Sample Design Research in the 2010 Sample Redesign

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Abstract
The sample design of the demographic or household surveys is a two stage design. In the first stage, primary sampling units (PSUs) are defined, stratified, and selected. PSUs are made up of counties or groups of contiguous counties. In the second stage, address records within each PSU are sorted by geographic and demographic information and selected systematically survey-by-survey with previously selected samples removed and the sampling interval adjusted in the next survey. In this paper, we provide an overview of the sample design for the household surveys. We also highlight research and results on major methodological changes for the 2010 Sample Redesign, including the frequency of sampling, and the use of data from the American Community Survey (ACS) and administrative records in sampling.

Key words: Sample design, household surveys, demographic surveys, 2010 Sample Redesign Program, multistage sample design, survey coordination

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1. Background

The 2010 Demographic Surveys Sample Redesign program, commonly referred to as "2010 Sample Redesign" is the U.S. Census Bureau program that selects and disseminates updated samples for a number of demographic surveys. The redesigning surveys include:

- Current Population Survey (CPS)[3]. The CPS is the primary source of information on the labor force characteristics of the U.S. population. Estimates obtained from the CPS include employment, unemployment, earnings, hours of work, and other indicators. To learn more about the CPS, go to http://www.census.gov/cps/.

- Survey of Income and Program Participation (SIPP). The SIPP provides comprehensive information about the income and program participation of individuals and households in the United States, and about the principal determinants of income and program participation. To learn more about the SIPP, go to http://www.census.gov/sipp/intro.html.

- Consumer Expenditure Survey (CE). The CE consists of two surveys, the Quarterly Interview Survey and the Diary Survey, which provide information on

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[3] State Children's Health Insurance Program Survey (SCHIP) is also a redesign survey. The SCHIP is an expansion of the CPS sample and collects similar information as the CPS.

the buying habits of American consumers, including data on their expenditures, income, and consumer unit (families and single consumers) characteristics. To learn more about the CE, go to http://www.bls.gov/cex/.

- National Crime Victimization Survey (NCVS). The NCVS provides information on characteristics and consequences of criminal victimization in the United States. To learn more about the NCVS, go to http://bjs.ojp.usdoj.gov/index.cfm?ty=dcdetail&iid=245.

- American Housing Survey (AHS). The AHS collects data on the Nation's housing stock, household characteristics, housing and neighborhood quality, housing costs, and recent movers. To learn more about the AHS, go to http://www.census.gov/hhes/www/housing/ahs/overview.html.

There has been a long tradition at the Census Bureau of conducting a coordinated sample redesign that included multiple demographic surveys to minimize costs. The sample redesign occurred after each decennial census because the census had been the sole source of data for redesigning. The 2010 Sample Redesign is also using this coordinated model; however, this redesign differs from the previous redesigns for several reasons. The Census Bureau now continually maintains and updates its Master Address File (MAF), which makes it possible for the demographic surveys to use the MAF to construct sampling frames, replacing the complex and costly multiple frame approach used in past redesigns. The American Community Survey (ACS), which has replaced the census long-form, is critical for the sample redesign because the ACS is a continuous monthly survey of households and is not tied to the decennial cycle. This makes it possible for implementing a more frequent sample redesign than in the past. Administrative records have also become a viable source of information with potential value for redesigning of demographic surveys.

The 2010 Sample Redesign continues using a traditional two-stage sample design; however, there are major changes in both stages of sampling, starting with the sampling frames. The first stage involves defining, stratifying, and selecting primary sampling units (PSUs). Section 2 discusses how the PSUs are formed, stratified, and selected for the demographic surveys, excluding CE. The second stage involves selecting the ultimate sampling units (USUs) within the sampled PSUs. The USUs are the specific housing units or address records to be interviewed in each demographic survey. Section 3 discusses the sampling frames used in the second stage sampling and section 4 discusses the three MAF-based frames for the 2010 Sample Redesign. Sections 4.1 and 4.2 discuss the sampling and major methodological changes of the housing unit (HU) frame and the group quarters (GQ) frame, respectively. Section 4.3 discusses the sampling methodology of the new MAF-omissions frame.

2. First Stage of the Sample Design: PSU Sampling

A sample of PSUs is selected in the first stage. The demographic surveys primarily use PSUs to reduce field travel costs for personal visit interviews. A PSU-design limits the sample to a number of geographic areas, thus producing less dispersed sample. Although telephone interviewing is also used to collect data for demographic surveys, computer assisted personal interviewing (CAPI) is widely used in order to meet surveys' data quality and response rate requirements. For example, in December 2005, more than 40 percent of the CPS interviews were completed in person (U.S. Census Bureau 2006b).

