Subsampling of Nonrespondents in the 2017 Census of Agriculture

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1. Introduction

As response rates decline, the costs associated with how the survey will be designed, conducted and analyzed to ensure the creditability of results increase. Data collection becomes more difficult and costly, and questions are raised about the best way to address the increased nonresponse bias due to low participation rates. When resources are fixed and initial participation rates are low, a recommended method to achieve the best possible precision levels is to subsample nonrespondents (Harter et al. 2007). Subsampling, also known as double sampling (Neyman 1938), two-phase or sequential sampling (Cochran 1977; Lohr 1999; Harter et al. 2007), has been shown to be effective and efficient in collecting data from nonrespondents and reducing nonresponse bias (Hansen, Hurwitz, and Madow 1953; Thompson 1992; Harter et al. 2007).

In many surveys, responses are initially sought using the most cost-effective design possible that will yield maximum results. In subsampling or two-phase designs, the initial phase of data collection is among all sample units, and the data collection procedure is more economical. The second phase is then among a probability-based subsample of nonrespondents that utilizes more costly, yet proven and effective, data collection procedures (Groves and Heeringa 2006; Thompson and Kaputa 2017). While the subsampling phase uses more costly methods, it has been shown to save resources overall when the likelihood of obtaining participation is low, or when the cost per interview increases (Elliott, Little, and Lewitzky 2000). Another feature of subsampling is that it can be used adaptively during data collection. Meaning, subsampling does not require planning before data collection begins, but rather can be implemented later in the process if it becomes apparent that resource constraints and nonresponse bias are imminent threats (Harter et al. 2007).

The 2017 Census of Agriculture conducted by the National Agricultural Statistics Service (NASS) is an example where higher than normal nonresponse bias became a concern during data collection. The Census of Agriculture is conducted on a quinquennial basis and is the only source of uniform, comprehensive and impartial agricultural data for every county in the United States. The response rate for the Census of Agriculture has declined over consecutive collections since 2002. Despite great efforts to increase public awareness and participation (including the addition of a new web mode), the 2017 Census of Agriculture response in the initial phase of data collection was significantly lower than reasonably anticipated given the Census of Agriculture's history. As a result, the nonrespondent pool was too large for NASS's traditional census nonresponse follow-up (NRFU) method in the available timeframe. Given the resource constraints, NASS needed to adapt its NRFU method, ultimately choosing a subsampling design to meet precision-related benchmarks.

The following report provides an in-depth overview of NASS's subsampling design to address nonresponse in the 2017 Census of Agriculture. The theory and methodology of subsampling in the survey methodological literature is presented, as well as examples of large, nationally representative sample surveys and censuses that use subsampling to improve response and quality metrics. The subsampling method developed by NASS and the conclusions drawn from this inaugural effort are detailed near the end of the report.

2. Subsampling Theory and Methodology

Subsampling nonrespondents is a special case of multi-phase sampling. Unlike a multi-stage sample design in a multi-phase sample design, the probabilities of selection in each round of sampling are conditional on the sample drawn in the prior rounds. Design unbiased estimators can be constructed for multi-phase sample designs using a Horvitz-Thompson estimator (Horvitz and Thompson 1952). The probabilities of selection can be calculated by multiplying the first phase probability of selection by the conditional probabilities of selection of each subsequent round. Joint probabilities of selection needed to calculate variances for means and totals can be obtained in a similar fashion. For more details on the construction of a Horvitz-Thompson estimators for multi-phase designs, see chapter 9 of Särndal et al. (1992)

Multi-phase sample designs were first proposed by Neyman (1938). Multi-phase sample designs were originally proposed to increase sampling efficiency in situations where there is little to no auxiliary information of the sampling frame. In this scenario, the first phase of sampling uses a simple sample design, and covariates that can be used for stratification are collected from the sampled units. The second phase design uses the covariates collected in the first phase in the sample design to sample a subset of the first phase sample. For example, the National Survey of College Graduates (NSCG) use the American Community Survey (ACS) as its first phase. Then respondents from the ACS are sampled for the NSCG using strata based on respondents response to the ACS such as demographics, occupation, and degree type and field) (Hall et al., 2011).

