Reducing Respondent Burden in the American Community Survey

A Feasibility Assessment of Methods to Ask Survey Questions Less Frequently or of Fewer Respondents

Acknowledgments

This report is the result of the work of a Census Bureau team which was co-chaired by Todd Hughes and Mark Asiala, and consisted of the following team members: Michael Beaghen, Aileen Bennett, Gary Chappell, Grace Clemons, Michael Coan, Arthur Cresce, Andy Dailey Jr., Ken Dawson, Gail Denby, Christine Gambino, Marisa Hotchkiss, Jennifer Ortman, Elizabeth Poehler, David Raglin, Dameka Reese, Kanin Reese, Jennifer Reichert, Nicole Scanniello, Jeff Sisson, and Tony Tersine.

Todd Hughes, Michael Beaghen, and Mark Asiala were lead authors and editors of this report.

Special thanks go to Deborah Stempowski, Patrick Cantwell, Victoria Velkoff, Karen Humes, Tommy Wright, Bill Bell, Eric Slud, Richard Moore, Robert Ashmead, Shirin Ahmed, Lisa Blumerman, and John Thompson for their valuable input into this work.

Table of Contents

Executive Summary

The Census Bureau convened an internal team in 2015 to examine methods such as matrix sampling which may allow the Census Bureau to meet data needs while reducing the burden on ACS respondents. The team identified four possible approaches for further study to reduce respondent burden through asking the survey questions less frequently or of fewer respondents. *These four options were presented as possibilities in order to convey the potential for the approach, without being limited to specific methods.* The four options are:

1. **Periodic Inclusion of Questions:** including questions on the ACS questionnaire only as frequently as the mandatory and required Federal data uses dictate
2. **Subsampling:** customizing the questionnaire such that the sample for individual questions is designed to meet the geographic need specified by the Federal uses of the resulting data
3. **Matrix Sampling:** dividing the ACS questionnaire into possibly overlapping subsets of questions, and then administering these subsets to different subsamples of the initial sample
4. **Administrative Records Hybrid:** using alternative data sources as a direct substitution for survey data collection, potentially in a hybrid approach by including the question on the survey in certain geographic areas to address coverage gaps in the alternative data, or to assist in periodically refining statistical models that use the administrative records to meet data needs

Each approach was assessed according to a set of factors that demonstrate the feasibility and impact of the method. These assessments are designated with "low," "medium," or "high" impact based on the professional judgment of the team members, and not on empirical criteria. These factors are:

1. Operational and processing complexity
2. Impact on the accuracy of the data
3. Impact on data availability for small geographies and groups
4. Estimated reduction in respondent burden
5. Impact on richness of the data products

6. Assessment of additional costs and resources required

The team's analysis yielded the following general observations:

- Option 4, Administrative Records Hybrid, appears to achieve the best balance between burden reduction and impacts on data accuracy, data availability for small geographies and groups, and richness of the data products.
- Option 1, Periodic Inclusion, clearly has the lowest costs across the operations both initially and for ongoing production.
- Although Option 1 has a low impact on the accuracy of the data and the richness of the data products, it does have a high impact on the data availability for small geographies and groups for the affected topics, while achieving only a small reduction in burden.
- Each option would add significant additional operational and processing complexity to the ACS program, though Option 1, Periodic Inclusion, introduces less complexity than the others.
- Option 2, Subsampling, also does not achieve a significantly higher burden reduction (given the set of questions proposed that met our initial criteria), and has higher impacts on data accuracy and the richness of the data products than Option 1.
- Option 3, Matrix Sampling, does achieve higher burden reduction for individual households, but has high impacts on data accuracy, data availability for small geographies and groups, and the richness of the data products.
- Options 2, 3, and 4 would all require significant additional resources to prepare for initial implementation, although Option 4, Administrative Records Hybrid, requires slightly less resources for ongoing production.

Given these assessments, the team makes the following recommendations:

1.) **Pursue Periodic Inclusion.** As an initial step, the team recommends only periodically including any questions where the frequency and geographic needs for the data can be supported through asking some questions less frequently than every year. This option includes a comparatively low level of both effort and negative impacts.
    a. This document identifies three questions on the ACS that, while known to contain Federal mandatory and required usages, might meet the criteria for periodic inclusion.

The Census Bureau will engage in further discussion with the impacted Federal agency stakeholders in order to clarify their needs.

b. The Census Bureau will also engage Federal and non-Federal data users to deepen its understanding about the impact of including these questions only periodically.

c. The Census Bureau will explore the possibility of expanding the list of potential questions for periodic inclusion by confirming with other Federal data users the timing of their needs for data, as well as the geographic levels necessary. Once this is confirmed, the Census Bureau will seek input from non-Federal data users to understand the impact of including any additional identified questions only periodically.

2.) **Pursue options for incorporating Administrative Records.** Preliminarily speaking, it appears that using administrative records either as a substitute for survey data collection for some topics included in the ACS, or via a hybrid approach with partial survey data collection, could significantly reduce respondent burden. When compared with subsampling and matrix sampling, using administrative records also seems to involve fewer potential undesireable impacts.

a. It would not be possible to pursue using administrative records until the availability and suitability of the data within them is evaluated. The Census Bureau has outlined a research program[1] to carry out this evaluation.

b. Because it is possible that the research program will reveal that hybrid approaches including some partial survey data collection will be necessary, the Census Bureau should continue researching how the ACS could operationalize multiple questionnaires into data collection and processing operations.

c. Pursuit of the research program will be dependent on sufficient FY16 resourcing.

3.) **Seek additional input on efficient possibilities for Matrix Sampling or topical subsampling.** Matrix sampling and topical subsampling could yield benefits such as expanding overall survey content while simultaneously reducing individual household respondent burden. However, they

[1] U.S. Census Bureau. (2015) "Evaluating the Availability and Suitability of External Data Sources for Use in the American Community Survey." (see http://www.census.gov/programs-surveys/acs/operations-and-administration/2015-16-survey-enhancements/external-data-sources.html)

also present potentially costly impacts on survey operations and the accuracy and richness of survey estimates. Therefore, the Census Bureau is seeking input that may help to develop research into efficient and effective designs for matrix sampling.

a. The Census Bureau is working with the National Academies of Science Committee for National Statistics (CNSTAT) to conduct a public workshop that will include this topic among others.
b. The Census Bureau is also planning an expert meeting with CNSTAT focused on this subject.

Introduction

Background

Balancing the nation's need for detailed social, economic, and housing information with the need to minimize burden on respondents is of great importance to the Census Bureau. Some respondents have expressed that the survey is too lengthy, burdensome, and intrusive. However, reducing the length of the survey could have profound consequences on the information available for decision-making by communities and businesses if the data they require cannot be obtained from another source. The goal of the Census Bureau is to strike a reasonable balance between minimizing respondent burden and providing communities and businesses with the necessary information to make informed decisions.

The Panel on Addressing Priority Technical Issues for the Next Decade of the American Community Survey, convened by the Committee on National Statistics, encouraged the Census Bureau to consider ways to "reconceptualize the survey as a set of 'core questions' that are administered using the current schedule and sample size, and other questions that are administered less often or to only a portion of the sample."[2] It went on to say that options such as subsampling, matrix sampling, special modules of questions, and the use of administrative records could reduce respondent burden, but would "unavoidably increase the complexity of an already complex survey, both in terms of survey operations and the analysis of the data."

The current design of the ACS asks all of the survey questions from all sampled households every year. However, the 2014 Content Review identified several opportunities to include some questions periodically, rather than asking every question, every year. For example, one question asks about the sale of agricultural products from a household's property. Data related to this question are only needed by the Department of Agriculture once every ten years and only at the state level, so it's not necessary for it to be included on the ACS annually. Methods such as matrix sampling may allow the Census Bureau to meet data needs with reduced burden on ACS respondents.

[2] *Realizing the potential of the American Community Survey: Challenges, Tradeoffs and Opportunities*. (2015). Panel on Addressing Priority Technical Issues for the Next Decade of the American Community Survey, Committee on National Statistics; Division of Behavioral Sciences and Education. Washington, DC: The National Academies Press.

The Census Bureau convened an internal team in 2015 to examine these issues in preparation for engaging both the Federal and non-Federal data users, as well as statistical experts, and the general public on the feasibility and impacts of using administrative records, matrix sampling, topical subsampling, and the periodic inclusion of questions. Team members reviewed the responses provided by other Federal agencies related to the needed frequency of the data for their uses, as well as the geographic levels needed. Through this review, the team was able to identify a set of topics and questions that may be asked less frequently or of fewer respondents while resulting in relatively few negative impacts. With this information, the team identified and assessed several possible designs for asking fewer questions of individual respondents, while still meeting the data needs of our Federal data users, several of whom have legal mandates for using ACS data.

The team devised potential design changes that when used alone or in combination could reasonably balance the burden to respondents with the needs of Federal and non-Federal data users. Further research is planned to determine conclusively if the design changes are feasible. Some of the design changes the Census Bureau would like to further explore are:

1. Revising the questionnaire each year to bring questions on and off the survey as needed in accordance with the mandated frequency of the data need.

2. Fielding multiple versions of the questionnaire simultaneously so that some households are asked fewer questions than others while still yielding sufficient data for producing estimates for the geographic areas each year that match a Federal agency's needs regarding a specific topic.

3. Combinations of design changes could potentially be buttressed with enhanced statistical methods (such as imputation and weighting) or through folding in data from alternative sources.

Although these options would be designed to reduce the number of questions that an individual household would be asked, there would be challenges in the complexity of the operational and statistical methods used to collect, tabulate, and release data. Additional research will allow the Census Bureau to determine the scope of the operational and statistical challenges so that they may be fully understood in relation to the associated reduction in respondent burden. In addition, some possible

designs could impact the accuracy of the data released or the richness of the data products produced. Therefore, the Census Bureau has prepared this initial report to outline the statistical and operational feasibility of these approaches, and potential impacts to respondents and data users.

Overview of this Document

This report provides an overview of four possible means to reduce respondent burden through asking the survey questions less frequently or of fewer respondents. *These four options are discussed as illustrative descriptions of how the Census Bureau could consider implementing each approach. The discussion and possible methods are meant to convey preliminary considerations of the potential of the approach, without being limited to specific methods.* Some initial discussion of the operational and statistical challenges for each approach is presented. Additionally, each approach is assessed according to a set of factors that demonstrate the feasibility and impact of the method. These assessments are designated with "low," "medium," or "high" impact based on the professional judgment of the team members, but not empirical criteria. These factors are:

1. Operational and processing complexity
2. Impact on the accuracy of the data
3. Impact on data availability for small geographies and groups
4. Estimated burden reduction
5. Impact on richness of the data products
6. Cost impact

Since some of the proposed options require the use of multiple questionnaires concurrently, or changing content from year to year, a general discussion of the operational context associated with these options is presented before the detailed discussion of individual options. Additionally, since some of the approaches outlined in this report have similar statistical challenges, an overview of statistical issues and potential tools is also provided before the discussion of the individual options.

A literature review of research for these statistical challenges and tools connected with these options is available in Appendix 1, while Appendix 2 provides some technical details associated with these challenges and tools. Appendix 3 provides an examination of what reductions in sample size we could make associated with Option 2 while still meeting programmatic requirements for reliability.