The two main constraints used in defining PSUs for the demographic surveys are land area and population size. The PSUs consist of single counties or groups of contiguous counties or county equivalents. Counties in large metropolitan areas are grouped into PSUs that are self-representing (SR) and selected in the first stage sample with certainty. All other PSUs are non-self-representing (NSR), with a probability of selection less than one. The stratification algorithm groups the defined NSR PSUs into strata in order to minimize the component of sampling variance due to the first stage of sampling. Within each of the NSR stratum, either one or two PSUs are selected, depending on the surveys. The probability of selection is affected by the PSU measure of size (MOS) and by the PSUs selected in the previous redesign. Each demographic survey defines the PSU MOS differently. For example, in the previous redesign the PSU MOS was defined as the number of housing units within a PSU for the AHS; while the PSU MOS was defined as the number of civilian, non-institutional people, sixteen years or older within a PSU for the CPS (U.S. Census Bureau 2010e).

2.1 Defining PSUs

There are no major changes in how the PSUs are defined for this sample redesign. A PSU consists of a U.S. county or a group of geographically contiguous counties or county equivalents. Each PSU is contained within the state boundary. Counties in large metropolitan areas or urban centers are grouped into PSUs that are SR. The SR PSU definitions are based on the delineation of metropolitan areas published by the White House Office of Management and Budget (OMB). These are called Core Based Statistical Areas (CBSAs). OMB delineates CBSAs using population density from the 2010 decennial census together with commuting data from the ACS, where each CBSA must include at least one county (U.S. Census Bureau 2009h). Each demographic survey designates the top largest number of CBSAs as SR PSUs; the numbers of SR PSUs vary by survey (Murphy 2008).

All other PSUs are NSR and are expected to contain a sufficient number of USUs to keep at least one interviewer fully employed. This has always been a requirement in defining PSUs since it is cost efficient. The NSR PSUs are defined by modifying the current PSU definitions from the previous sample redesign. Population and geography data from the 2010 decennial census are used in grouping adjacent counties to form NSR PSUs. An NSR PSU should not be larger than 3,000 square miles and have a minimum of 7,500 people. These constraints were established in early 1950 to reduce data collection costs (U.S. Census Bureau 2002). That is, an NSR PSUs should have enough population to support one interviewer, but should not be too geographically large that it would require additional travel time. Counties with large populations are usually single-county NSR PSUs. There are instances where the land and population constraints are violated, such as sparsely populated and geographically large counties, counties with large water areas, and counties with road conditions that make travel difficult.

The number of SR and NSR PSUs formed are different for different demographic surveys. For example, in the previous redesign CPS created 446 SR and 1,579 NSR PSUs and SIPP created 123 SR and 1,902 NSR PSUs (U.S. Census Bureau 2004a and U.S. Census Bureau 2004b).

2.2 Stratifying PSUs

After the PSUs are defined, the NSR PSUs are grouped into strata where each stratum is as homogeneous as possible with respect to the characteristics being measured by each demographic survey. The stratification attempts to group the PSUs in order to minimize the between-PSU component of sampling variance. In general, the between-PSU component of the total variance is less than 10 percent for most key characteristics being measured by demographic surveys. Refer to U.S. Census Bureau 2006c for CPS between-PSU variance. The stratification is performed independently for each demographic survey and of the previous sample redesign.

The demographic surveys use the PSU Stratification Program (PSP) that is created by the Demographic Statistical Methods Division (DSMD) of the Census Bureau to stratify PSUs. The methodology for the PSP is based on the "hill-climbing" procedure proposed by Friedman and Rubin (1967) and is similar to a stratification algorithm used in the previous sample redesign. This algorithm is characterized by iterative reallocation of PSUs to strata. The PSP includes some variations that were not in the previous sample redesign stratification algorithm, such as the option of using between-PSU or total variance to evaluate potential stratifications, and the creation of more initial stratifications. These new options increase the likelihood of finding the optimal stratification (U.S. Census Bureau 2009c).

An objective of the PSU stratification is to group NSR PSUs with similar characteristics into strata with roughly equal population sizes. Recall from the previous section that an NSR PSU is supposed to contain a sufficient number of USUs to keep at least one interviewer fully employed. Since all demographic surveys, except SIPP, select one PSU per stratum, equal size stratum yields reasonable interviewer workloads. As a result of the PSU stratification, some NSR PSUs are reclassified as SR PSUs because the workload is too large for one interviewer to handle or the NSR PSU is not similar to other NSR PSUs. This results in surveys with a number of states having all SR PSUs.

The number of strata created by each demographic survey varies. For example, in the previous redesign CPS created 446 SR strata and 374 NSR strata and SIPP created 123 SR strata and 114 NSR strata (U.S. Census Bureau 2004a and U.S. Census Bureau 2004b).

Besides the stratification algorithm, the other important aspect of PSU stratification is the data that are needed to stratify the PSUs. The stratification variables used in each survey are highly correlated with the characteristics being measured by that survey. For example, the CPS is interested in measuring the unemployment statistics, but these data are not available to use in PSU stratification, so the data on social and economic characteristics that are highly correlated with unemployment are used instead. Each demographic survey has a different set of PSU stratification variables.