Neyman's multi-phase sample design methodology was adapted by Hansen and Hurwitz (1946) to address unit nonresponse. Hansen and Hurwitz (1946) proposed subsampling nonrespondents before moving to the nonresponse follow-up (NRFU). The idea was to use less expensive data collection methods initially and then follow-up on a subset of the nonrespondents with more expensive methods. This strategy fits into the multi-phase sample design framework by using the response indicator as a stratification variable. All respondents are assigned to one stratum and sampled with certainty. Nonresponses are then sampled using a standard sample design. Since it is unknown if a unit on the frame will respond, the probability of selection for a case in the nonrespondent subsample is conditional on the original sample selected.

If 100 percent response is achieved in NRFU, then the Horvitz-Thompson estimators obtained by using the probabilities of selection after the nonresponse subsample is design unbiased. This protection from nonresponse bias is not free since nonresponse subsampling induces sampling variance. Rarely if ever do surveys achieve 100 percent response in NRFU even when more expensive methods are used. If 100 percent response in not achieved, the potential for nonresponse bias still exists. Nonresponse bias is a function of the response rate and the difference in the estimate of interest between respondents and nonrespondents. For subsampling of nonrespondents to reduce nonresponse bias, the data collection after subsampling must reduce the difference in estimates of interest between respondents and nonrespondents while increasing the response rate. This will only be achieved by obtaining responses from respondents not well represented in the original respondent pool. If methods used in NRFU do not obtain a more representative respondent pool, nonresponse bias may not be substantially reduced and the

subsampling will induce sampling error, leading to a larger mean squared error for the estimate of interest.

One criticism of subsampling nonrespondents is that it focuses on one error source, namely nonresponse bias (Groves, 1989). One major concern should be measurement error. As stated above, for subsampling of nonrespondents to be successful in reducing nonresponse bias, the NRFU needs to obtain responses from respondents not in the original respondent pool. If the methods used in the NRFU have different measurement properties than the original data collection methods, this differential response could induce measurement error. This is particularly a concern when the NRFU is conducted in a different mode than the original data collection.

3. Examples of Subsampling in Surveys

There are several prominent examples of subsampling in large nationally representative surveys covering individuals, households and establishments. In each of these surveys, nonresponse during the first phase of data collection provides the impetus for two-phase designs with follow-up (i.e., subsampling) among the nonrespondents. The organizations that have implemented subsampling range from private research organizations to academic survey research centers to federal statistical agencies and can be found in the methodology reviews of some of the most widely cited and used surveys.

For instance, the General Social Survey (GSS), which is conducted by the National Opinion Research Center (NORC) at the University of Chicago, has used subsampling of nonrespondents over the last several iterations of the survey. The GSS is the most prominent active survey that monitors societal characteristics and public opinion in the United States and is widely used by researchers and policymakers. Typically, the nonrespondent subsamples in the GSS have been sampled at rates ranging from about 40 percent to 55 percent (Smith et al., 2019). The sampling rate is built into the subsample design, with a constant rate (e.g., 45 percent in the 2006 version of the GSS) used across all strata in the subsample. The subsample is weighted up to represent all nonrespondents, and the design allows for concentration of the remaining resources to be allocated toward a smaller number of hard-to-reach respondents, thereby reducing response error and nonresponse bias (Smith et al., 2019).

The American Community Survey (ACS), conducted by the Census Bureau, is another prominent example of a large national survey that uses subsampling of nonrespondents. The ACS uses four modes of data collection: mail, internet, telephone and in-person interviews. The mail, internet and telephone modes are used in the first phase of sampling to collect data, with nonrespondents to the mail and internet modes being automatically assigned to telephone follow-up. After the telephone follow-ups, all the remaining nonrespondents then become eligible for the sub-sample frame, where in-person computer-assisted personal interviews (CAPI) are conducted. Sub-sampling rates are determined based on a variety of factors related to mailable and unmailable addresses (e.g., mailable addresses with predicted response rates between 0 and 35 percent), and range from as low as 33 percent in certain subsample strata to as high as 100 percent (i.e., in remote regions of Alaska with at least 10 percent American Indian populations)

(Tersine and Starsinic, 2003). The National Survey of Family Growth (NSFG) is sponsored by the National Center for Health Statistics (NCHS) and conducted by the University of Michigan's Survey Research Center. The NSFG uses a two-phase (or double sample) design to address nonresponding cases. Data collections run for about 10 weeks, and all nonresponding cases that have not at that point been given a final disposition code fall into a subsampling frame. The subsampling frame of nonresponding cases are then stratified by eligibility status and estimated probabilities of response. A stratified random sample of about one-third of the subsample of nonrespondents is selected to send back to the in-person interviewers. This subsampling rate allows for the NSFG to better control costs and efforts to ensure that targeted response rates are met, such as by allowing for larger incentives to be given to the subsampled cases for completed interviews (Wagner et al., 2012).