Appendix 4 provides insights into the ripple effects on edits processes due to changes to the set of potential items included as meeting the criteria for Option 1, periodic inclusion, and Option 2, subsampling.

The Census Bureau team is cognizant that any decisions about ACS design changes will necessarily include holistic consideration of:

1) The nature of the design change

2) The degree of respondent burden reduction associated with the change

3) Operational context

4) Statistical complexities introduced by the design change, and

Viewing any of these four factors in isolation from the others does not provide enough context for responsible decision-making about any of the potential changes the team identified. The factors are, in fact, interdependent.

Discussion of Operational Context

Some of the options described later in this document involve having different questionnaire content for some subgroups of the ACS sample, or significantly modifying the ACS questionnaire content from year to year (for example, if asking some questions less frequently than every year). Each option that involves multiple questionnaire versions would yield its own set of operational impacts on data collection and processing due to simulateous data gathering based on different combinations of questions. Significant year-to-year content changes would introduce a further degree of complexity for data gathering and processing. As it strives to pursue new survey options that strike a reasonable balance between burden reduction and operational complexity, the Census Bureau details the operational impacts below.

Operational Impacts of Frequent Changes from Year-to-Year in Questionnaire Content

The current design of the ACS housing unit data collection involves multiple modes with questionnaire formats for web, paper, telephone and personal visit interviews. Additional versions of the paper questionnaire and automated instruments are also available in Spanish. Separate automated instruments are also developed for Telephone Questionnaire Assistance and Failed Edit Follow-Up operations. Designing, developing, reviewing, and testing the many varied questionnaire formats, and integrating data from the multiple operations and formats, requires significant effort and careful oversight.

Given that the various data collection operations are generally in production every day of the year, and each monthly sample panel continues for approximately three months of data collection, introducing new or revised questions and removing old questions must be carefully planned and executed in order to produce an annual set of data for tabulation and dissemination. In many instances, individual questions also have connections to many other questions in the current edit and imputation processes, so individual question changes can have significant ripple effects throughout the edit and imputation process for other items.

Given the complex nature of tabulating ACS data and disseminating billions of estimates and more than a thousand tables each year for ACS topics that are often crossed by other topics, individual

changes to one question can impact numerous tables and many tabulation and dissemination systems. Producing multi-year estimates is a key part of the ACS design, and data collected and compiled across five years are required to produce an estimate for the lowest levels of geography and small population groups. Question changes may require mapping response data from previous years to enable production of the multi-year estimates, or may make it impossible to produce some multi-year estimates. Given all of this complexity, the Census Bureau has historically worked to minimize ACS questionnaire content changes each year, and resources and schedules must be scaled appropriately to support additional work associated with more frequent content changes.

Operational Impacts of Concurrent Use of Multiple Questionnaires

Design options that would include multiple questionnaires with different combinations of content concurrently being used in data collection create additional complexities. Having multiple versions of a paper ACS questionnaire is especially challenging given that each additional version of a paper form in production requires additional design, printing, templates for imaging and data capture, as well as integrating different streams of captured data through data processing and coding. Quality assurance processes for data capture and coding for this design alternative would need to be examined for possible revision, and coder performance measures that are based on current form lengths would need updating.

If multiple versions of the questionnaire were used concurrently, the automated instruments used for web, telephone and personal visit data collection would likely need to employ strategies that rely on custom routing through a shared questionnaire, skipping questions as needed based on input values fed into the software in advance. This approach would allow for a single instrument to be used for each mode and would simplify interviewer training compared to having separate automated instruments for each version, but it would significantly complicate the instrument specification, as well as design, and testing for each. Definitions for various outcome and status codes related to partially completed interviews would be especially complicated and require careful revision. Integrating data from these automated instruments would be similarly complex. The Telephone Questionnaire Assistance operation currently requires collecting the ID from the respondent's mail materials, but occasionally respondents are unable to provide the ID and a matching process is used after the interview to use address information to link the case data to a case ID. With multiple forms in production simultaneously, households that are unable to provide an ID would not be able to receive only the custom content that

was intended for that household, and a full questionnaire would likely have to be asked of the household.

Programs that review mail and web returns for data completeness to determine eligibility for the Failed Edit Follow-Up operation would need significant revision to account for the intended missing data for that particular case, given the correct version of the questionnaire. In summary, changes to the automated instruments to account for different sets of households receiving different questions in production at the same time would result in greatly increasing the complexity of developing, testing, and processing data from these instruments, because all paths of the instrument must be tested, and these changes would greatly increase the number of instrument paths. Development and testing schedules would need to be extended, and resources to participate in the development and testing process would need to be expanded.

Using multiple questionnaires with different combinations of content concurrently would also impact the operational challenges associated with editing, weighting, and use of the Primary Selection Algorithm or PSA. The PSA is the set of rules used to select the best return when two returns are received, such as when both a mail return is received and a computer assisted personal interview is conducted. As described earlier, the new statistical approaches needed in these operations will significantly increase the complexity of these processing operations that are already quite complex, and will require significant modification from the current approach. New approaches to these processes will require a high initial level of effort to design and program changes to the systems that support editing, weighting, and use of the PSA, and an ongoing increased level of effort for testing and validation of these systems. As an example of the processing complexity introduced, the edits and PSA would need to account for the fact that missing data may be intentional due to not asking the question on this version of the questionnaire versus unintentional due to the respondent not answering the question. This may require increased complexity in the outputs produced by the data collection instruments to differentiate missing data for questions based on eligibility for collection for that household. Given that imputation matrices are currently limited to five dimensions, the addition of new factors accounting for geography or eligibility to be asked the question may exceed current capacity and would potentially require significant redesign of the imputation process.

Operations supporting the production of the ACS data products would also be impacted by the use of multiple questionnaires concurrently with differing content. Depending on the statistical methods used to integrate data from these different versions and account for missing data, the response data for individual questions may have higher variances. Given that table filtering is based on the reliability of the data presented, data products would potentially require increased filtering resulting in reducing the richness of data released.

Options for reducing individual respondent burden that involve having multiple versions of questionnaires in production concurrently would increase complexity of testing other enhancements to the ACS data collection methods. In an effort to improve agility and responsiveness in testing various methodological changes in data collection, in 2014 the Census Bureau parsed the production ACS sample into multiple, nationally representative subgroups that could be invoked to conduct split-panel experiments in the field using production sample units. This has enabled the Census Bureau to move more quickly from experimental design through implementation of field tests, and has reduced the cost of testing compared to fielding experiments using separate samples. This agility and responsiveness to emerging needs using embedded experiments could be hampered if the ACS employs multiple production versions of the questionnaire in a complex design.

Special Considerations for Group Quarters and Puerto Rico

The Committee on National Statistics' Panel on Statistical Methods for Measuring Group Quarters Population in the American Community Survey recommended that the Census Bureau consider "customizing by group quarters (GQ) type the American Community Survey Questionnaire for the GQ population with the goal of reducing item imputation rates, improving data quality, and reducing the burden on the GQ respondents who are required to answer questions that are not applicable to their circumstances."[3] The Census Bureau agrees that efforts to significantly reduce burden through

[3] National Research Council. (2012). *Small Populations, Large Effects: Improving the Measurement of the Group Quarter Population in the American Community Survey.* Panel on Statistical Methods for Measuring Group Quarters Population in the American Community Survey, Paul R. Voss and Krisztina Marton, Editors. Committee on National Statistics, Division of Behavioral and Social Sciences and Education. Washington, DC: The National Academies Press.

customized questionnaires for different GQ types would have value, and data needs by specific GQ types should drive decisions regarding modifications to the ACS GQ questionnaire. Therefore, GQ questionnaire design would not necessarily follow other options proposed in this document for the ACS housing unit questionnaire.

Additionally, special consideration should be given for the Puerto Rico Community Survey (PRCS). The design of the PRCS includes somewhat customized questionnaire content to address the needs of Puerto Rico, and the sample was designed to provide reliable data given the population size of Puerto Rico and the lower self-response rates historically seen there. Employing strategies to reduce respondent burden that would reduce the amount of data collected in Puerto Rico would likely have more significant impacts on the quality of the data produced from the PRCS, and should be considered with great caution.

Given these special considerations, we have not included specific modifications to GQ data collection or the PRCS in the discussion of the various options presented in this document.

Discussion of Statistical Challenges and Tools

Overall Background on Statistical Challenges

As previously described, burden reduction potential, while compelling, cannot be viewed in isolation from other impacts. Burden reduction presents several broad statistical challenges for the ACS, though they vary with the four options presented in this report. These challenges, along with statistical tools to handle them, are discussed briefly in this section and in more detail in Appendix 2.

The foremost challenge is the loss in precision of ACS estimates. (Precision refers to how close estimates from different samples are to each other. The standard error and margins of error are measures of precision and sampling error.) The loss in precision would entail scaling back from the current ACS mission to produce estimates for the smallest geographies or for the smallest population groups.

Another challenge would be that the ability to produce cross-tabulations, a key form of ACS data products, might be limited. A cross-tabulation is a table of data which shows estimates for groups defined by two or more characteristics. Certain cross-tabulations may be impossible to produce, or they may be of lower quality and not suited for publication.

If we ask only a subset of households a particular question, we will have a large proportion of blank responses for that question. These blank responses result in operational challenges to the edit and imputation process, disclosure avoidance, weighting, and final tabulation recode processes that create the final file used for tabulation.

Burden reduction methods could lead to complications with the Public Use Microdata Sample (PUMS). The PUMS data may be incomplete, or we may have to publish PUMS with large amounts of imputed data items. Publishing substituted administrative data may be against policy of the data provider.

Burden reduction methods also have the potential to introduce significant bias into ACS estimates. A biased estimate is one that on average over- or underestimates the quantity being estimated. In particular, modeling and imputation methods can introduce bias into estimates. A bias that is small in

comparison to the improvement in precision gained by a method is generally considered acceptable. It would be necessary to assess any potential bias of our methods.

Lastly, the administrative record hybrid approach would require a strong source of administrative records and a successful match to the ACS. These challenges are currently being investigated by other groups at the Census Bureau and are beyond the scope of this report.

Overall Background on Statistical Tools

The statistical tools described in this section pertain only to matrix sampling. The periodic inclusion is simple enough that it requires no new statistical methodology, and the methods for building and matching to an administrative records database are beyond the scope of this report. There are several established tools for the statistical handling of matrix sampling which could be applied, each with its particular strengths and demands on resources. A literature review of matrix sampling can be found in Appendix 1, and a more detailed discussion on these statistical tools for matrix sampling can be found in Appendix 2.

The simplest approach for weighting with matrix sampling is to use content-specific weights for those questions which were subsampled. Instead of one weight assigned to each person and housing unit to apply to all characteristics, each person and housing unit would have multiple weights. One of these weights would be used to tabulate any particular characteristic or to cross-tabulate two or more characteristics. The data file would be left incomplete for those questions not asked of a given sampled household. It would be advantageous for the weighting and tabulation to group the variables into modules which are selected together in the matrix sampling, as this would require fewer additional weights. With more weights the tabulation is more burdensome, and some cross-tabulations may be impossible to create.