2.3 Selecting PSUs

After PSUs are stratified, the NSR PSUs are selected with probability proportional to the PSU MOS in each stratum. PSU selection is carried out independently of the previous redesign for some demographic surveys, while others continue to maximize the overlap of the PSU sample with the PSUs from the previous redesign. The maximizing overlap methods documented in Ernst (1986) and Ernst and Ikeda (1995) were used in previous sample redesigns and will be used in the 2010 Sample Redesign to select PSUs for those

surveys that want to increase the probability of reselecting PSUs that were in sample in the previous redesign.

The objective of maximizing overlap is to control the cost of hiring and training new interviewers. Rottach and Murphy (2009) found that the average expected PSU overlap for CPS using Ernst (1986) is about 60 percent and the percent of the average expected PSU overlap for CPS when selecting PSUs independently is about 35 percent. U.S. Census Bureau 2010c roughly estimated that the savings in reselecting the PSUs from the previous redesign using maximizing overlap for a demographic survey is about $400,000. This amount is considered to be large.

The number of SR and NSR PSUs are different for different demographic surveys. For example, in the previous redesign CPS selected 446 SR and 374 NSR PSUs and SIPP selected 123 SR and 228 NSR PSUs (U.S. Census Bureau 2004a and U.S. Census Bureau 2004b). CPS selected one NSR PSU per stratum and SIPP selected two NSR PSUs per stratum.

Rottach and Murphy (2009) and U.S. Census Bureau 2010c had compared Ernst (1986) to alternative methods of maximizing PSUs overlap, in particular Ohlsson (1996, 1999). The average expected overlap for the two methods are found to be about 60 percent for CPS using data from two previous redesigns. Important properties of the Ohlsson method are that it can be used repeatedly across any number of redesigns without deviating from the probability proportional-to-size sampling constraints and that it maintains independent sampling from stratum-to-stratum. The Ernst method also satisfies the constraints of the probability proportional-to-size sampling; however, this method leads to dependent sampling stratum-to-stratum. This stratum dependency has implications on variance estimation. The level of the variance bias is unquantifiable because the joint probability of selection for the previous redesign is unknown due to the usage of the Ernst method. Nevertheless, U.S. Census Bureau 2010c has made a compelling argument in the importance of having an unbiased variance that at least one demographic survey is changing its maximizing overlap method from Ernst's to Ohlsson's.

3. Second Stage of the Sample Design: Sampling Frames

3.1 MAF-Based Sampling Frames

DSMD conducted extensive coverage and content quality evaluations of the continually updated MAF to replace the four-frame system used in the previous redesign. The U.S. Census Bureau (2006a, 2007, 2008a, 2008b, 2009a) concluded that the MAF can be used to construct MAF-based sampling frames for the demographic surveys in the 2010 Sample Redesign with coverage quality comparable to the four-frame system at the national level. However, the undercoverage of the MAF in rural areas can have a negative impact on the quality of certain state-level survey estimates in some states that have a high number of housing units located in rural areas. The MAF is the U.S. Census Bureau's database that contains addresses for all living quarters in the United States. The major MAF updates occur in preparation for the decennial censuses, such as during the decennial census address canvassing and the local update of census addresses. The largest source of MAF updates outside the decennial census years is the United States Postal Service (USPS) Delivery Sequence File (DSF). The DSF is a nationwide address file of residential and commercial mail delivery points serviced by the USPS (U.S.

Census Bureau 2009b). As an aside, the ACS, which is also conducted by the U.S. Census Bureau, has been using the MAF-based frame since its inception more than five years ago.

The desired universe for the demographic surveys consists of housing units and non-institutional non-military group quarters in the U.S. To operationally identify and locate these units, the three MAF-based sampling frames are used in the 2010 Sample Redesign. The three MAF-based frames are the HU frame, GQ frame, and MAF-omissions frame. These frames are constructed by sub-setting the MAF units that best represent the definitions of the frames. The HU frame consists of single-family and multi-unit address records in the U.S.; the GQ frame consists of non-institutional non-military group quarters in the U.S.; and the MAF-omissions frame consists of housing units found through annual area listing[4] that were missed by MAF updates operations during and in between decennial census years. The MAF-omissions frame consists of housing units mostly in rural areas where the MAF does not have good coverage.

Newly built housing units are added to the HU frame semi-annually, coming mainly from the DSF. New group quarters (GQs) are captured during area listing of sampled GQs and calling universities and colleges to inquire about GQs construction projects[5].