The 2003 Survey of Small Business Finances (SSBF) is an example of an establishment survey that used subsampling of nonrespondents. The 2003 SSBF was conducted by the NORC on behalf of the Federal Reserve Board (FRB) to collect detailed information on the finances of small businesses, their sources and use of credit. On previous iterations of the survey, the sampling approach constituted what was termed a "single pass," where all cases were sampled once and given an equal level of effort to get completed interviews (Potok et al., 2005). In 2003, the decision was made to use a "two-pass" approach that would more efficiently and effectively work nonresponse cases. Specifically, this approach was designed to reduce efforts to reach difficult cases with low probabilities of completion by prioritizing the cases with the highest probabilities of completion first, and then subsampling the more difficult cases for further NRFU methods.

The Census Bureau investigated using adaptive NRFU strategies in the 2017 Economic Census (Thompson and Kaputa 2017). The goal was to develop a design for the 2017 Economic Census that would maintain the survey's historic response quality while reducing costs. They found that one-size-fits-all subsampling of nonrespondents may not be the best approach and should be determined based on evidence of the best approach to follow. The conclusion was that, of the two approaches tested – (1) only subsampled units receive NRFU and (2) all units receive at least some NRFU with a subsample receiving more effective yet expensive NRFU methods – the NRFU design should follow the evidence available from data collection about the best subsampling protocol to follow, which may differ from survey to survey or population to population (Thompson and Kaputa 2017).

4. Nonresponse Follow-up in the Census of Agriculture

The Census of Agriculture has historically attained relatively high response rates, although they have been trending downward in recent iterations. For example, in the 2007 and 2012 Censuses of Agriculture, the response rates were 78.2 and 74.6, respectively. In the 2012 Census of Agriculture, data collection primarily revolved around mailout/mailback and was supplemented by Electronic Data Reporting (EDR) on the internet and personal enumeration for special classes of records. Follow-up rounds of data collection were used until certain benchmarks and response criteria were met. The initial phase of data collection began with a mailout in December 2012 of approximately 3 million mail packets containing a cover letter, an instruction sheet, a labeled

report form and a return envelope. In February of 2013, the first round of follow-up mailouts were sent to the approximately 1 million nonrespondents to the initial mailout phase and EDR. The remaining approximately 750,000 nonrespondents to EDR, the initial mailout and follow-up mailout received a second round of follow-up mailouts in mid-March 2013.

The NASS nonresponse follow-up (NRFU) typically begins after the initial three rounds of mailouts to all remaining nonrespondents. However, select targeted groups among the Census nonrespondents are usually given extra effort in the form of telephone and in-person enumeration. In 2012, the targeted groups were those records determined to be Suspicious Out-of-Scope Records, Criteria Records, Must Cases, American Indian and Alaska Native Farm Operators, Low Response Counties, Last-Call Nonresponse, or Not-on-Mail List (NML). These groups received personal follow-up through either a call from a NASS telephone call center or an in-person enumerator.

Follow-up for the Criteria Record group is one example where a method akin to subsampling occurred in the NRFU stage of the 2012 Census of Agriculture. Criteria Records are those for which the farm status has not been confirmed through a response to the National Agricultural Classification Survey. Some Criteria Records are recently identified potential farms, and others have either refused or failed to respond to the survey. These records are determined to have the lowest probability of being farms and responding to surveys. However, it has been important to enumerate these records because if they are farms, they are likely to be small farms. Therefore, it was necessary to identify records in the Criteria Records group that were farms in order to improve coverage of the small farm population. In 2012, there were 276,043 Criteria Records included in the Census Mail List (CML). After the returns from the initial mailout phase were processed, a sample of the nonrespondents with a Criteria Record label was taken for telephone follow-up using CATI. Of the Criteria Records nonrespondents after the initial mailout phase, 23,739 were subsampled for CATI, with 18,831 being re-contacted by certified mail after being unable to be reached during CATI follow-up. The subsampling of the Criteria Records nonrespondents resulted in 10,887 returns from both telephone and certified mail. This equates to a subsampling response rate of approximately 46 percent using the American Association for Public Opinion Research's Response Rate 1 (RR1) method for this group.