Imputation methods can complete the data file for those questions not asked of all sampled households. A complete data file would allow for more seamless editing, imputation, disclosure avoidance, and tabulation. One approach to imputation would be to extend the current ACS production hot-deck imputation. A hot-deck imputation would be relatively straightforward to implement and it may mitigate the loss of precision due to subsampling. With this method we can produce

cross-tabulations of subsampled-out questions which are not in the same sample, although such tabulations would consist entirely of imputed data and may not be of sufficiently sound quality.

An alternative to hot-deck imputation would be multiple imputation. This method is grounded advanced statistical theory and leads to complexities in implementation. It may have statistical advantages in mitigating the loss of precision and in other aspects of the estimation. However, multiple imputation would be a new method for the ACS and it would require substantial research and development for implementation.

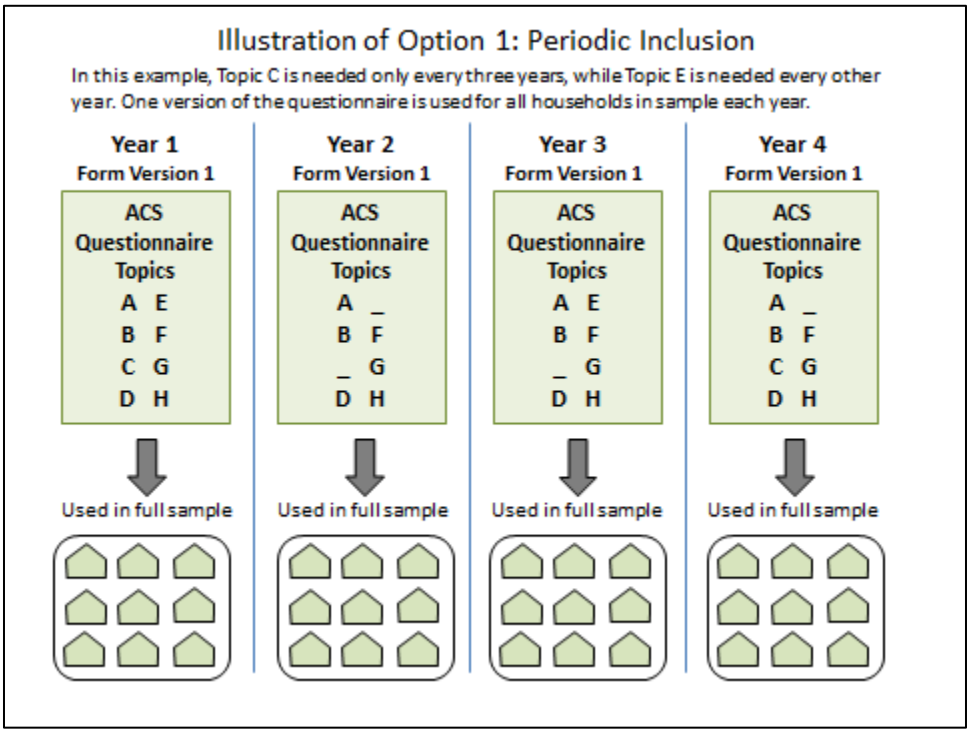
If an incomplete data file with content-specific weights as described earlier is acceptable, then there may be additional methods available to mitigate the loss of precision with matrix sampling. First, one could use generalized regression models to exploit the correlation between subsampled questions. Further, if there is a source of administrative records but direct substitution is not feasible or desirable, one also could incorporate the administrative records into the current ACS generalized regression step (also referred to as model-assisted estimation).[4] This approach would exploit the correlation between the subsampled questions and the administrative records data. The implementation of both of these methods would be straightforward.

[4] American Community Survey: Design and Methodology. Chapter 11, page #25. http://www2.census.gov/programs-surveys/acs/methodology/design_and_methodology/acs_design_methodology_ch11_2014.pdf

Option 1: Periodic Inclusion of Questions

Operational Overview

The Census Bureau conducted an examination of the responses provided by Federal agency stakeholders during the 2014 ACS Content Review concerning the frequency of data collection and level of geography needed for each topic on the ACS in order for these agencies to meet their program requirements. The current design of the ACS provides estimates each year for the nation, all states, and geographic areas with a population of 65,000 or more. Five years of data are required to produce data for smaller geographic areas and population groups. If the frequency and geographic needs for the data can be supported through asking some questions less frequently than every year, respondent burden could be reduced by having a given topic on the questionnaire only as often as is necessary to produce the data. The figure below provides an illustration of how this might work from year-to-year.



The team considered the criteria below as indicators of potential periodic inclusion during its review of the 2014 Federal agency responses to the 2014 ACS Content Review.

1.) There are no mandatory[5] and required[6] Federal usages that rely on data at the Tract or Block Group level,

AND

2.) All of the mandatory and required Federal usages are needed less frequently than every 1 year, or the timing of the need is unclear.

This led to the identification of three topics on the ACS questionnaire that potentially met these criteria:

- Agricultural Sales (question number 5 in the housing unit section of the questionnaire): five mandatory uses at the state level, needed every 10 years. Given that state level estimates can be produced with only one year of ACS sample, this could potentially lead to asking this question only once each ten years.
- Period of Service (question number 27 in the person section of the questionnaire): two mandatory uses and one required use at the county level, with unclear timing needs.
- VA-Service Connected Disability Rating and Status (question number 28 in the person section of the questionnaire): one mandatory use and three required uses at the county level, with unclear timing needs.

We acknowledge that removing these three questions would not lead to significant reductions in the burden for each responding household. These are preliminary criteria, and other items may be potential candidates for periodic inclusion. For example, in a May 29, 2015 notice in the *Federal Register*, the Census Bureau informed the public that it would continue to look into periodically including the questions on marital history[7]. Additionally, if further discussion with Federal agency data

[5] **Mandatory** – a federal law explicitly calls for use of decennial census or ACS data on that question

[6] **Required** – a federal law (or implementing regulation) explicitly requires the use of data and the decennial census or the ACS is the historical source; or the data are needed for case law requirements imposed by the U.S. federal court system

[7] https://www.federalregister.gov/articles/2015/05/29/2015-13061/submission-for-omb-review-comment-request#p-14

users could clarify their needs, we may be able to identify ways that additional topics could be asked with less frequency. Although one key design feature of the ACS is the provision of updated data each year, prior to the full implementation of the ACS in 2005, Federal agency stakeholders had been accustomed to using Census long form data that had been updated only once every ten years. Therefore, there may be instances where Federal agency stakeholders can meet their needs without having updated data each year. We also acknowledge that the criteria used to identify the potential questions above did not account for programmatic[8] uses by Federal agencies, or other important uses outside of the Federal government.

Discussion of Statistical Approach

Assuming periodically included questions are used to produce only 1-year estimates they would have no implications for the weighting. They would simply use the 1-year weights. Depending on the level of geography required, a question could be asked periodically for only a subset of the sample. In this case, one would also need to consider the assessments of using subsampling or matrix sampling in the later discussion of Options 2 and 3. Periodic inclusion can be implemented in conjunction with other methods of burden reduction in an uncomplicated manner in terms of statistical methodology.

Discussion of Operational Context

To implement this approach, questionnaire content would change from year to year. If multiple questions are coming on and off the form with differing yearly frequencies, a schedule of questionnaire changes would be needed. This would be quite feasible given the ACS program's experience with managing other questionnaire changes at the start of a new data collection year. However, in the assessment of the feasibility of this option, the Census Bureau is assuming that periodic changes in questionnaire content would be limited to the start of each year—no question changes would be implemented for sub-annual periods or during the year. The issues outlined in the "Operational Impacts of Frequent Changes from Year-to-Year in Questionnaire Content" section of this document would be relevant in connection with this option.

[8] **Programmatic** – the data are needed for program planning, implementation, or evaluation and there is no explicit mandate or requirement

Assessment Criteria[9]

	Operational and Processing Complexity	Impact on the Accuracy of the Data	Impact on Data Availability for Small Geographies and Groups	Estimated Burden Reduction	Impact on Richness of the Data Products
Periodic Inclusion	Medium	Low	High	Low	Low

Operational and Processing Complexity

Given that this option does not require the use of multiple questionnaires concurrently, altering data processing to accommodate this approach is similar to what is currently done when changing content from year to year. There are no implications for the weighting and tabulation, except that what was tabulated for 1-year ACS estimates would change from year to year. The 1-year PUMS processing would not change, and we would simply omit the subsampled items from the 5-year PUMS. However, adding back onto the questionnaire a topic that had been removed for a period of time is not as simple as re-inserting old edit and imputation rules back into production—a reassessment each time would be necessary to evaluate effects throughout the edit and imputation processes. The overall complexity of this approach is medium.

Impact on Accuracy of the Data

The tabulations based on the periodically-included questions would have the same accuracy as the 1-year ACS data for those years for which we collect the data. For the data based on the questions included every year, the accuracy would be unaffected for both 1-year and 5-year estimates. Therefore, we consider the overall impact on the accuracy of the data to be low.

[9] These assessments are designated with "low," "medium," or "high" impact based on the professional judgment of the team members, and not on empirical criteria.

Impact on Data Availability for Small Geographies and Groups

Periodic inclusion of questions would create some limitations regarding small geographies and groups. We could not produce 5-year estimates of those characteristics based on the periodically included questions for geographies below the population threshold of 65,000 (the standard cutoff for producing 1-year estimates). This restriction would eliminate any estimates for tracts and for many counties and places. In addition, with just one year of data as opposed to five, the standard errors and margins of error of estimates for small populations could be expected to more than double in size. Many estimates would become unpublishable, and parts of (or even entire) tables might have to be suppressed. The impact would be greater on cross-tabulations than on univariate statistics as the groups defined by cross-tabulations are smaller. The impact on estimates for rare populations would be severe if the questions that identify them were only periodically included. Thus we assess the overall impact on data availability for small geographies and groups as high.

Estimated Burden Reduction

There are two measures of burden that the Census team discussed in relation to its work on changes in survey design. First is the amount of time it takes to answer a question. As part of the 2014 Content Review, the Census Bureau produced a report on how long it takes respondents to answer questions, based on auxiliary data from the electronic data collection instruments (Internet, telephone, and personal visit).[10] That paper shows the median amount of time to answer each question on the ACS. The second, also from the 2014 ACS Content Review, is a measure of the cognitive burden, sensitivity, and difficulty of each question, as measured by a survey of ACS telephone and personal visit interviewers.[11] Table 1 (see below) shows the questions that met the initial criteria for consideration for periodic inclusion along with measures for the time to answer the question and the perceived burden from the interviewer survey.

[10] "American Community Survey Fiscal Year 2014 Content Review Response Time Per Item", http://www2.census.gov/programs-surveys/acs/operations_admin/2014_content_review/methods_results_report/Response_Time_per_Item_Report.pdf

[11] "American Community Survey Fiscal Year 2014 Content Review Interviewer Survey Results" http://www2.census.gov/programs-surveys/acs/operations_admin/2014_content_review/methods_results_report/Interviewer_Survey_Results_Report.pdf

The Census team measured the 'time to complete' burden in two ways. First itlooked at the median time to complete the question, in seconds, for all households that were asked the question at least once, either in the housing section for the household or for at least one person in the household. However, not all questions are asked of all households, so the Census Bureau also computes an adjusted median that takes that into account. The adjusted median is computed by multiplying the median time for households that got the question by the percentage of households that got the question.[12] Each median yields important information. The median time shows the burden for households that were asked the question and the adjusted median reveals a measure of overall burden. More details on the methodology can be found in the referenced report.