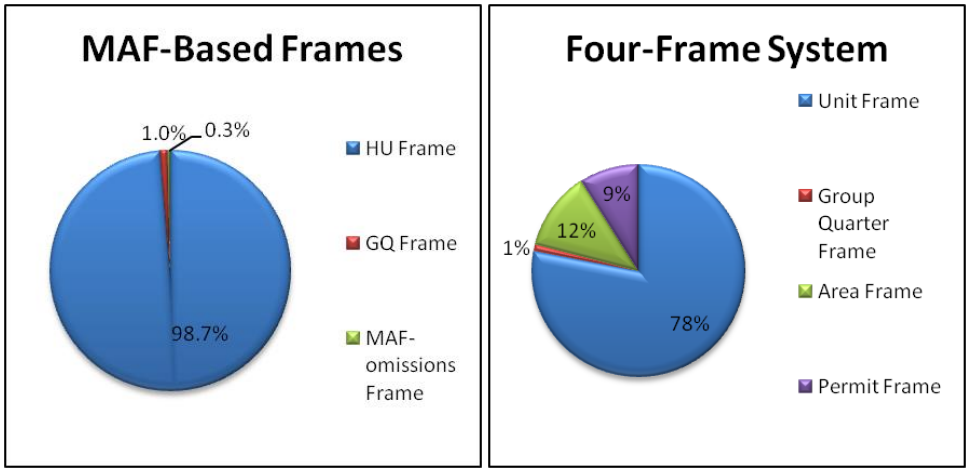
The MAF-based frames that are used in the 2010 Sample Redesign are different than the four-frame system used in the previous redesign, but the desired universe for the demographic surveys remains unchanged. The four-frame system consists of the unit frame, group quarter frame, permit frame, and area frame. The unit frame and group quarter frame were constructed using a master list of addresses from the 2000 Decennial Census. The permit frame consists of new constructions or living quarters in existence after April 1, 2000 that are in permit-issuing blocks; and the area frame consists mainly of blocks where the percentage of complete city-style addresses (a house number and street name) is low and in non-permit-issuing blocks (U.S. Census Bureau 2009b).

The MAF-based frames are much less costly and complex than the four-frame system. Figure 1 provides a visual comparison of the MAF-based frames for the 2010 Sample Redesign to the four-frame system used in the previous redesign. The HU and unit frames' units are the least expensive for the demographic surveys to identify and locate compared to the units from the other frames because no listings are needed in these two frames. The size of the GQ frame and the group quarter frame from the previous redesign remains the same; however, the MAF-omissions frame compared to the area frame decreases drastically. The permit frame and large portion of the area frame units are covered by the HU frame, with no area and permit listings needed. The portion of the subuniverse that requires area listing was reduced by about 80 percent compared to the previous redesign, contributing to significant savings in the 2010 Sample Redesign (U.S. Census Bureau 2011a).

[4] Area listing is the process of compiling a sampling frame for specific areas by having the interviewers canvass the structures in those areas.

[5] The telephone operation is in the testing phase.

Figure 1: Comparison of the Distributions of the Sampling Frames (In Percent)



3.2 Sorting the MAF-Based Sampling Frames

Before selecting the USU to interview, the units are sorted independently within each of the three MAF-based frames. A major part of the 2010 Sample Redesign research, and previous redesigns, is the evaluation and determination of the sorting scheme to use in sorting the sampling frame. The address records on the sampling frame are sorted either at the housing unit level or at the census block level, depending on the demographic survey and the frame. Each survey determined a sorting scheme that would minimize the second stage within-PSU sampling variance of the key survey estimates. For example, a key survey estimate for the CPS is the total number of people unemployed. The largest component of the total sampling variance for the demographic surveys is from the second stage sampling of the USUs. To minimize this component of the sampling variance, each survey is ensuring proportional representation of certain key characteristics by using related detailed information to sort the address records on the MAF-based frames prior to sample selection.

The sorting scheme consists of an ordered list of variables created using the 2010 Decennial Census, ACS, MAF, and administrative records data sources. These sort variables describe the demographic, geographic, and socio-economic characteristics of a block or block-groups. In general, the sort variables need to be sufficiently correlated with the key survey estimates and stable over time, that is, the correlations between a sort variable and a key survey estimate does not deteriorate over time (Gorsak, Mansur, Fenstermaker, and Petroni 1991). For example, the CE sorts the HU frame on the value of the property and monthly rental expenditures, in addition to geography information, because these variables are highly correlated to what this survey measures, that is, consumer expenditures and income (U.S. Census Bureau 2011e).

The decennial census short form data continue to provide basic demographic and geographic information needed for sorting the address records on the sampling frames, as in previous redesigns. However, the ACS has replaced the census long form that had provided additional information for sorting the sampling frames in the past. The ACS is a continuous monthly survey of households that samples in every county in the United States. The ACS provides more timely information on demographic, housing, social, and economic characteristics than the once a decade census long form. The estimates from the long form represent the census year, while the ACS estimates cover a period of one to five years. For populous geographic areas, those with more than 65,000 people, one year of ACS data yield estimates with reliability similar to the census long form sample. For smaller geographic areas, multiple years of ACS

data must be combined: three years of data for areas of between 20,000 and 65,000 people, and five years for areas with less than 20,000 people (Hall 2006 and Murphy 2006).