Another subsampling-related procedure in the 2012 Census of Agriculture took place with the Low Response County Follow-up methods. This method involved NRFU to only those counties where the nonresponse rate was greater than 25 percent (in other words: where the response rate was below 75 percent). Additionally, an adaptive design method was designed to prioritize NRFU efforts so that response from minority operations and specialty commodity producers would increase. Nonresponse follow-up to this group was successful in its goal to increase the number of minority operations covered in the census, and to ensure that each county achieved at least a 75 percent response rate. Under this method, NRFU ended for a given county when a 75 percent response rate for that county was reached.

A third form of a subsampling-related procedure in the 2012 Census of Agriculture occurred with the Last Call Nonresponse Follow-up group. This group was used to push the goal of achieving a national response rate of 80 percent and involved targeting only the remaining

nonrespondents with an expected value of sales greater than $50,000. Furthermore, only these records from counties with response rates below 75 percent were eligible for this NRFU method. These records received personal CATI enumeration, and the activity terminated for a given county when the county reached a 75 percent response rate. The NRFU stopping rules for Low Response County and Last Call Nonresponse records can be compared to the Must Case Follow-up group, where there virtually was no stopping rule. For these specialized records, personal enumeration advanced to the effort level of in-person follow-up for any remaining nonresponding cases until all the Must Case records were accounted for in the Census. In 2012, all Must Cases were ultimately accounted for as a result of this NRFU method.

Although these methods are similar to nonresponse subsampling, these methods did not use a probability sampling method for which a design unbiased estimator could be formed. This meant that these methods could only be accounted for in the nonresponse adjustment. This is not to say that these methods did not increase the quality of the 2012 Census estimates since they all had the potential to increase the representativeness of the respondent pool and thus had the potential to mitigate the risk of nonresponse bias.

5. Subsampling in the 2017 Census of Agriculture

Consistent with the downward response rate trend seen in the Census of Agriculture from 2002 to 2012, the 2017 Census of Agriculture experienced difficulties achieving desired response rates through the initial rounds of data collection, however, not for a lack of effort. For the 2017 Census of Agriculture, NASS implemented a comprehensive public relations campaign to increase messaging around the Census, and a pre-notification strategy was used at the outset of data collection to increase awareness, improve overall response rates and encourage respondents to report early. For this iteration of data collection, NASS also used Computer-Assisted Self Interview (CASI) on the internet to provide respondents with a web mode to complete the report. Personal enumeration, in the form of CATI and CAPI data collection instruments, was also used to enumerate the special classes of records important to overall response. For CATI data collection, enumerators from five NASS Data Collection Centers were used. For telephone and in-person enumeration, enumerators under contract with the National Association of State Departments of Agriculture (NASDA) helped get reports from respondents. The mail packet preparation, initial mailout and two follow-up mailings to nonrespondents were handled by the U.S. Census Bureau's National Processing Center (NPC). Additionally, all records with a known email address were sent notifications highlighting the improved web census form and notice that the mail packets would be arriving.

Pre-notification to respondents began on November 17, 2017. Between November 27 and November 30, 2017, letters with survey codes and instructions for completing the census online were sent to approximately 1 million producers. In December 2017 and January 2018, around 3 million producers were mailed census mail packets containing cover letters, instruction sheets, labeled report forms and return envelopes. The first and second rounds of follow-up mailouts were sent in February 2018 and March 2018 to 1.5 million nonrespondents and 1 million nonrespondents, respectively. Similar to earlier iterations of the census, select groups of nonrespondents were targeted for personal enumeration via phone and in-person. However, at

this point in data collection, it became apparent that, in comparison to earlier iterations of the census, a new approach to nonresponse follow-up would be needed to reach desired Census representation criteria since the volume of cases that were identified by the 2012 methodology for phone follow-up was larger than the capacity of the phone centers. Instead of the seven targeted selected groups from the 2012 iteration of the census, the number was reduced to three targeted selected groups from the previous iteration (Must Cases, American Indian Producers, and Not on Mail List (NML)) with the rest of the remaining nonrespondents falling into the new National Nonresponse Follow-up group.

