American Community Survey Sample Size Research

Steven P. Hefter
U.S. Census Bureau
Washington, DC 20233

Abstract
As a replacement for the once-a-decade decennial long form sample estimates, the reliability of the American Community Survey (ACS) estimates is an important consideration. This paper presents research completed to assess the reliability of the ACS estimates. The reliability of theoretical tract level estimates from the Census 2000 Long Form sample is used to determine the annual sample size and sampling rate necessary for the ACS 2011-2015 five-year estimates to achieve various levels of reliability. In this approach, the levels of reliability for the ACS are described as a function of the Census 2000 Long Form reliability, as measured by the coefficient of variation (CV) for a fixed 10 percent population estimate of the poverty rate. Note that the poverty rate estimate has been identified as a key measure for the ACS and has been shown, in general, to have relatively large standard errors.

Key Words: American Community Survey, reliability, sampling

1. ACS Statistical Design and History

The following sections provide a brief discussion of the overarching goal of the ACS, a condensed history of the ACS sample design, and the current sampling methodology.

1.1 Design goal of the ACS

The basic objective of the ACS is to produce five-year estimates for all levels of geography down to tabulation block group, replacing data traditionally obtained by the decennial census long form data collection program. As with most surveys, the ACS is designed to publish estimates of comparable reliability for areas with similar population sizes.

1.2 History of the ACS sample design

When the initial ACS sample design was developed, the target sample size was calculated using an annual sampling rate of three percent, yielding a 15 percent sample over each five-year span. The intent of the design was for the CVs of the ACS estimates to be approximately 33 percent larger than the CVs of the estimates achieved by the Census 2000 Long Form. Subsequent to the delay of full implementation in 2003, the sampling rate was lowered to 2.5 percent a year or 12.5 percent over five years. At that time the Census Bureau began describing the ACS sample in terms of a fixed annual target sample of approximately three million housing unit addresses.

1.3 Current State of the ACS

1.3.1 Sample Size

The combination of growth in the housing unit frame, the fixed sample size, and declining mail and telephone response rates have all contributed to reducing the effective sampling rate and increasing the CVs of the ACS estimates. As a result of the fixed sample size and the increasing number of housing unit addresses in the frame, the initial

This report is released to inform interested parties of (ongoing) research and to encourage discussion (of work in progress). Any views expressed on (statistical, methodological, technical, or operational) issues are those of the author(s) and not necessarily those of the U.S. Census Bureau.

overall percent in sample has decreased each year from 2.26 percent in 2005 to a rate of 2.12 percent in 2009. Using the 2009 universe size as the denominator yields approximately 11 percent in sample over the 2005-2009 time period. In comparison, the long form sample was based upon an overall fixed target sampling rate of approximately 17 percent, leading to increased sample sizes with each subsequent census. Note that an increase of the five-year ACS sampling rate to 17 percent will not achieve the level of reliability seen in the 2000 long form estimates due to subsampling for nonresponse in the ACS. The 2000 long form had 100 percent follow-up of non-respondents as part of census operations.

1.3.2 Subsampling Nonrespondents for Personal Visit

The ACS subsamples for Computer Assisted Personal Interview (CAPI) follow-up to increase sampling efficiency, which by definition includes cost considerations. This subsampling causes an increase in the ACS CVs, relative to the full sample, due to the reduced size of the interviewed sample. Reducing the amount of, or eliminating CAPI subsampling altogether would improve the CVs of the estimates without a change to the current sampling rate, though the increase in cost would introduce an overall sampling inefficiency. However, targeted changes in the CAPI subsampling for specific areas of interest may improve the CVs or margins of error of the estimates for these areas without substantial cost increases.

1.3.3 Reliability Measures

During the first five-year period of full data collection of the ACS (2005-2009), the average annual percent in sample was 2.2 percent with sample sizes of approximately 2.9 million annually. This results in a CV for a 10 percent estimate of the poverty rate for a tract of average size that is approximately 1.75 times as large as the Census 2000 Long Form CV for the same estimate. This level of reliability translates to a margin of error (MOE) of 4.37 percent at the 90 percent confidence level.