Each question was rated "low," medium," or "high" on cognitive burden, sensitivity, and overall difficulty based on the answers to the questions in the interviewer survey. More details on the methodology can be found in the referenced report.

Table 1: Burden for Periodic Inclusion Questions

Question (and number on the 2015 paper form)	**Median Time (in Seconds)**	**Adjusted Median Time (in Seconds)**	**Cognitive Burden**	**Sensitivity**	**Difficulty**
Agricultural Sales (H5)	7	1	Medium	Low	Low
Period of Service (P27)	18	3	Medium	Low	Low
VA Service-Connected Disability Rating and Status (P28)	7	1	Medium	Low	Low
Total	32	5	Low: 0 Medium: 3 High: 0	Low: 3 Medium: 0 High: 0	Low: 3 Medium: 0 High: 0

The total of the median times is 32 seconds and the total of the adjusted medians is five seconds. Both measures indicate the amount of timed saved by deleting these three questions would be minimal,

[12] For example, if the median time to answer a question took 20 seconds, but only half of the households were asked the question, then the adjusted median would be 10 seconds.

under two percent of the average 40 minutes required to complete the survey. All three questions were judged to have medium cognitive burden and low sensitivity and difficulty.

Overall, the drop in burden with this option would be low, assuming the scope is the three questions discussed here. If additional questions were also considered for this option, there would be an additional drop in burden, but a large number of questions would need to be included periodically for this option to have a noticeable impact on the burden reduction.

Impact on Richness of Data Products

Based on the initial criteria for periodic inclusion, three tables would be affected: two veterans' service-connected disabilities and one veterans' period of service tables. Since 1-year estimates would only be available in years the variables were sampled, documentation and outreach for data users who were accustomed to yearly estimates would be necessary. Multi-year estimates would be possible if the loss in sample were mitigated, but estimates for small subpopulations, particularly those with service-connected disabilities, may still be problematic at lower geographies and the level of detail may not be as rich as the current tables. PUMS files should be unaffected for 1-year, but may also be problematic for multi-year tabulations. It is possible that variables used in this method would be removed from the 5-year PUMS. These three tables would be highly impacted; however, these tables are a very small percentage of the overall data products, and therefore, the impact would be low.

Table 2: Potentially Impacted Data Products for Option1, Periodic Inclusion

Question	Number of Tables Impacted	Potential Geographic Restrictions	Restrictions on Level of Detail for All Geographies	Impact on Multi-Year Data Products	PUMS
Agricultural Sales (H5)	0	Low	Low	Low	Medium
Period of Service (P27)	1	Medium	Medium	Medium	High
VA Service Connected Disability Rating (P28)	2	Medium	Medium	Medium	High
Total	3	Low: 1 Medium: 2 High: 0	Low: 1 Medium: 2 High: 0	Low: 1 Medium: 2 High: 0	Low: 0 Medium: 1 High: 2

In general, crosses between variables would be possible for variables sampled in the same period. However, this becomes more problematic for variables sampled during different periods. Stakeholder engagement would be necessary to determine the minimum level of geography and detail necessary for each variable. Additionally, data users would need to use caution when comparing estimates created before and after the option was implemented. Documentation and user outreach regarding the new methodology and its effect on the tables would be necessary.

If periodic inclusion were extended more broadly across the survey, caution should be given to variables with small and sensitive subpopulations. It is possible that this method would not yield the richness of data that data users have come to expect from these smaller populations. If this method were broadly extended across the survey, the impact to the richness of the data products would be medium.

Assessment of Additional Costs and Resources Required

	Data Collection	Data Processing	Statistical Application & Modeling	Statistical Support	Tabulation & Review
Initial Implementation	Low	Low	Low	Low	Low
Ongoing Production	Low	Low	Low	Low	Low

It is important to note that costs for data collection operations account for roughly three quarters of the overall ACS program budget, therefore, impacts on data collection costs are more significant than impacts to costs for other operations. For data collection activities, periodic inclusion of content will result in a minor increase in cost and complexity over the current design. Although the length of the interview may have minor decreases in this option, the relative costs of contacting respondents versus conducting the interview would lead to negligible reductions in the cost of conducting the interview. There are already processes in place to manage content changes, and the cost and complexity of data processing activities would only increase slightly under this option due to the need to change the layout of data files and data products every year.

The level of effort for ***initial implementation*** of periodic inclusion of some questionnaire items is low relative to the other options for data collection and processing. Changing content from year to year could eventually become a stable process that could be planned for and could follow standard

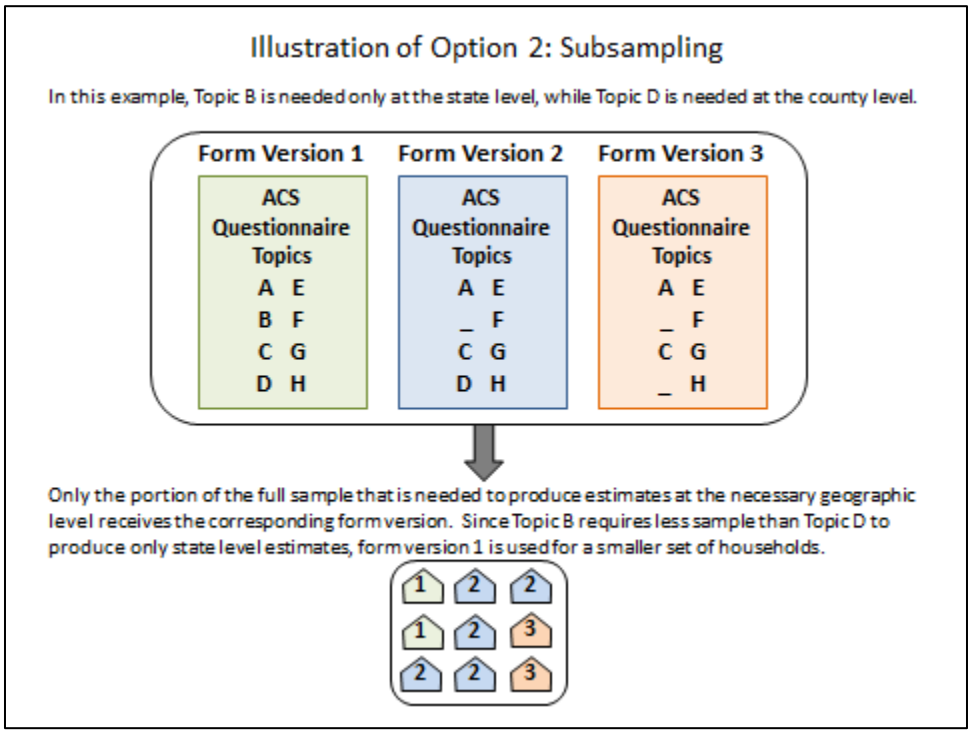
processes. However, in the initial year or two of implementation, additional effort would be required to adjust production schedules to allow for additional quality checks to ensure changes were implemented correctly. Since the ACS program occasionally accommodates content changes from year to year, there is precedent and the current process for developing questionnaires and instruments and adjusting processing requirements will support the periodic inclusion option. Little additional statistical support would be required to implement this option. The initial changes for tabulation would be minimal and mainly involve setting up different specifications and processing rules for single- and multi-year tabulations and review. The changes required would only be a modest increase over the normal year-to-year processing changes for data products.

The level of effort for **ongoing production** of periodic inclusion of some questionnaire items is low relative to the other options. Changing content from year to year can be planned for and can follow standard processes. Since the ACS program already accommodates content changes from year to year, there is precedent and the current process for developing questionnaires and instruments and adjusting processing requirements will support the periodic inclusion option. Once this process has been established as an annual occurrence, the effort to incorporate the changes every year will be minimal. Little additional statistical support would be required for ongoing production of this option. There is only a slight increase in operational costs after initial implementation. The differences between single and multi-year products introduces some continued complexities in processing and review. However, some of this increase would be offset by a reduction in the overall number of products for multi-year data.

Option 2: Subsampling

Operational Overview

The sample design of the ACS is based on reliability criteria for producing five-year estimates for Census tracts. Having reliable data down to the tract level is important for many Federal uses, but other Federal uses for the data only require estimates for larger levels of geography, such as states or counties. The intent for this option is to consider whether we could ask some questions of only a subset of the current ACS sample in order to match the sample size to the data need for a given question. Using multiple versions of the questionnaire in production simultaneously, or employing intelligent skip patterns in the automated modes, would be necessary to ask individual questions from only a subset of the sample households. The figure below provides an illustration of how this might be implemented.



In a similar manner to Option 1, to identify the potential scope of the subsampling option, the Census Bureau conducted an examination of the responses provided by Federal agency stakeholders during the 2014 ACS Content Review for the documented needs for the frequency of data collection and

level of geography needed. The team considered the following criterion as an indicator of potential subsampling during its review of the 2014 Federal agency responses to the 2014 ACS Content Review:

> There are no mandatory and required Federal usages that rely on data at the Tract or Block Group level.

Based on this criterion, the team identified the candidate items for potential subsampling presented in table 3. If individual questions have different subsampling rates, consideration should be given to whether to maximize burden reduction for a given household, or to spread the burden reductions across more households by subsampling independently for different questions.

Table 3: Candidate Items for Potential Subsampling

Question	Description of Mandatory and Required Uses
Agricultural Sales (H5)	Five mandatory uses at the state level, needed every 10 years
Year of Entry (P9)	Two required uses at the county level and American Indian Area/Alaska Native Area/Hawaiian Home Land level, one mandatory and one required uses at state level, all are needed every year
Undergraduate Field of Degree (P12)	No mandatory or required usages, used for subsampling in a survey conducted every 2 years
Marital Status Change in Past 12 Months (P21)	Three required uses at state level needed every year
Times Married (P22)	Three required uses at state level needed every year
Year Last Married (P23)	Three required use at state level needed every year
Period of Service (P27)	Two mandatory uses and one required use at the county level, with unclear timing needs
VA-Service Connected Disability Rating and Status (P28)	One mandatory use and three required uses at the county level, with unclear timing needs
Hours Worked per Week (P40)	Six required uses at place/county/ZCTA/American Indian Area/Alaska Native Area/Hawaiian Home Land level and two required uses at the state level, with some needed each year

Discussion of Statistical Approach

From a statistical perspective, the approaches that could be used to address the impacts of some questions being asked of only a subset of the ACS sample would be the same as tools developed for matrix sampling methods. The key statistical challenges are: the loss in precision of the estimates of characteristics based on subsampled questions; limitations in producing cross-tabulations involving

subsampled out questions; an incomplete data file, which would complicate data processing steps; limitations for the PUMS data; and, the introduction of potential biases. There are several established tools for the statistical handling of matrix sampling which could be applied to Option 2, each with its particular strengths and demand on resources. These include content-specific weights, hot-deck imputation of subsampled out questions, multiple imputation of subsampled out questions, calibrating weights, and the incorporation of administrative records into the current ACS production generalized regression. See Appendix 2 for a more detailed discussion of the challenges with subsampling or matrix sampling and the methods for implementing it. Appendix 3 provides an examination of what reductions in sample size we could make associated with Option 2 while still meeting programmatic requirements for reliability.