The National Nonresponse Follow-up group followed a subsampling design consistent with the literature on subsampling theory and methods. As such, this design focused on nonresponse follow-up that would statistically reflect the characteristics of the nonresponders and increase response rates. The result was a subsample of 249,521 nonrespondents from the remaining 864,260 nonrespondents. The subsample was selected using a stratified random design, where strata were based on state, county, farm size, farm type, producer race and response propensity. Subsample data collection ran from April 2018 through July 2018, with extensive efforts to achieve responses from CASI pushes, autodial calls and CATI and CAPI enumeration. The result was a weighted farm count of 143,847 from 51,846 in-scope completed subsample reports.

5.1 Developing the 2017 Census of Agriculture Subsample

Throughout the initial mail and web pushes of data collection for the 2017 Census of Agriculture, it was apparent that the overall response rate was lower compared to the 2012 response rate during the same time frame. Consequently, the number of counties with nonresponse greater than 25 percent (under 75 percent response rate) was significantly higher than in 2012. Given the data collection time constraints and limited staff resources of the Data Collection Center (DCC), a subsampling design for follow-up of nonrespondents became necessary. For perspective, before data collection began, the DCC had planned for approximately 100,000 nonrespondents in counties with less than a 75 percent response rate for follow-up data collection. By the time the initial three rounds of mailouts were returned and processed, there were more than 800,000.

In March 2018, nonresponses that were going to be taken with certainty were sent to the phone follow-up. This included cases with a large estimated Total Value of Production, including Government Payments (TVPG), cases that potentially had aquaculture, cases needed for coverage adjustment estimation and cases with a high Measure of Priority (MOP). The MOP is a measure intended to address undercoverage of certain populations, such as small farms and minority and women-owned operations, to name a few. Therefore, operations estimated to address undercoverage of targeted subpopulations of farms are given a higher priority score (or, higher MOP) than nonresponding operations estimated to resemble operations with generally good coverage. The MOP values were 0, 5, 10 and greater than 10 (with 0 being the lowest priority and greater than 10 being the highest). The remaining cases continued to be followed up using a combination of robocalls and EDR invite letters.

In late May 2018, a sample of approximately 110,000 cases was selected from the nonrespondents who had not been taken with certainty. These cases were sent an additional questionnaire and then sent to the phone follow-up. These cases were selected using a stratified simple random sample design. Strata were defined by county, MOP and estimated propensity to respond. A bootstrap random forest model fit on Census 2012 data was used to estimate the propensity to respond. These strata were chosen to both target cases identified as important to the final estimates and the desire to increase the number of completed cases.

The sample was allocated using an optimal Neyman allocation for TVPG with a cost based on the average propensity to respond and average MOP of the stratum. The Neyman allocation was adjusted to ensure that no case would have a weight greater than 10. Also, the sample size was increased for counties that had large coefficients of variations after the Neyman allocation. Finally, some cases were grouped for phone follow-up since they had an operator in common. In these cases, if operators were contacted by phone, they would be asked to respond for both cases. Because of this, if one of these cases was selected, the other case was added to the sample.

5.2 Sampling Weights for the 2017 Census of Agriculture

Cases that were sampled were assigned a sampling weight based on the cases inverse probability of selection. These weights were then adjusted at the end of data collection for a few different reasons: (1) Cases not in the subsample that responded after subsampling. These cases were given a weight of one, and cases sampled in the stratum containing this case were adjusted by removing the case from the population size of the stratum. (2) Sampled cases that responded before June 1, 2018. These cases responded before they would have received the questionnaire, and thus it was assumed that they would have responded even if they would not have been subsampled. The weight of these cases was set to one, and cases sampled in the stratum containing this case were adjusted by removing the case from the population size of the stratum and the sample size of the stratum. (3) Cases that were linked to another case in phone follow-up. As discussed above, weights were adjusted to account for the fact that there were two ways that they could have been included in the sample.

6. CONCLUSION

Census results can be powerful, because they serve as a foundation of farm policy and people make decisions based on this information. Declining response rates have increased the costs associated with how the Census is designed, conducted and analyzed to ensure the creditability of these results.

This report provided an in-depth overview of NASS's subsampling design to address nonresponse in the 2017 Census of Agriculture. The theory and methodology of subsampling in the survey methodological literature is presented, as well as examples of large, nationally representative sample surveys and censuses that use subsampling to improve response and quality metrics.

Subsampling in the 2017 Census focused on nonresponse follow-up that would statistically reflect the characteristics of the nonresponders and increase response rates. The result was a weighted farm count of 143,847 from 51,846 in-scope completed subsample reports.

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