2. Research Goals and Objectives

The goal of this research was to assess the reliability of the ACS estimates. The reliability of theoretical tract level estimates from the Census 2000 Long Form sample is used to determine the annual sample size and sampling rate necessary for the ACS 2011-2015 five-year estimates to achieve various levels of reliability. In this approach, the levels of reliability for the ACS are described as a function of the Census 2000 Long Form reliability, as measured by the CV for a fixed 10 percent population estimate of the poverty rate. Note that the poverty rate estimate has been identified as a key measure for the ACS and has been shown, in general, to have relatively large standard errors. Based on this work we provide a proposal for the magnitude of an increase to the initial ACS sample.

We also investigated the expected change in the CAPI workload if there was full CAPI follow-up for specific areas. The specific areas considered were Remote Alaska, American Indian, Alaska Native Village Statistical Areas, and Hawaiian Homelands (AIANHH) based on size; and places and Minor Civil Divisions (MCDs) based on the percent of addresses in rural blocks. Increasing the CAPI follow-up to 100 percent would have a direct positive impact on the reliability of the estimates, in particular for small areas.

2.1 Research Questions

We attempted to answer the following questions in our research:

- *What initial housing unit address sample size is necessary during the 2011-2015 period to provide specified levels of precision relative to the Census 2000 long form?*

- *Are there ways to improve the reliability of the ACS estimates for specific areas without an initial, overall sample increase?*

3. Determining the Overall Five-year ACS Sample Size

3.1 Methodology Description

We used the following method to calculate the 2011-2015 ACS sample size required to match various levels of the Census 2000 long form reliability for a tract of average size[1].

- Determine the average number of people per tract in Census 2000.
- Determine the national long form sampling rate in 2000.
- Determine the long form design factor for 'poverty status – persons'. The design factor is used to approximate the reliability (as measured by the CV) of the long form [1].
- Calculate the long form CV (CV_{lf}) for a 10 percent population estimate of poverty for an average size tract in Census 2000.
- Project the annual growth in the ACS sampling frame.
- Project the number of addresses in the 2010 ACS frame.
- Project the number of addresses in the ACS frame for each year in the 2011-2015 time period.
- Project the average number of people per tract for each year in the 2011-2015 time period.
- Calculate the average tract size (number of people per tract) for the 2011-2015 time period (note, this equals the expected average number of people per tract in 2013).
- Determine an average ACS design factor for poverty.
- Determine the 2011-2015 ACS sample size required to achieve a fixed level of reliability ($CV_{acs} = R \times CV_{lf}$) for a 10 percent population estimate of the poverty rate for an average size tract in 2013.
- Determine the annual sample size needed to satisfy the previous step for each alternative design and each year in the 2011-2015 time period.
- Determine the annual overall percent in sample for each year in the 2011-2015 time period based on the previous step.

3.2 Assumptions

We used the assumptions and fixed quantities in Table 1 in the calculations. In addition to the parameters that we used Table 1 provides the logic behind each assumption listed and the implications of each.

---

[1] All calculations in this report include the housing unit population only.

Table 1. Research Assumptions

#	Assumption	Value	Logic	Implications if Assumption is Incorrect
1	Annual overall growth in the ACS sampling frame.	= **2,200,000**	Average growth from 2006 to 2008 = 2,183,170	Realized CVs could deviate to the extent that the growth in the frame differs.
2	Growth rate is uniform across all geographic areas and across years.	n/a	Allows generalization to entire U.S.	Realized CVs for individual tracts will differ from the research.
3	Average number of people per tract in 2010 = average number of people per tract in 2000	= **4,181**	2010 design goal: target same number of people per tract as in 2000 [2].	Realized CVs for individual tracts will differ from the research.
4	Projected total number of addresses in the frame in 2013	= 132,841,861 + (6 × 2,200,000) ≅ **146,041,000**	= 2007 universe size + (6 × projected growth)	Realized CVs for individual tracts will differ from the research.
5	Average number of people per tract in 2011-2015 = expected average number of people per tract in 2013	= **4,379**	Projected year to year change applied to the projected average number of people per tract in 2010 (4,181)	Realized CVs for individual tracts will differ from the research.
6	Average value of the characteristic (p) is fixed.	= **10%**	Allows generalization to entire U.S.	If a particular entity has a higher poverty rate (p), the CV will tend to be smaller. Conversely, if P is smaller, the CVs will be larger.
8	Census 2000 Long Form design factor = average of three design factors: poverty 5-17, poverty families, and poverty population.	= (1.65 + 1.29 + 1.47) / 3 ≅ **1.5**	National design factor for the "less than 15% in sample" as well as independently calculated using Census data files for same data groupings as used for the ACS calculation for all LF final weighting areas < 12.5% in sample in the ACS test counties.	Smaller design factors would produce smaller CVs.
9	ACS design factor = average of three design factors: poverty 5-17, poverty families, and poverty population	= (2.17 + 1.5 + 2.5) / 3 = **2.1**	Attempt to smooth ACS variability.	Realized CVs for individual tracts will differ from the research.
10	The Census 2000 Long Form initial sampling rate of addresses on the frame	= **17.1%**	From long form sampling results memo[2]	n/a
11	The actual Census 2000 Long Form percent of the population in sample	= **15.4%**	American Fact Finder[3]	n/a