Discussion of Operational Context

Given that this option would require using multiple questionnaires with different combinations of content concurrently in data collection, the additional complexities outlined in the "Operational Impacts of Concurrent Use of Multiple Questionnaires" section of this document would be important to consider.

Assessment Criteria[13]

	Operational and Processing Complexity	Impact on the Accuracy of the Data	Impact on Data Availability for Small Geographies and Groups	Estimated Burden Reduction	Impact on Richness of the Data Products
Subsampling	High	Medium	High	Low	Medium

[13] These assessments are designated with "low," "medium," or "high" impact based on the professional judgment of the team members, and not on empirical criteria.

Operational and Processing Complexity

Processing systems must be heavily modified under this option in order to incorporate data from multiple questionnaires with differing content being used concurrently. Updates to the edits, imputation, and primary selection algorithm have the potential to be significant, and may exceed the current methodological capacity of those systems. Appendix 4 provides insights into the ripple effects on edits processes due to changes to the set of potential items included as meeting the criterion. Weighting and tabulation could become significantly more complex, depending on the specific approach used. Data collection operations would also have significant impacts from using multiple questionnaires, as described earlier. Therefore, the overall operational and processing complexity of this approach is high.

Impact on Accuracy of the Data

The subsampling would have a strong impact on the variances of estimates of characteristics based on the subsampled questions. For example, a subsampling rate of one-half implies twice the variance and about a 44% increase in the margins of error. However, since the accuracy of the great majority of characteristics would be unaffected, we assess the overall impact on the accuracy as medium. Some of the statistical methods described earlier may mitigate the loss of precision due to subsampling. However, there are practical limits as to how much mitigation we could expect. The prospects of a large reduction in variance are not promising enough to change the assessment of medium. Furthermore, methods to improve precision, such as modeling, or to produce a complete data file, such as hot-deck imputation, could introduce biases.

Impact on Data Availability for Small Geographies and Groups

The impact would be high for those estimates based on the subsampled questions. The substantial increases in variances expected with subsampling would lead to some estimates being unpublishable because they no longer met the Census Bureau criteria for release, and entire tables might have to be suppressed. The impact on cross-tabulations would be greater than on univariate statistics as the groups defined by cross-tabulations are smaller. The impact on estimates of rare populations would be severe if the questions that identify them were subsampled. The prospects of a large reduction in variances with models are not promising enough to change the overall assessment.

Estimated Burden Reduction

Using the same methodology described in the "Periodic Inclusion" section, the table below shows the burden for the nine questions that met the initial criteria for subsampling.

Table 4: Burden for Subsampling Questions

Question (and number on the 2015 paper form)	Median Time (in Seconds)	Adjusted Median Time (in Seconds)	Cognitive Burden	Sensitivity	Difficulty
Agricultural Sales (H5)	7	1	Medium	Low	Low
Year of Entry (P9)	17	3	Medium	Medium	Low
Undergraduate Field of Degree (P12)	23	9	Low	Low	Low
Marital Status Change in the Past 12 Months (P21)	17	14	Low	Medium	Low
Times Married (P22)	7	6	Low	Medium	Low
Year Last Married (P23)	9	7	Medium	Medium	Low
Period of Service (P27)	18	3	Medium	Low	Low
VA Service-Connected Disability Rating and Status (P28)	7	1	Medium	Low	Low
Hours Worked Per Week (P40)	16	12	Medium	Low	Low
Total	121 (2 min, 1 sec)	56	Low: 3 Medium: 6 High: 0	Low: 5 Medium: 4 High: 0	Low: 9 Medium: 0 High: 0

The total of the median times is two minutes and one second. That is a high-end measure of how much time would be saved, since it assumes that the household received all nine questions and that all nine questions were on the questionnaire at the same time under periodic inclusion. More likely, certain households would be subsampled to receive only some of these questions, minimizing the burden savings. The adjusted median is a better measure since it takes into account the number of households that actually received the questions. Approximately a minute would be saved if all these questions were removed from the ACS for a typical household. Either way, the amount of timed saved by deleting these question would be minimal at best.

Of the nine questions, six of them have a medium cognitive burden and three have a low burden. Five of them were measured to have medium sensitivity and four low. All of the questions were judged to lave low difficulty. None of the questions had high cognitive difficulty, sensitivity, or difficulty.

Overall, the drop in burden with this option would be low, assuming the scope is the nine questions discussed here. If additional questions were also considered for this option, there would be an additional reduction in burden.

Impact on Richness of Data Products

Based on the initial criteria for the subsampling method, 57 tables would be affected: 27 for hours worked per week, 13 for field of degree, seven for year of entry, seven for marital status change, two for veterans' service-connected disabilities, and one for period of service. Single- and multi-year data would be possible with this method, but due to the decrease in sample size, the level of detail that is published for smaller geographies may be problematic. If the smaller sample size was mitigated by allocation or modeling, there is still a possibility that products for such a small subpopulation would need to be limited for the multi-year product. An additional concern is that as the sample gets smaller and margins of error increase, the number of tables that are filtered could potentially increase, resulting in less data available to data users.

Subsampling of smaller subpopulations may be problematic at lower levels of geographies and at the level of detail of current products. This is of particular importance for the question on year of entry, which is a sensitive topic with a small universe. Even though there are only seven tables, those tables are extremely important and provide key information on our foreign-born population. It is also important to note that some variables only have a few tables, but that variable could be a critical component in other products. For example, hours worked per week has four tables, but that variable is used to determine full-time, year-round worker status, which is used in another 23 tables. Full-time, year-round worker estimates are used by the Census Bureau to compare earnings of similar workers, and it is used in statistics created and used by other Federal agencies. Stakeholder engagement and clear documentation would be necessary to explain the change in methodology and the potential affects on the data products.

Table 5: Potentially Impacted Data Products for Option 2, Subsampling

Question	Number of Tables Impacted	Potential Geographic Restrictions	Restrictions on Level of Detail for All Geographies	Impact on Multi-Year Data Products	PUMS
Agricultural Sales (H5)	0	Low	Low	Low	Medium
Period of Service (P27)	1	Medium	Medium	Medium	Medium
VA Service Connected Disability Rating (P28)	2	Medium	Medium	Medium	Medium
Year of Entry (P9)	7	High	High	Medium	High
Undergraduate Field of Degree (P12)	13	Medium	High	Medium	High
Marital Status Change, Times Married, Year Last Married (P21, P22, P23)	7	Medium	High	Medium	High
Hours Worked per Week (P40)	27	Medium	Medium	Medium	Medium
Total	57	Low: 1 Medium: 5 High: 1	Low: 1 Medium: 3 High: 3	Low: 1 Medium: 6 High: 0	Low: 0 Medium: 4 High: 3

Single-year PUMS should not be affected, but multi-year PUMS would be greatly affected with the potential for different weights, possible inconsistencies with drawing the sample, and potential disclosure concerns. Applying the subsampling method may also cause significant usability issues for data users and there is a possibility that the current PUMS may need to be redesigned to adjust for the new methodology. The impact on data products using the subsampling method would be low to medium due to the small number of tables affected based on the items identified using the initial criteria, coupled with the range and sensitivity of the affected topics.

If the subsampling method were applied more broadly across the survey, then the impact to data products would be medium. Stakeholder engagement would be critical to determine the minimum geographic requirements and level of detail needed for each affected variable. However, we must keep in mind that the ACS was created to provide demographic, economic, social, and housing characteristics to America's communities. If lower levels of geographies are not possible for some topics, we may not meet the needs of our data users and the mission of the survey may be compromised.

Assessment of Additional Costs and Resources Required

	Data Collection	Data Processing	Statistical Application & Modeling	Statistical Support	Tabulation & Review
Initial Implementation	High	High	Medium	Medium	High
Ongoing Production	Medium	Medium	Medium	Medium	Medium

For data collection activities, subsampling questionnaire content is a moderate increase in cost and complexity over the current design because of the introduction of multiple questionnaire versions. Having to develop, design, and deploy multiple paper questionnaires each year leads to higher costs in design and printing. Similarly, the multiple paths required in the automated instruments leads to an increase in costs for development and testing. The continued need for enhanced quality assurance to ensure the accuracy of assembly and mailout activities also leads to increases costs. Reducing the length of the survey interview by only a couple of minutes would not lead to significant reductions in the cost of interviewing, given the relative costs of contacting respondents versus conducting the interview. Data processing activities will eventually stabilize as the questionnaire versions are stabilized, but some additional testing activities could lead to slight increases in cost. The statistical modeling work reflects a moderate increase due to a somewhat limited set of variables in scope, and the detailed items discussed as meeting the initial criteria for this are easier than many other items to handle statistically, especially compared to Option 3. However, implementing the content specific weights is operationally more complex, thereby requiring more resources for statistical support. Alternatively, if statistical modeling or hot-deck imputation is the primary tool used, then it would be more or less transparent to the weighting but the variance estimation would require significant effort.

The level of effort for ***initial implementation*** of subsampling for some questionnaire items is high for data collection and processing. Subsampling by questionnaire item would impact all aspects of operations from questionnaire/instrument design through final data processing and development of data products. Subsampling will necessitate development of multiple questionnaire versions. For paper questionnaires, this complicates the design phase, requiring that the layout of the form be adjusted for questions that are removed. Similarly, the automated instrument development is complicated by the introduction of multiple paths to accommodate the subsampling. The mailout of paper questionnaires would have to be monitored and managed much more closely to ensure that the correct questionnaire versions are packaged, addressed, and mailed to the correct address according to the subsampling

requirements. The paper processing equipment would need to be updated to handle the different questionnaires. Those processing areas are familiar with processing multiple form types since the ACS currently has a handful of questionnaire versions (e.g., Puerto Rico, Group Quarters, etc.), but the subsampling option would significantly increase the number of form types and therefore make the equipment set-up more complex and increase the amount of time to assemble and label packages. Data processing activities would require additional set-up to accommodate all of the various questionnaire versions. Since different questionnaire types would contain different sets of variables, all processing systems would have to be updated to reflect the different sets of content. Development of data products would also be much more complicated since not all data would be published at the same geographic level. Subsampling would also lead to changes in the initial inputs to data product production and would require system changes and updates to the production systems. In addition, the changes in the data products would require changes in the supporting review system as well as the review process for subject matter experts.

The level of effort for ***ongoing production*** for subsampling for some questionnaire items is medium for data collection and processing. Even during ongoing production, subsampling by questionnaire item will impact all aspects of operations from questionnaire/instrument design through final data processing and development of data products. Even assuming the questionnaire design changes are minimal from year to year, the effort to develop and manage multiple questionnaire versions each year is nontrivial. Similarly, the automated instruments and the multiple paths have to be reviewed and tested each year. Despite a growing proportion of self-response by Internet rather than by paper questionnaire, the ACS continues to rely on self-response by paper questionnaire as an important mode of data collection. The mailout of paper questionnaires will continue to require close monitoring and management to ensure that the correct questionnaire versions are packaged, addressed, and mailed to the correct address according to the subsampling requirements. Once established, and assuming the subsampling requirements are fairly constant from year to year, the processing activities (e.g., paper processing at NPC, data processing, and development of data products) would be stable and require the normal amount of management and monitoring. The complexity in the data products, especially multi-year products would have an ongoing impact on both production and review of data products. Changes in the products from year-to-year driven by subsampling would require ongoing system changes, testing and review.