The use of administrative records data, in particular, the rental assistance data from the U.S Department for Housing and Urban Development (HUD) in conjunction with variables created from other data sources is a new and promising data source for one of the demographic surveys. Recall that the MAF database contains addresses for all living quarters in the United States; therefore, this is an extensive source of geographic information that is also available for use in creating sort variables.

Each demographic survey has a unique sorting scheme for sorting the HU frame address records, but all surveys use the same sort variables in the MAF-omissions and GQ frames. The MAF-omissions frame blocks will likely have a random sort. The GQ frame blocks will be sorted geographically by populations of college dormitory and non-college dormitory status.

4. Second Stage of the Sample Design: USU Sampling

4.1 HU Frame Sampling

All demographic surveys listed in Section 1 select sample from the HU frame. The demographic surveys have historically selected a decade of sample housing units all at once from a sample frame that is equivalent to the HU frame, occurring just after a decennial census, with periodic supplementation of new construction. The selected housing units are then parsed into monthly or quarterly samples as needed throughout the decade. This approach was the most cost effective and sensible method of sampling in the context of once-a-decade operations. For the 2010 Sample Redesign, these restrictions no longer exist because the HU frame is constructed from the continually updated MAF and the ACS provides the data needed to sort the HU frame records. The opportunity to select sample for the demographic surveys throughout the decade now exists. The second-stage sample selection of housing units is changing from once-a-decade sampling to annual sampling. Annual sampling is selecting a fully representative sample of housing units for demographic surveys from the HU frame on an annual basis. Note that annual sampling does not apply to the first-stage sample selection of the PSUs[6].

The initial discussions of annual sampling among Census Bureau staff and the demographic surveys sponsoring agencies started because of the possibility of using the continually updated MAF to build the sampling frame and the availability of the ACS data, collected monthly, that can be used to sort the housing units on the frame. Extensive research and evaluations concluded that there are many benefits to annual sampling compared to the current once-a-decade sampling. Annual sampling provides the flexibility to implement changes to methodology and process improvements throughout the decade. Incremental improvements can be made without needing to wait for a major redesign as was done in the past.

The U.S. Census Bureau (2009d, 2009c, 2010a, 2011b) found that the implementation of annual sampling is both statistically and operationally feasible. A major statistical concern with annual sampling was how to coordinate samples to avoid duplication of housing units among the demographic surveys to reduce respondent burden. Coordination ensures that any housing units selected for interview are not eligible for selection in the same or other demographic surveys for a set period of time. Under once-a-decade sampling, this coordination is achieved by having each survey select its sample from the same sampling frame in series. Each survey selected a representative sample without replacement using a single

[6] The frequency of PSU selection needs to be evaluated and decided after the work of the 2010 sample redesign work is completed.

sampling rate[7] within a Basic PSU Component (BPC), which are the basic building blocks of the PSUs. The next survey selected from the units remaining, which ensured that no units of either sample overlapped and the probability of selection for the units were adjusted to account for the previously selected sample(s). This process continued until all surveys had selected their samples. This is referred to as exclusion sampling.

For the 2010 Sample Redesign, the following design requirements and constraints need to be accommodated when coordinating among the different annual samples:

- Having a dynamic HU frame, that is, new units enter the frame in subsequent years (births) and previously valid units become invalid over time (deaths)
- Having multiple demographic surveys select sample in the same year and subsequent years
- Allowing previously sampled housing units to be re-eligible for selection five years from their last interview (U.S. Census Bureau 2010b)

With these constraints, the process of tracking housing unit eligibility and adjusting probabilities of selection becomes operationally complex under annual sampling. Sample coordination is more straightforward for once-a-decade sampling because sample selection only occurs once and the coordination period lasted until the next sample redesign, about ten years. The method of sample coordination for annual sampling is also the exclusion sampling method, but the adjustment to the probabilities of selection is computed differently than how it was done under the once-a-decade sampling.

Under once-a-decade sampling, the method for adjusting the probabilities of selection is referred to as the theoretical adjustment. It is computed using the expected[8] proportion removed by the previous surveys. For example, if two surveys have selected sample, the expected proportion removed is the sum of both surveys' sampling rates. To adjust the probabilities of selection for the demographic survey under annual sampling, the U.S. Census Bureau 2010a compares this method to an alternative method referred to as the empirical adjustment. The empirical adjustment uses the ratio of remaining housing units to all housing units on the HU frame to adjust for the excluded housing units. This approach only needs to flag which units are eligible for selection at a given time. The calculations for the empirical adjustment are simpler than the theoretical adjustment. The theoretical adjustment method is sufficient for once-a-decade sampling, but for sampling on an annual basis this method could increase the chance of computational errors and processing delay. Adjusting the probabilities of selection for a demographic survey under annual sampling using this method would require tracking and referencing the sampling rates of all the surveys that have sampled over the years, including those units that are re-eligible for selection. The amount of information that needs to be tracked continues to grow with each new sampling cycle. The empirical adjustment is statistically equivalent to the theoretical adjustment (U.S. Census Bureau 2010a).