[2] DSSD Census 2000 Procedures and Operations Memorandum Series #LL-9, dated August 28, 2002.

[3] http://factfinder.census.gov/servlet/DTTable?_bm=y&-geo_id=01000US&-ds_name=DEC_2000_SF3_U&-_lang=en&-_caller=geoselect&-state=dt&-format=&-mt_name=DEC_2000_SF3_U_P004

3.3 Calculations

3.3.1 Census 2000 Long Form CV for a 10% Poverty Estimate for a Tract of Average Size

Let
f_{lf} = LF sampling rate = 0.171
DE_{lf} = LF design effect = $(DF_{lf})^2 = 1.5^2 = 2.25$
N_{lf} = population size of an average tract = 4,181 (as of 2000)
p = population characteristic = 0.10
q = 1 – p = 0.90

then

$$CV_{lf} = \sqrt{((1-f_{lf}) \times DE_{lf} \times q))/(f_{lf} \times p \times N_{lf})} \quad (1)$$

CV_{lf} = 0.153

3.3.2 Five-year ACS Sampling Fraction ($f_{acs\text{-}5yr}$) for Specified Reliability Level

Let

CV_{lf} = 0.153 (from formula (1))
R = Reliability factor or goal = 1, 1.25, 1.33, 1.50, 1.63, and 1.75
DE_{acs} = design effect for ACS = 4.41
$N_{acs\text{-}tract}$ = population size of an average tract = 4,379 (as of 2013)
p = population characteristic = 0.10
q = 1 – p = 0.90

then

$$f_{acs-5\,yr} = (DE_{acs} \times q)/((R \times CV_{lf})^2 \times p \times N_{acs} + (DE_{acs} \times q)) \quad (2)$$

As an example, let R=1, then
$f_{acs\text{-}5yr} = (2.1^2 \times 0.9) / ((1 \times 0.153)^2 \times 0.1 \times 4{,}379 + (2.1^2 \times 0.9))$
$f_{acs\text{-}5yr}$ = 27.9%
Note that for R = 1.50, $f_{acs\text{-}5yr} \cong 15.0\%$

3.3.3 Five-year and Annual Sample Sizes for Each Alternative Design Option

We calculated the five-year ACS sample sizes simply as:

$n_{acs\text{-}5yr} = f_{acs\text{-}5yr} \times N_{acs}$

where
$f_{acs\text{-}5yr}$ = five-year ACS sampling rate [from (2)]
N_{acs} = projected 2013 universe size
Therefore, for R = 1.50,
$n_{acs\text{-}5yr} \cong 0.15 \times 146{,}041{,}000$
$n_{acs\text{-}5yr} \cong 22{,}000{,}000$

Thus the ACS annual sample size, n_{acs}, = $n_{acs\text{-}5yr}$ / 5 = 4,400,000. Note that this calculation uses the rounded value of $f_{acs\text{-}5yr}$, which is shown here.

3.3.4 Margin Of Error (MOE) for Each of the Six Options

$MOE = SE \times 1.645$ (3)
where
SE = the standard error for an estimate
$SE = CV_{lf} \times R \times 0.1$
We use 1.645 in the MOE calculation to form 90 percent confidence intervals.