Option 3: Matrix Sampling

Operational Overview

Also referred to as split-questionnaire design, matrix sampling would involve the use of a sampling design that divides the ACS questionnaire into possibly overlapping subsets of questions, and then administering these subsets to different subsamples of an initial sample. It is an extension of Option 2 (subsampling) which considers all items on the questionnaire for possible inclusion in the portions of the questionnaire that would be subsampled. There are multiple ways that such a design could be approached.

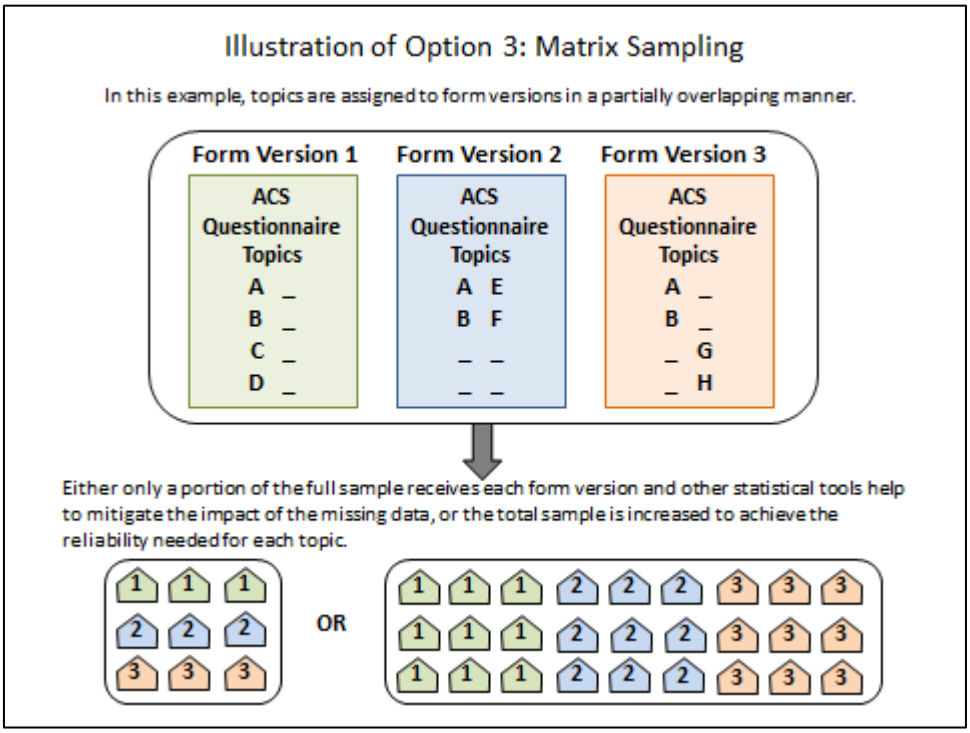
Under one possible design, a core set of questions would be asked of all households (such as the basic demographic section of the questionnaire) and the rest of the questionnaire would be divided into additional modules. An individual household would receive a questionnaire that includes the core module and one or more additional modules, thereby significantly reducing the burden for that household to respond. If reliability targets require that we collect survey responses from a similar number of sample households or persons as is done under the current design, then the total sample size for the survey would potentially need to increase from current levels. Therefore, the number of questions answered by an individual household would be significantly reduced, but more households overall may be included in the survey. Other designs for this could be considered that would rely on other statistical tools to impute or model the responses from the missing sections in a given household's modularized questionnaire, which may not require an overall increase in the survey sample size.

This is not the first time the Census Bureau has explored matrix sampling. During the design phase for Census 2000, a team considered various options for a matrix sample design for the long form questionnaire.[14] The team considered different options for the construction of modules from the long form content that were based on item response rates, correlation between questions (with highly correlated questions in separate modules to assist in modeling and estimation), and coding needs for related items. The team proposed developing five separate content modules, and several different

[14] *Final Report of the Matrix Sampling Working Group*, U.S. Census Bureau, February 27, 1996

alternatives for combining these modules into pairs on different questionnaires, as well as the possibility of one comprehensive form including all of the content to assist in production of cross-tabulation and modeling. After an assessment of the time and resources needed to develop matrix sampling as a viable approach, the Census Bureau decided not to pursue this methodology for Census 2000.

The grouping of questions into meaningful modules for the ACS could be approached in multiple ways. Related questions or questions that follow a logical sequence can be put in the same group. Further, it may be necessary to include two questions in the same module when the result of one question is used in the imputation of the other question. The figure below provides an illustration of one possible way that this might be implemented.



We assume throughout that there is a module of core questions which are asked of all samples. For Option 3, these core questions could include basic demographics used in the weighting and also rare questions which would be less robust to subsampling. The simplest designs would assign one module to each sampled housing unit, in addition to the core module. One could add a sample which has all the modules, a feature which has advantages for producing cross-tabulations and potentially in mitigating

the loss of precision. It is also possible to assign two or more modules to each sample. Ultimately, the design of the matrix sample depends on the burden reduction goals and statistical tools.

One additional potential benefit of employing a matrix sampling design, is the possibility to add additional questionnaire content to the ACS, while still reducing the burden for individual households. This would allow the ACS to expand its ability to meet emerging data needs without increasing the questionnaire length above the current 40 minutes per household. It would also facilitate a survey design and infrastructure that would allow the Census Bureau to consider implementing other more broad flexibility to survey content, such as adding and removing question modules for additional topics.

Discussion of Statistical Approach

Note that from a statistical perspective, Options 2 and 3 are both forms of matrix sampling. Where they differ is in the number of questions to be subsampled. Thus the challenges and statistical tools described for Option 2 apply to Option 3. These statistical methods include content-specific weights, hot-deck imputation of subsampled out questions, calibrating weights, and incorporating administrative records into the ACS production generalized regression. Given that multiple imputation works better with a smaller number of characteristics to impute, it is likely not a viable method for Option 3, as most of the characteristics are sampled. See Appendix 2 for a more detailed discussion of the challenges with matrix sampling and the methods for implementing it.

Discussion of Operational Context

Given that this option would require using multiple questionnaires with different combinations of content concurrently in data collection, the additional complexities outlined in the “Operational Impacts of Concurrent Use of Multiple Questionnaires” section of this document would be important to consider. To the extent that this would also involve adding and removing modules from year to year, the issues outlined in the “Operational Impacts of Frequent Year-to-Year Changes in Questionnaire Content” section of this document would also be relevant.

Assessment Criteria[15]

	Operational and Processing Complexity	Impact on the Accuracy of the Data	Impact on Data Availability for Small Geographies and Groups	Estimated Burden Reduction	Impact on Richness of the Data Products
Matrix Sampling	High	High	High	Medium	High

Operational and Processing Complexity

Processing systems must be heavily modified under this option in order to incorporate data from multiple questionnaires with differing content being used concurrently. Updates to the edits, imputation, and primary selection algorithm have the potential to be significant, and may exceed the current methodological capacity of those systems. Weighting and tabulation could become significantly more complex, depending on the specific approach used. Data collection operations would also have significant impacts from using multiple questionnaires, as described earlier. Therefore, the overall operational and processing complexity of this approach is high.

Impact on Accuracy of the Data

The subsampling would have a strong impact on the variances of estimates. For example, a subsampling rate of one half implies twice the variance and about a 44% increase in the margins of error. Since the majority of characteristics would be affected by this option, we assess the overall impact on the accuracy as high. We note that some of the statistical methods described earlier may mitigate the loss of precision due to subsampling. However, there are practical limits as to how much mitigation we could expect. The prospects of a large reduction in variance are not promising enough to lower the assessment of high. Furthermore, some methods to improve precision, such as modeling, or to complete the data file, such has hot-deck imputation, could introduce biases.

[15] These assessments are designated with “low,” “medium,” or “high” impact based on the professional judgment of the team members, and not on empirical criteria.

The univariate tabulations would be less impacted than cross-tabulations, as the groups defined by cross-tabulations are smaller. We also note that methods which produce a complete data file through imputation or modeling would allow us produce cross-tabulations of characteristics based on subsampled-out questions that are not on the same interviews. However, these estimates would be based entirely on imputed or modeled data and may be of lower quality. Lastly, this assessment assumes no increase in the size of the ACS sample. An increase would counter the impact of the matrix sampling and might reduce the impact on the accuracy of the data from high to medium.

Impact on Data Availability for Small Geographies and Groups

The impact would be high for those estimates based on the subsampled questions, which would include all estimates except those based on the core questions. The substantial increases in the variances may lead to some estimates being unpublishable. Further, entire tables may have to be suppressed. The impact on cross-tabulations would be greater than on univariate statistics, particularly if the cross-tabulations are based on imputed or modeled data.

The impact on estimates of small populations would be severe if the questions that identify them were subsampled. As with the accuracy of the data, the prospects of reducing variances with models are not promising enough to change the overall assessment. This assessment assumes no increase in the ACS sample. Such an increase would counter the impact of the matrix sampling and would reduce the impact from high to medium.

Estimated Burden Reduction

The effect on burden with this option is not as clear, as we do not have a list of what possible topics would be included in various modules in a matrix sampling design. To provide some context for potential burden reductions per household, the table below shows the median time to complete, the adjusted time to complete, and the cognitive burden, sensitivity, and difficulty ratings for each topic on the questionnaire, using the methodology described in the “Periodic Inclusion” section. For topics where we had differing ratings for questions within a topic, we took the highest rating.