4.2 GQ Frame Sampling

The blocks in the GQ frame are selected based on the block-level GQ MOS. The block GQ MOS is the ratio of noninstituional GQ population (excluding military GQs) and two times the average household size[9] in the U.S., adjusting for the number of institutional GQs in the block. The factor of two in the denominator of the GQ MOS ratio is used to create housing unit equivalent, which allows the GQ frame and HU frame to have the same sampling interval (U.S. Census Bureau 2011d). All demographic surveys

[7] A sampling rate of 1/500 means that out of every 500 housing units, 1 unit is selected.

[8] It is an expectation because the expected sample sizes are usually fractions. For example, a sampling rate can give an expected sample size of 18.9 units, though we would always select either 18 or 19.

[9] The average household size based on the 2010 Census is 2.58.

listed in Section 1 select sample from the GQ frame and use the same GQ MOS, except for the AHS. The AHS does not select sample from the GQ frame.

In the previous redesign, the GQ MOS was computed using the same computation above, except the factor of four was used to create the housing unit equivalent. The U.S. Census Bureau 2011d found that changing from four housing unit equivalent to two helps alleviate the problems caused by blocks with low GQ populations. This problem is caused, for the most part, when the GQ block population is less than ten people. In this case, the block population would be rounded to ten, giving the block a measure of four housing unit equivalent. This upward rounding produces higher expected sample size than the actual number of GQ units[10] on the ground, discovered during listing of the GQs. Additionally, a block with a population of three and a block with a population of ten would each receive a block measure of four housing unit equivalent due to rounding, which give the smaller block the same probability of being selected as the larger block. However, when a block measure with a two housing unit equivalent is used, the block with a population of three would receive one measure of a two housing unit equivalent and the block with a population of ten would receive two measures. This approach gives the block with a population of ten the same chance of selection as in the previous design, but the block with a population of three has a smaller probability of selection than before. A block measure with a two housing unit equivalent is found to be more efficient.

For the 2010 Sample Redesign, a new sample of GQ blocks is to be selected every three years. The frequency of GQ sampling has been changed from the previous redesign, where the GQ samples were selected for the entire decade, with periodic updating of new GQs captured during area listing. New GQs that are captured after the sample of GQ blocks has been selected will not be added to the existing sample (U.S. Census Bureau 2011c). Since the size of the GQ frame is only one percent of desired universe, it is less critical that the GQ sample is updated with new GQs each year. Not updating the existing sample makes the GQ operation less complex. New GQs that are discovered after the three-year sample has been selected will be given a chance of selection in the next round of sampling.

A three-year sample of GQ will be parsed into quarterly samples for field listing. The sampled blocks will be sent out for listing to identify the number of GQ units within a GQ structure. If more GQ units are found during listing than what was estimated at the time of GQ block level sampling, each survey will subsample if the number of GQ units is higher than the predetermined survey's threshold. Data collection from the potential respondents who occupy the GQ units will occur approximately five months after the GQ listing is completed (U.S. Census Bureau 2011c).

Similar to the HU frame, respondent burden is also a concern in the GQ frame. Potential GQ-level duplication between two consecutive three-year sampling cycles will be controlled by incrementally shifting the random start[11] in the next three-year sampling cycle to avoid selecting the same block in two consecutive sampling cycles. If GQ-level duplication occurs, then the units within a GQ are ineligible for data collection by the same survey or another demographic survey within two years from the date of the last interview (U.S. Census Bureau 2011c).

4.3 MAF-Omissions Frame Sampling

The U.S. Census Bureau 2009b determined that the HU and GQ frames could not provide the same level of coverage as what was provided by the four-frame system used in the previous redesign without improvement or enhancement. These two frames have coverage quality comparable to the four-frame system at the national level, but the U.S. Census Bureau 2009a found that the bias in some state-level

[10] GQ units can represent people, beds, or room within a GQ structure.
[11] The starting point to begin sampling based on a random number.

survey estimates is significant due to address undercoverage of the MAF in rural areas for certain states with large portion of housing units in rural areas. One of the reasons for this MAF undercoverage is because the DSF only includes city style addresses and most addresses in rural areas are non-city style, which are not added to the MAF.

Potential methods of frame undercoverage adjustments and improvements, such as, adjusting the survey weights to account for the missing MAF address records and supplementing the MAF with address information from a commercial source were evaluated and found to yield unsuccessful results (U.S. Census Bureau 2009f, U.S. Census Bureau 2009g, and U.S. Census Bureau 2010d). The commercial source that was compared to the MAF also has undercoverage in rural areas, and the weighting adjustments were found to reduce bias for some estimates and increase the bias for others[12]. These frame improvement methods were evaluated because these are less expensive techniques to adjust for frame undercoverage than canvassing the areas to identify missing housing units through area listing to construct a sampling frame. The 2010 Sample Redesign continues using area listing to improve the coverage of the HU frame, but with an 80 percent reduction in listing workloads compared to the area frame listing workloads from the previous redesign (U.S. Census Bureau 2011a). Area listing for the 2010 Sample Redesign is concentrated in certain states and only those blocks with a high probability of MAF undercoverage.

