 long form, but they were considered as such for the ACS/Long Form comparison project tabulations.) Note that for the last three categories, the long form median CV, while less than the ACS median CVs, are quite high. While ACS CVs may be too high to draw meaningful inferences about tract-level differences of estimates in the Ancestry category, the same is likely true for long form estimates as well. ACS variances (in the form of margins of error) are published along side each estimate. Long form variances must be constructed using generalized variance methods, a sometimes complex and daunting task to users, and so are much less visible and less likely to draw scrutiny.

The last three columns again show the median CVs, but exclude estimates less than 100. There is very little change in the three totals, as few tracts have a population, housing unit, or household total less than 100. However, the three categories with the worst median CVs all show substantial improvement when dropping out the smallest estimates. These smallest estimates have very poor reliability in not just the ACS as we saw in the previous section, but in the long form as well.

4. Conclusions and Future Research

The g-weight method has shown its worth. At the targeted geographic levels (tract for five-year and places/MCDs for three-year), there were large improvements in CVs for key estimates. At other geographic levels and for other categories, the improvements were smaller. But, even with the worst cases, CVs remained essentially unchanged from the without g-weight estimates, so the methodology's "do no harm" goal was met.

We were also reminded that for the very smallest estimates, there is little that weighting can do to improve very large CVs. Small sample sizes will always lead to large variances and relatively low reliability of estimates. Even the Census 2000 long form estimates suffer the same problem with high CVs for small estimates, although it is not as visible to users. Excluding these smallest estimates from the analysis shows large improvements in median CVs for many topics.

We plan to continue examining the g-weight procedures to try to further improve its variance reduction. We also plan to look further at comparisons between the with g-weight estimates and the long form at geographic levels other than tract, such as place and block group.

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