4. Results

4.1 Distribution of Improvement in MOEs

In Table 2 we show a summary for eight different designs. The most reliable design, which matches the Census 2000 Long Form reliability, has an average annual sampling rate of 5.6 percent with an annual sample size of approximately 8.1 million addresses. The last line of Table 2 shows the measures of reliability during the 2011-2015 time period associated with the current annual sample size of approximately 2.9 million addresses.

Table 2. 2011-2015 ACS Sample Sizes and Sampling Rates for Various Levels of Reliability

ACS Average Annual Sampling Rate (*f*) [1]	ACS Annual Address Sample Size (*n*) in millions[4] [2]	CV_{ACS} Level of Reliability [3]	CV_{ACS} as a Function of the CV_{LF} [4]	MOE at the 90 Percent Confidence Level[5] [5]	Percent Improvement in MOEs, Relative to 2.9 Million Annual Sample[6] [6]
5.60%	8.1	15.30%	1.00 CV_{LF}	2.52%	45.8%
4.00%	5.8	19.10%	1.25 CV_{LF}	3.15%	32.3%
3.60%	5.2	20.40%	1.33 CV_{LF}	3.35%	28.0%
3.00%	4.4	22.50%	1.50 CV_{LF}	3.71%	20.2%
2.50%	3.7	24.90%	1.63 CV_{LF}	4.11%	11.6%
2.40%	3.54	25.64%	1.67 CV_{LF}	4.22%	9.2%
2.20%	3.3	26.80%	1.75 CV_{LF}	4.42%	5.0%
2.00%	2.9	28.31%	1.85 CV_{LF}	4.65%	--

4.2 Confidence Levels for a Fixed Margin of Error

We can look at the information in Table 2 in terms of the impact on the confidence level. Using the design with an average annual sampling rate of three percent, we see that at the 90 percent confidence level, this provides a MOE for a 10 percent poverty rate estimate of 3.71 percent. In Table 3 we show how the confidence level changes as the sampling rates and sample sizes change for a fixed MOE of 3.71 percent.

[4] The number of actual sample housing units will be smaller due to imperfections on the frame such duplicate addresses, units that no longer exist, and ineligible addresses such as business addresses.
[5] MOE for a 10% poverty rate estimate, for an average-sized tract.
[6] $[(MOE_{2,9M} - MOE_{\#}) / (MOE_{2,9M})] \times 100$, where # = sample size for the corresponding row.

Table 3. 2011-2015 ACS Sample Sizes, Sampling Rates, and Impact on Reliability of a Fixed Margin of Error by Sampling Rate

ACS Average Annual Sampling Rate (*f*) [1]	ACS Annual Address Sample Size (*n* - in millions) [2]	CV_{ACS} Level of Reliability [3]	CV_{ACS} as a function of the CV_{LF} [4]	Confidence Level of the MOE= 0.0371 [5]	Loss of Reliability Relative to Long Form [6]
5.60%	8.1	15.30%	1.00 CV_{LF}	98%	0%
4.00%	5.8	19.10%	1.25 CV_{LF}	95%	25%
3.60%	5.2	20.40%	1.33 CV_{LF}	93%	33%
3.00%	4.4	22.50%	1.50 CV_{LF}	90%	50%
2.50%	3.7	24.90%	1.63 CV_{LF}	86%	63%
2.40%	3.54	25.64%	1.67 CV_{LF}	85%	67%
2.20%	3.3	26.80%	1.75 CV_{LF}	83%	75%
2.00%	2.9	28.31%	1.85 CV_{LF}	81%	85%

In the most reliable design (5.6% in sample) there is a one-in-fifty chance that the true value lies outside the confidence interval formed by a 3.71 percent MOE. In comparison, under the design with the current sample size, there is nearly a one-in-five chance that the confidence interval does not cover the population value.

Note that if we fix the sample size at the current level of approximately 2.9 million per year for the 2011-2015 time period, the ACS CV associated with a 10 percent estimate of poverty for an average size tract will be roughly 1.85 times as large as the CV for the same estimate from the Census 2000 Long Form.

5. Implementation

5.1 Options

The ACS has two options for implementing a change in sampling rate and sample size. We can continue with a fixed but higher annual sample size or implement a fixed annual sampling rate increase that allows the sample size to grow in size every year.