Table 6: Burden by Topic

Question (and number on the 2015 paper form)	Median Time (in Seconds)	Adjusted Median Time (in Seconds)	Cognitive Burden	Sensitivity	Difficulty
Building/Structure Type and Units (H1)	15	15	Medium	Low	Low
Year Built (H2)	11	11	High	Low	Medium
Year Moved In (H3)	14	14	Medium	Low	Low
Acreage (H4)	6	5	Medium	Low	Low
Agriculture Sales (H5)	7	1	Medium	Low	Low
Rooms (H7)	37	37	High	Medium	Low
Facilities (H8a-f)	14	14	Low	Low	Low
Telephone Service Available (H8g)	3	3	Medium	Low	Low
Computer (H9, H10, H11)	53	53	High	Medium	Medium
Vehicles Available (H12)	9	9	Low	Low	Low
Home Heating Fuel (H13)	11	11	Medium	Low	Low
Utilities (H14)	71	71	High	Medium	Medium
SNAP/Food Stamp Benefit (H15)	7	7	Low	Medium	Low
Condo (H16)	4	4	Medium	Low	Low
Tenure (H17)	11	11	Low	Low	Low
Rent (H18)	11	3	Low	Medium	Low
Home Value (H19)	17	11	High	Medium	Medium
Taxes & Insurance (H20, H21)	32	22	High	Medium	Medium
Mortgage (H22)	31	17	Medium	Medium	Medium
Second Mortgage (H23)	7	5	Medium	Medium	Low
Mobile Home Costs (H24)	18	1	Medium	Medium	Low
Relationship (P2)	12	9	Medium	Medium	Low
Sex (P3)	6	6	Low	Low	Low
Age/Date of Birth (P4)	36	36	Low	Medium	Medium
Hispanic Origin (P5)	11	11	Medium	Medium	Low
Race (P6)	14	14	High	Medium	Medium
Place of Birth (P7)	29	29	Low	Low	Low
Citizenship Status (P8)	19	4	Medium	Medium	Low
Year of Entry (P9)	17	3	Medium	Medium	Low
School Enrollment (P10)	18	18	Low	Low	Low
Educational Attainment (P11)	29	29	Medium	Low	Low

Table 6: Burden by Topic

Question (and number on the 2015 paper form)	Median Time (in Seconds)	Adjusted Median Time (in Seconds)	Cognitive Burden	Sensitivity	Difficulty
Undergraduate Field of Degree (P12)	23	9	Low	Low	Low
Ancestry (P13)	34	34	High	Medium	Medium
Language (P14)	10	10	Low	Low	Low
Residence One Year Ago (P15)	59	18	Medium	Low	Low
Health Insurance (P16)	53	52	Medium	Medium	Low
Disability (P17, P18, P19)	60	59	Medium	Low	Low
Marital Status (P20)	8	5	Low	Medium	Low
Marital History (P21, P22, P23)	35	29	Low	Medium	Low
Fertility (P24)	5	2	Low	Medium	Low
Grandchildren (P25)	8	2	Low	Low	Low
Veteran Status (P26)	12	12	Low	Low	Low
Military History (P27, P28)	13	13	Medium	Low	Low
Worked Last Week (P29)	16	16	Medium	Medium	Low
Place of Work (P30)	78	57	Medium	Medium	Medium
Journey to Work (P31, P32, P33, P34)	50	36	Medium	High	Medium
Employment Status (P35, P36, P37)	19	11	Medium	Low	Low
Work Status (P38, P39, P40)	37	36	High	Medium	Medium
Industry and Occupation (P41, P42, P43, P44, P45, P46)	153	129	Medium	Medium	Medium
Income (P47, P48)	173	170	High	High	High

There are a wide variety of differences in time to complete and ratings by topic. Some topics, such as industry and occupation and income, take a relatively long time to complete. Others, like facilities, tenure, rent, and home value, either take a short time to complete or are not burdensome otherwise. Unfortunately, some of the topics that would save the most time, like income, health insurance, disability, and place of work, are among the most used data from the survey. Without specific topics, it is hard to rate the burden reduction for this option, but it could be high.

Impact on Richness of Data Products

All 1,298 data products would be affected by the matrix sampling option. Shorter forms for several different questionnaires for the entire survey will decrease the raw amount of survey responses per variable. We assume that modeling and allocation would be applied, but whether the delivered file will be complete and without inconsistencies is unknown. Even if the loss in sample were mitigated, it is unlikely that a significant decrease in the sample per variable would allow the data products to continue to be produced in their current state. It is possible that all tables will need to be redesigned to allow for less detail and fewer crosses with other variables. The loss in sample might be mitigated by having two different sets of products to account for the smaller sample: 1-year products being more timely with less detail and 5-year products pooling several years of data to allow for more detail. Stakeholder engagement would be necessary to determine the minimum level of geography and detail necessary for each variable.

If the sample per question were reduced, then geographic restrictions may be necessary to preserve data quality with the possibility of different geography restrictions per question. Detailed tables could be condensed with a smaller sample per question, but those higher-level estimates may not be meeting the needs of the data user who are accustomed to the current level of detail. All products would need to be evaluated since the smaller sample will most likely mean higher filtering of tables, and therefore, less data available for the public. Depending on the methodology used, multi-year estimates during the transition period may not be possible. However, once a consistent set of data using the new method was available, multi-year estimates would be possible. Extensive outreach and clear documentation to inform data users of the changes in the products and potential impact to the available data will be necessary.

Both the 1-Year and 5-Year PUMS files will be greatly affected using this method. Since PUMS are record-based and draw a sample of the survey sample, a smaller sample is more problematic for this product than in tabulated tables. The PUMS system would need to account for different weights, inconsistencies with drawing the sample, disclosure concerns, and ease of use for the PUMS data user. It is likely that a new system to release public use microdata would need to be designed to account for the vast differences in the form and collection process.

The overall impact for data products using the shorter form, same sample method would be high because all data products would be impacted, the potential loss of publically released data, and possible need to redesign the entire table package and PUMS. If methods are used to replace some of the data not collected through allocation and modeling, this could decrease some of the impact to data products. However, it is unknown if new data products created to accommodate the change in methodology will be as rich in detail and availability at as many lower-level geographies as current products.

Table 7: Potentially Impacted Data Products for Option 3, Matrix Sampling

Question	Number of Tables Impacted	Potential Geographic Restrictions	Restrictions on Level of Detail for All Geographies	Impact on Multi-Year Data Products	PUMS
All	1298	High	High	High	High

Assessment of Additional Costs and Resources Required

	Data Collection	Data Processing	Statistical Application & Modeling	Statistical Support	Tabulation & Review
Initial Implementation	High	High	High	Medium	High
Ongoing Production	Medium	Medium	High	Medium	Medium

The operational impacts for using shorter forms being administered to multiple samples are the same as those of Option 2 above. This option does not significantly reduce overall data collection costs, because of the relative costs of contacting respondents versus conducting the interview. To employ a matrix sample approach for a broad set of questions would require significantly more work, upkeep, and coordination from a statistical perspective. We also have more potential for conflicting measurement goals that will require the development of statistical solutions. Building out a complete file would reduce the resources needed to develop weighting solutions, but addressing variance impacts would still be challenging.

The level of effort for ***initial implementation*** of shorter forms being administered to multiple samples is high. The operational impacts of this option are similar to the impacts of Option 2 because this option involves development of multiple questionnaire versions and creates similar complexities for

the production and review of data products. Matrix sampling is likely to initially require a more significant redesign of the entire data product suite.

The level of effort for ***ongoing production*** using shorter forms being administered to multiple samples is medium. The operational impacts of this option are similar to the impacts of Option 2 because this option involves the use of multiple questionnaire versions and creates similar complexities for the production and review of data products.

Option 4: Administrative Records Hybrid

Operational Overview

The Census Bureau is exploring whether alternative data sources, including administrative records, can be used to replace some of the questions included on the ACS questionnaire. This research assesses the availability and suitability of various data sources, including data from other Federal, state, and local government sources as well as commercial data, and is evaluating the coverage and quality of each data source and the resulting matching to the ACS. The research will also evaluate integrating the external data into the ACS, and compare distributions between ACS data and external data sources for each topic, documenting any measurement issues that are identified. This research is intended to be a first look at the various topics to document the coverage, quality, and availability of external data sources for potential ACS integration, and will enable ACS to evaluate the potential of the replacement data sources, identify challenges, and provide direction for further research.[16]

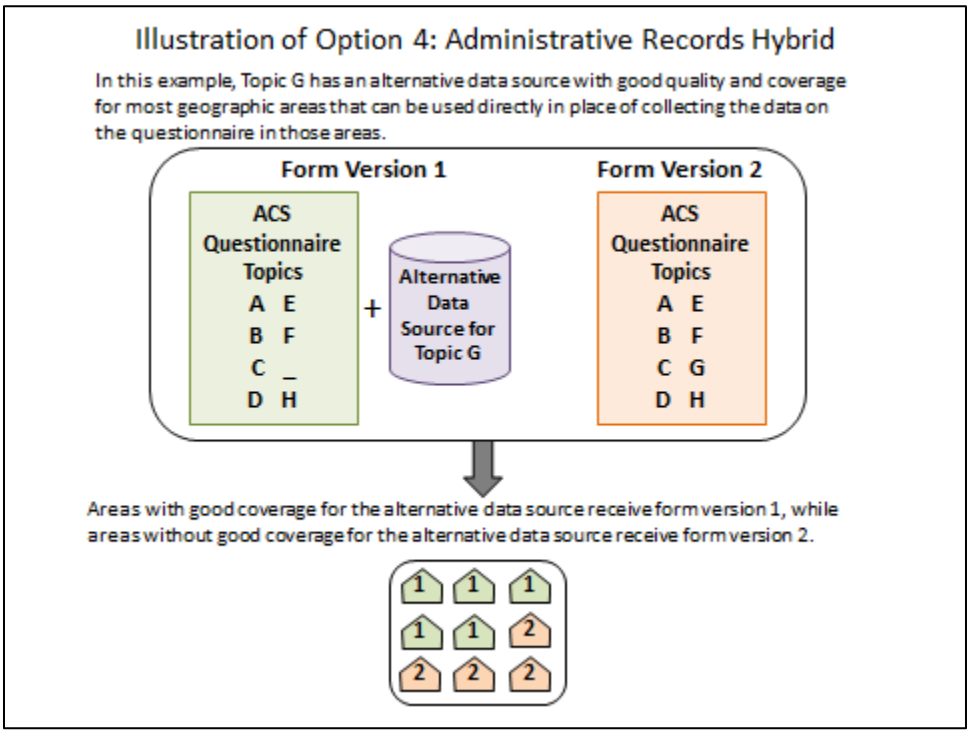
As the Census Bureau conducts this research, it is expected that coverage gaps will be identified for some geographic areas for a given records source. It is also expected that alternative data sources may not provide a comprehensive replacement for every question on a given topic, which may possibly lead to the development of models based on comparisons of historical ACS survey data and the alternative data source's records. Because of issues like these and others, the Census Bureau may find it difficult to entirely and indefinitely remove some questions from the questionnaire and replace them with alternative data sources. A hybrid design may be necessary to blend the collection of some survey data for the topic from a subset of the sample, such as asking some housing questions with administrative data available from tax records only in those counties where records from tax assessors' offices are determined to be insufficient for ACS needs.

Additionally, the periodic inclusion of the question may be necessary to re-validate statistical models over time. We might also have to reassess the definitions or concepts of what is being measured using

[16] *Agility in Action: A Snapshot of Enhancements to the American Community Survey*, U.S. Census Bureau, June 29, 2015

our current questions and how that might differ through partially or fully replacing a question with administrative records, and the required data uses would need to be validated in light of any differences.

The illustration below demonstrates one way that a hybrid approach involving survey data collection and alternative data sources might be implemented.



Discussion of Statistical Approach

This method would require a matching operation between the ACS housing unit and/or person listing with the administrative record housing unit and/or person listing. We can use current hot-deck imputation methods for ACS records that do not match to the administrative record data, though in this case the imputed data would itself be administrative record data substituted to the donor. Successful implementation requires a reasonably high match rate. False matches and nonmatches would effectively reduce the sample size and precision, and potentially introduce bias.

The main advantages of direct substitution are that it would lead to little or no loss of precision (assuming a high match rate), and it would engender no disruption of weighting or tabulations. Furthermore, it would not present additional complexities for the variance estimation, as the substituted data effectively is a sample from the administrative record database.

An important consideration is that the administrative record data could differ in interpretation or form from the currently collected ACS data. Any such differences would induce a break in series. For example, if we received household income from the IRS, there could be year-over-year changes in total household income that do not reflect real changes, but the differences in the sources. Furthermore, we would not be able to produce some data products related to the particular source of income.