A simple random sample of blocks is to be selected from the list of blocks that to have poor MAF coverage will be selected. The sampled blocks are then listed to identify housing units that the MAF missed, which are referred to as omissions. The MAF-omissions frame consists of these omissions and will likely be sampled with certainty or probability less than one[13]. Some demographic surveys will not need area listing, and thus will not be sampling from the MAF-omissions frame. As was mentioned above, the MAF undercoverage is concentrated in rural pockets of a small number of states; it is not critical for surveys that only publish national-level estimates to sample from the MAF-omissions frame. The U.S. Census Bureau 2009a found that the survey estimates are not significantly biased at the national-level, only state-level survey estimates are affected by the MAF rural area undercoverage. For those surveys that do not publish state-level estimates, cost is the key factor in deciding whether to sample from the MAF-omissions frame.

5. Summary

This paper has provided an overview of the sample design for the redesigning demographic surveys and highlighted the major changes to the methodology for the 2010 Sample Redesign, starting with the continually updated MAF-based sampling frames to changing the frequency of the USU sampling from once every ten years to annually. These are significant changes. It changes how the U.S. Census Bureau will select and disseminate samples. This provides more opportunities to implement methodological and process improvements, not needing to wait for ten years as in the past. With that, the continuing research for the redesign surveys beyond 2010 has begun. The continuing research agenda includes the following: exploring the potential of administrative records data, such as, IRS income and demographic information from the Social Security Administration to use outside of decennial census years for stratifying PSUs and sorting housing units on the sampling frames; evaluating the benefits of a clustered-design to reduce field travel costs for personal visit interviews; and comparing the potential risks of disclosure in a clustered survey versus a non-clustered survey. As was mentioned in Section 2.1, basing the size of PSUs on the constraints established in the early 1950 needs to be re-evaluated. There is also high interest in continuing research into frame improvement methods that are less costly than area listings.

[12] Overall, the weighting adjustments research was inconclusive because the needed data were either not available or readily available for the detail-level computations.

[13] The sampling methodology for the MAF-omissions frame is under development (U.S. Census Bureau 2011f).

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References

Ernst, L . R. (1986), "Maximizing the Overlap between Surveys When Information is Incomplete," *European Journal of Operational Research*, 27, 192-200.

Ernst, L. R. and Ikeda, M. (1995), "A Reduced-Size Transportation Algorithm for Maximizing the Overlap between Surveys," *Survey Methodology*, 21, 147-157.

Friedman , H.P. and Rubin, J. (1967), "On some invariant criteria for grouping data," *Journal of the American Statistical Association*, 62, pp. 1159-1178.

Murphy, Padraic (2008), "An Overview of Primary Sampling Units (PSUs) in Multi-Stage Samples for Demographic Surveys," *Proceedings of the American Statistical Association, Government Statistics Section*.

Ohlsson E. (1996), "Methods for PPS Size One Sampling Coordination," Institute of Actuarial Mathematics and Mathematical Statistics, Stockholm University, No. 194.

Ohlsson E. (1999), "Comparison of PRN Techniques for Small Sample Size PPS Sample Coordination," Institute of Actuarial Mathematics and Mathematical Statistics, Stockholm University, No. 210.

Rottach, R. and Murphy, P. (2009), "Maximizing Overlap of Large Primary Sampling Units in Repeated Sampling," *Proceedings of the Federal Committee on the Statistical Methodology Research Conference*, pp. 4.

U.S. Census Bureau (1991), "Within-PSU Sort and Stratification Research to Improve Survey Efficiency," October 2, 1991.

U.S. Census Bureau (2002), "*Current Population Survey Design and Methodology Technical Paper 63 Revised Version*," March 2002.

U.S. Census Bureau (2004a), "SIPP Fact Sheet (2000 Design)," February 6, 2004.

U.S. Census Bureau (2004b), "CPS Fact Sheet (2000 Design)," July 29, 2004.

U.S. Census Bureau (2006a), "Report from Frame Assessment of Current Household Surveys – Area Frame Study (Doc. #2010-1.0-G-3)," February 17, 2006.

U.S. Census Bureau (2006b), "Decision to Keep Primary Stratification Units (PSU) for the 2010 Survey Redesign (Doc. #2010-3.0-D-1)," March 27, 2006.

U.S. Census Bureau (2006c), *Current Population Survey Design and Methodology Technical Paper 66*, October 2006.