5.1.1 Fixed Sample Size

Table 4 shows the impact if we fix the sample size at the 1.50 CV_{LF} level for a five-year period. Even though the sample size is constant, the sampling rate will decrease over time due to growth in the number of addresses on the frame. With a fixed sample size, the percent in sample in the early years of the five-year period is greater than three percent, while the ending year(s) is below that threshold. It is important to note here that the five-year percent in sample is three percent.

Table 4. Impact Over Time of a Preliminary Fixed Sample Size by Characteristic for Average Tracts

Measure	2011	2012	2013	2014	2015	2011-2015
Fixed Sample Size	4,427,220	4,427,220	4,427,220	4,427,220	4,427,220	22,136,100
Sampling Fraction	3.1%	3.1%	3.0%	3.0%	2.9%	15.1%

5.1.2 Fixed Sampling Rate

In contrast to the fixed sample size option, the option of fixing the sampling rate would account for growth in the frame each year and the sample size would increase proportionally to the total number of addresses. Table 5 illustrates this with the annual sampling rate set to 3.0 percent. The annual sample sizes in Table 4 vary, as opposed to the fixed annual sample sizes reflected in Table 3, but over the five year period the total sample sizes are equal.

Table 5. Impact Over Time of a Preliminary Fixed Sampling Fraction by Characteristic for Average Tracts

Measure	2011	2012	2013	2014	2015	2011-2015
Fixed Sampling Fraction	3.0%	3.0%	3.0%	3.0%	3.0%	15.0%
Sample Size	4,293,835	4,360,528	4,427,220	4,493,912	4,560,605	22,136,100

6. Implementing Full Follow-up in Specific Areas

We evaluated three sets of areas to assess the impact of implementing a 100 percent CAPI follow-up of non-responding and unmailable addresses instead of sampling for CAPI; Remote Alaska, American Indian/Alaska Native Village Statistical/Hawaiian Homeland areas by size (measured in estimated occupied housing units), and places and MCDs by the percent of addresses in rural blocks. The reasoning for this was that improvement in reliability is possible without an increase in the initial sampling rate by implementing full CAPI follow-up in areas where we have traditionally observed lower response rates, and for Remote Alaska addresses which are all unmailable and therefore sampled at a 2-in-3 rate for CAPI.

Tables 5, 6, and 7 were generated to assess the impact on the workloads of performing a 100 percent follow-up of non-responding cases in areas where this would have the largest positive impact. Table 5 shows the projected 2013 universe size, sample, CAPI sample, and projected CAPI sample – including 100 percent follow-up – as well as the difference. The projections in Table 5 show the expected workloads under the current sample design of approximately 2.9 million addresses annually. Table 6 and Table 7 show the same projections as found in Table 5 – with an increase in the sample to 3.7 million and 4.4 million addresses per year, respectively.

Table 5. 2013 CAPI Sample Size Projections with Full CAPI Follow-up for Selected Areas Under the Current Design

Area	Total Valid Universe	Selected Sample	CAPI - Sample	CAPI - 100% Follow-up	Difference in CAPI Workloads
Remote Alaska[1]	33,025	2,323	1,549	2,323	774
AIANHH[2] - ALL	2,743,893	90,422	24,695	55,510	30,815
AIANHH < 800 MOS	596,547	39,635	10,204	23,687	13,483
AIANHH < 1200 MOS	732,419	44,218	11,757	26,871	15,114
AIANHH < 2000 MOS	836,032	47,824	13,020	29,347	16,327
All Rural Blocks	32,379,050	898,417	202,647	468,333	265,686
Places and MCDs > 50% Rural	23,365,268	599,686	140,687	320,867	180,180
Places and MCDs > 75% Rural	22,617,908	591,852	138,953	316,536	177,583
Places and MCDs > 90% Rural	22,144,413	585,147	137,875	313,743	175,868

[1] All addresses in Remote Alaska are flagged unmailable

[2]AIANHH=American Indian and Alaska Native Village Statistical Areas and Hawaiian Homelands (*Note: a large proportion of Remote Alaska addresses are also in Alaska Native Village Statistical Areas*)

Table 6. 2013 CAPI Sample Size Projections with Sample Increase to 3.7 Million per Year and Full CAPI Follow-up