U.S. Census Bureau (2006d), "Summary of 2000 Sample Redesign Stratification and Sort Variables, and Ideas for Using Other Data Sources in the 2010 Sample Redesign (Doc. #2010-3.0-R-2)," March 7, 2006.

U.S. Census Bureau (2006e), "2010 Demographic Surveys Redesign Sample Selection Files (Doc. #2010-3.0-R-3, Version 1.0)," May 26, 2006.

U.S. Census Bureau (2007), "Second Analytical Report for Frame Assessment for Current Household Surveys (FACHS) Area Frame Study (Doc. #2010-1.0-G-5)," October 2, 2007.

U.S. Census Bureau (2008a), "Analytical Report - Frame Assessment for Current Household Surveys – New Construction Study for 2008 (Doc. #2010-1.0-G-2)," September 4, 2008.

U.S. Census Bureau (2008b), "Frame Assessment for Current Household Surveys (FACHS) National Evaluation: Final Analytical Report (Doc. #2010-4.0-G-12)," December 22, 2008.

U.S. Census Bureau (2009a), "A Supplemental Report of the Frame Assessment for Current Household Surveys: Effects of MAF-Based Frame Coverage on Survey Estimates (Doc. #2010-4.0-G-7, Version 1.0)," February 20, 2009.

U.S. Census Bureau (2009b), "Preliminary Recommendation for Using the MAF-based Frame for Title-13 Household Surveys in the 2010 DSSR (Doc. #2010-4.0-R-1, Version 1.0)," September 30, 2009.

U.S. Census Bureau (2009c), "Recommendation of Stratification Methodology of Primary Stratification Units (PSU) for the 2010 Survey Redesign (Doc. #2010-3.2-R-3, Version 1.1)," October 27, 2009.

U.S. Census Bureau (2009d), "CPS Annual Sampling: Preliminary Findings (GEN2010-2)," December 29, 2009.

U.S. Census Bureau (2009e), "Annual Sampling for Demographic Surveys (Doc. #2010-3.8-G-5, Version 1.0),"December 29, 2009.

U.S. Census Bureau (2009f), "Report on Using InfoUSA Address Data for Developing and Enhancing Demographic Survey Frames (Doc. #2010-4.0-G-13, Version 1.0)," August 27, 2009.

U.S. Census Bureau (2009g), "Summary Report for Evaluating the Use of Propensity Weighting Adjustments to Reduce the Impact of Rural Undercoverage of the Master Address File (MAF)-Based Frame (Doc. #2010-4.1-G-2, Version 1.0)," November 16, 2009.

U.S. Census Bureau (2009h), "Charter for PSU Definitions Team (Doc. #2010-3.5-C-1, Version 1.0)," May 19, 2009.

U.S. Census Bureau (2010a), "Exclusion Sampling for the 2010 Sample Redesign (Doc. #2010-3.8-G-6, Version 1.0)," May 24, 2010.

U.S. Census Bureau (2010b), "Decision on Sample Coordination in the 2010 Sample Redesign (Doc. #2010-1.0-D-4, Version 1.0)," June 30, 2010.

U.S. Census Bureau (2010c), "Results of Primary Sampling Unit Selection Methodology Research (Doc. #2010-3.6-G-1, Version 1.0), August 31, 2010.

U.S. Census Bureau (2010d), "Results of Research on Some Weighting Adjustments to Compensate for MAF Undercoverage in Rural Areas (Doc.#2010-4.1-G-1, Version 1.0)," July 1, 2010.

U.S. Census Bureau (2010e), "2010 Sample Redesign Requirements for the PSU Master Stratification Research File (Doc. #2010-3.2-Q-1, Version 1.0)," September 21, 2010.

U.S. Census Bureau (2011a), "Recommendation for the Frame Improvement Universe for Title-13 Household Surveys (Doc. #2010-4.0-R-3, Version 1.0), 2011.

U.S. Census Bureau (2011b), "Operational Logistics of Annual Sampling for the 2010 Sample Redesign (Doc. #2010-3.8-G-7, Version 1.0)," March 16, 2011.

U.S. Census Bureau (2011c) "Recommendation for Selecting Group Quarters Sample Every Three Years and Unduplication Strategy (Doc. #2010-3.4-R-1,Version 1.0), March 1, 2011.

U.S. Census Bureau (2011d) , "Recommendation for Selecting GQ Sample Using a Measure Size of Two Housing Unit Equivalents (Doc. #2010-3.4-Q-4, Version 1.0), March 1, 2011.

U.S. Census Bureau (2011e), "2010 Sample Redesign Requirements for Creation of Unit Frame (Doc. #2010-3.8-Q-3, Version 1.0), May 3, 2011.

U.S. Census Bureau (2011f), "Recommendation for Coverage Improvement (CI) Frame Creation and Sampling Methodology for the 2010 Demographic Surveys Sample Redesign (Doc. #2010-3.8-R-5, Version 1.0), 2011.