Area	Total Valid Universe	Selected Sample	CAPI - Sample	CAPI - 100% Follow-up	Difference in CAPI Sample Sizes
Remote Alaska	33,025	2,952	1,969	2,952	984
AIANHH – ALL	2,743,893	114,924	31,387	70,552	39,165
AIANHH < 800	596,547	50,375	12,969	30,106	17,137
AIANHH < 1200	732,419	56,200	14,943	34,152	19,210
AIANHH < 2000	836,032	60,783	16,548	37,299	20,751
All Rural Blocks	32,379,050	1,141,869	257,560	595,241	337,681
Places and MCDs > 50% Rural	23,365,268	762,188	178,810	407,815	229,005
Places and MCDs > 75% Rural	22,617,908	752,231	176,606	402,311	225,704
Places and MCDs > 90% Rural	22,144,413	743,710	175,236	398,761	223,525

Table 7. 2013 CAPI Sample Size Projections with Sample Increase to 4.4 Million per Year and Full CAPI Follow-up

Area	Total Valid Universe	Selected Sample	CAPI - Sample	CAPI - 100% Follow-up	Difference in CAPI Sample Sizes
Remote Alaska	33,025	3,543	2,362	3,543	1,180
AIANHH – ALL	2,743,893	137,909	37,664	84,662	46,998
AIANHH < 800	596,547	60,450	15,563	36,127	20,564
AIANHH < 1200	732,419	67,440	17,931	40,983	23,051
AIANHH < 2000	836,032	72,940	19,858	44,759	24,902
All Rural Blocks	32,379,050	1,370,243	309,072	714,290	405,218
Places and MCDs > 50% Rural	23,365,268	914,626	214,572	489,378	274,806
Places and MCDs > 75% Rural	22,617,908	902,678	211,928	482,773	270,845
Places and MCDs > 90% Rural	22,144,413	892,451	210,283	478,513	268,229

While Tables 5, 6, and 7 look at the impact on the CAPI workloads across all areas within each category, the reliability of the estimates for the small areas in these groupings would necessarily be improved. The increase in reliability for individual areas was not quantified.

7. Summary and Conclusions

7.1 Sample Size Increase

The current ACS design has a sampling rate of roughly 2.2 percent with an average reliability for estimates of the poverty rate for tracts of average size of approximately 1.75 CV_{LF} . Any increase in the sampling rate leads to larger sample sizes and will improve the reliability of future ACS estimates. Once the sample needed to obtain the desired reliability is determined, there is then the choice of fixing the sample size at that amount or using a constant sampling rate every year thereafter. Fixing the sample size addresses the issue of decreasing reliability of the ACS estimates for a short time period but there would remain a need to increase the sample size in regular intervals across time to address growth in the population which leads to growth in the frame. By fixing the sample rate, the desired level of reliability can be achieved on a consistent year to year basis. This would entail including an annual growth factor in the ACS budget.

7.2 Full CAPI Follow-up

Performing full CAPI follow-up in targeted areas would result in improvements in reliability without a change in sampling rate or sample size. Full CAPI implementation in Remote Alaska and American Indian and Alaska Native Village Statistical Areas and Hawaiian Homelands yields improvement for these areas with little cost impact. Although if there is not an overall increase in the ACS sampling rates, only the reliability of the estimates containing these specific areas will be positively effected. However, full implementation in rural areas may be as expensive as increasing the overall sampling rate.

7.3 Future Research

We continue to investigate different allocations of the ACS sample, potentially adding several new strata to increase the reliability in the smaller areas. Initial research indicates that we may be allocating too much of the ACS sample to the largest areas. It may be possible to shift sample from these large areas to the smaller areas so that the we minimize the differences in the reliability measures across all areas, regardless of size.

Acknowledgements

I wish to thank the following people who provided significant help by generating and assisting in analyzing the data contained in this paper, or aided by providing many clear and useful comments and suggestions: Edward C. Castro Jr., Karen E. King, Alfredo Navarro, Don Keathley, and Lynn Weidman.

References

[1] U.S. Census Bureau, Census 2000 Summary File 3 Technical Documentation, Table C,

[2] Federal Register / Vol. 73, No. 51 / Friday, March 14, 2008 / Notices, Department of Commerce, Bureau of the Census, [Docket Number 070321065–7903–02], Census Tract Program for the 2010 Decennial Census—Final Criteria,
http://www.census.gov/prod/cen2000/doc/tablec-us.pdf