Discussion of Operational Context

Based on the coverage and frequency requirements specified for the individual topic or administrative records source, this option would likely require multiple questionnaire versions concurrently in data collection. Therefore, the additional complexities outlined in the "Operational Impacts of Concurrent Use of Multiple Questionnaires" section of this document would be important to consider.

Assessment Criteria[17]

	Operational and Processing Complexity	Impact on the Accuracy of the Data	Impact on Data Availability for Small Geographies and Groups	Estimated Burden Reduction	Impact on Richness of the Data Products
Administrative Records Hybrid	High	Medium	Low	Medium	Low

[17] These assessments are designated with "low," "medium," or "high" impact based on the professional judgment of the team members, and not on empirical criteria.

Operational and Processing Complexity

Processing systems would need to incorporate preparation of the administrative records data, and matching and merging of the administrative records data and the survey data. Editing and imputation processes would likely need a throrough re-examination to determine how to use a blend of administrative records data and survey data. The weighting and tabulation operations would not present significant challenges since directly substituted administrative records data would be treated in many ways like the interview data for these processes. Depending on the extent that the proposed hybrid design requires multiple concurrent questionnaire versions, data collection and processing could have significant increases in complexity. Therefore, the overall operational and processing complexity of this approach is high.

Impact on Accuracy of the Data

Assuming a high match rate between the ACS sample and the administrative records data, and comprehensive coverage of administrative records data, the accuracy with direct substitution could be nearly as good as with interview data. In fact, if a question had a high missing rate, the administrative records data could be better. However, nonmatches or false matches would increase the variances because there would be less effective sample. Potentially of greater concern, they would likely introduce bias. Based on experiences with administrative records data, we should assume some lack of coverage and nonmatches. Given both a modest increase in sampling variance and potential bias, we expect a medium overall impact on the accuracy of the data.

Impact on Data Availability for Small Geographies and Groups

Any increase in variance would affect the ability to produce estimates for small geographies and groups. However, since the increase in variance would likely be modest, we assess the impact as low. We point out that if the substituted administrative records data differs qualitatively from the ACS data, then the break in series may make it difficult to form useful 5-year estimates. For several years it may not be feasible to publish 5-year estimates, which are essential for producing estimates for small geographies and groups. This limitation would resolve itself after five years of administrative records data had been used in the ACS.

Estimated Burden Reduction

Using the same methodology described in the discussion of Option 1, periodic inclusion, the table below shows the burden for the 20 questions that met the initial criteria for the administrative records option.

Table 8: Burden for Administrative Records Questions

Question (and number on the 2015 paper form)	Median Time (in Seconds)	Adjusted Median Time (in Seconds)	Cognitive Burden	Sensitivity	Difficulty
Phone Service (H8g)	3	1	Medium	Low	Low
Year Built (H2)	11	11	High	Low	Medium
Part of Condominium (H16)	15	5	Medium	Low	Low
Tenure (H17)	11	11	Low	Low	Low
Property Value (H19)	17	11	High	Medium	Medium
Real Estate Taxes (H20)	14	9	High	Medium	Medium
Have mortgaged/mortgage amount (H22a and H22b)	23	11	Medium	Medium	Medium
Second mortgage/HELOC and payment (H23a and H23b)	7	5	Medium	Medium	Low
Sale of Agricultural Products (H5)	7	1	Medium	Low	Low
Social Security (P47d)	11	10	Medium	Medium	Medium
Supplemental Security Income (SSI) (P47e)	8	8	Medium	Medium	Medium
Wages (P47a)	49	41	High	High	High
Self Employment Income (P47b)	10	8	Medium	High	Medium
Interest/dividends (P47c)	21	20	Medium	High	Medium
Pensions (P47g)	9	8	Medium	High	Medium
Residence 1 year ago and Address (P15a)	48	7	Medium	Low	Low
Number of Rooms and Bedrooms (H7a and H7b)	36	13	High	Medium	Low
Facilities (H8a, H8b, H8c, H8d, H8e, H8f)	13	6	Low	Low	Low
Fuel Type (H13)	11	11	Medium	Low	Low
Acreage (H4)	6	5	Medium	Low	Low

Table 8: Burden for Administrative Records Questions

Question (and number on the 2015 paper form)	Median Time (in Seconds)	Adjusted Median Time (in Seconds)	Cognitive Burden	Sensitivity	Difficulty
Total	330 (5 min, 30 sec)	202 (3 min, 22 sec)	Low: 2 Medium: 13 High: 5	Low: 9 Medium: 7 High: 4	Low: 10 Medium: 9 High: 1

If we were able to incorporate the use of administrative records for all of these questions, which would be unlikely, households that would have received all of these questions would save about five and a half minutes. If we take into account the fact that many households would not receive each of the questions, by using the adjusted median, the savings would be about three and a half minutes. Even that implies that we would not have to ask any of these questions for any household. If, for example, we had administrative records for some areas but not others, or we still asked these questions of a subsample of households for validation, the savings would be smaller still.

Some of these questions have high cognitive burden, sensitivity, or difficulty. In particular, the financial questions tend to be medium or high in these categories. Year Built and the Number of Rooms and Bedrooms have high cognitive burden.

This option could potentially reduce burden more than the Periodic Inclusion or Subsampling options, and we consider the drop in burden to be medium for this option. That rating assumes the scope is the 20 questions discussed here. If additional questions were also considered for this option, there would be an additional drop in burden.

Impact on Richness of Data Products

The number of affected tables depends on the variables that are collected through administrative records. If the 20 potential topics were replaced with administrative records, 257 tables would be affected or about 20 percent of the data products. The majority of the potential topics only have a handful of tables associated with it and a change in methodology would be minimal. However, some potential topics for administrative records have a larger impact on tables. Tenure, for example, is an

important variable that is responsible for about 10 percent of all the data products. Changes in the survey's methodology would potentially affect a significant portion of our tables.

If administrative records were applied uniformly across the sample, then there should be little to no effect on data products. However, if administrative records are applied inconsistently and based on availability, then geography restrictions might be needed, especially for administrative records that are collected by state or local areas and not nationally. Additionally, if administrative records are applied inconsistently, then condensing of the detailed tables may be needed. Again, condensing the detail in many of our tables may not meet data user needs and significant outreach and detailed documentation is necessary.

We assume the microdata will continue to be delivered in the same method as done currently. Multi-year products would be possible even during the transition period if the quality of the administrative records is high enough to mitigate the loss of the variables on the questionnaire. If there are inconsistencies in the availability of the administrative records, then multi-year products would not be available during the transition period and could be available after the transition period depending on how the microdata are created and delivered.

It is possible that the PUMS 1- and 5-Year files would continue to be produced; however, data provided by administrative records may need to be removed. It is possible that the record providers will not allow individual records to be released, particularly more sensitive data (e.g., income, wages). Operationally, if Title 26 records are used for administrative records, then the process of producing the PUMS might need additional security clearance, which would increase the length of time to process and release the product. It is possible that the administrative records would not be reported and removed from the PUMS file. Further discussions with the record provider would be needed.

Although a large number of tables are impacted, the overall impact of incorporating administrative records on data products would be low to medium with PUMS having the majority of the impact. If methods are used to replace some of the data not collected through allocation and modeling, this could decrease some of the impact to data products.

Table 9: Potentially Impacted Data Products for Option 4, Administrative Records Hybrid

Question	Number of Tables Impacted	Potential Geographic Restrictions	Restrictions on Level of Detail for All Geographies	Impact on Multi-Year Data Products	PUMS
Phone Service (H8g)	1	Low	Low	Low	High
Year Built (H2)	11	Medium	Low	Medium	High
Part of Condominium (H16)	0	Low	Low	Low	High
Tenure (H17)	136	High	Low	High	High
Property Value (H19)	20	Medium	Medium	Medium	High
Real Estate Taxes (H20)	3	Medium	Low	Low	High
Have mortgaged/mortgage amount (H22a and H22b)	16	High	High	High	High
Second mortgage/HELOC and payment (H23a and H23b)	1	High	Low	Low	High
Agricultural Sales (H5)	0	Low	Low	Low	Medium
Social Security (P47d)	1	Low	Low	Low	High
Supplemental Security Income (SSI) (P47e)	2	Low	Low	Low	Medium
Wages (P47a)	43	High	High	High	High
Self Employment Income (P47b)	1	Low	Low	Low	Medium
Interest/dividends (P47c)	1	Low	Low	Low	Medium
Pensions (P47g)	1	Low	Low	Low	Medium
Residence 1 year ago and Address (P15a)	44	High	High	High	High
Number of Rooms and Bedrooms (H7a and H7b)	10	Low	Low	Low	High
Facilities (H8a, H8b, H8c, H8d, H8e, H8f)	9	Medium	Medium	Medium	High
Fuel Type (H13)	2	Low	Low	Low	High
Acreage (H4)	0	Low	Low	Low	High
Total	302	Low: 11 Medium: 4 High: 5	Low: 15 Medium: 2 High: 3	Low: 13 Medium: 3 High: 4	Low: 0 Medium: 5 High: 15

Assessment of Additional Costs and Resources Required

	Data Collection	Data Processing	Statistical Application & Modeling	Statistical Support	Tabulation & Review
Initial Implementation	High	High	High	Medium	High
Ongoing Production	Medium	Medium	Medium	Low	Low

For data collection activities, incorporating the use of administrative records data will have similar effects to Options 2 and 3 above due to the use of multiple questionnaire versions. For that aspect of the operational impacts, there would be a moderate increase in cost and complexity over the current design. Once updated to handle the administrative records data, the systems should be able to continually merge the administrative records data and response data from data collection activities, but there could be periodic cost increases to purchase or renew administrative data sources. This option does not significantly reduce overall data collection costs, because the time it takes to administer a CAPI interview may be reduced, but the travel time to the case remains the same. From a statistical perspective, the burden would primarily fall to modelers to adapt the administrative records data for our uses, including addressing missing data, etc., whereas the weighting and variance work could be simpler. If the burden falls to modelers for producing complete data, it is possible that the statistical support could be low.

The level of effort for ***initial implementation*** of the use of administrative records data is high. This option would involve use of multiple questionnaire versions, depending on the availability of source data and the case- or geography-based determination of eligibility for use of administrative records data. For this aspect of the operational impacts, the detailed impacts are similar to Option 2. However, there are additional complexities to overcome for this option. Because the data processing activities would have to incorporate the results of our traditional data collection activities and data from administrative sources, the systems would need to be updated to gather and integrate data from those various sources. In addition, there may be other initial level-of-effort impacts associated with identifying and obtaining the necessary administrative records data. This could involve coordinating and developing complicated data user agreements with vendors, other Federal agencies, etc. Developing the initial modeling methods to incorporate and standardize data from these sources and impute missing data would require a high level of additional resources. The initial impacts on data product production would be high, since we assume that there would be some coverage issues with the use of

administrative records that would require revising tables, tabulation specification and changes to both single-year and multi-year products. In addition, it is likely that filtering and suppressions rules would need to be updated to account for any changes in data quality associated with administrative records. If the coverage of administrative records is more complete and provides similar coverage as current sampling, then the initial implementation impacts on data product production would be low.

The level of effort for ***ongoing production*** for the use of administrative records data is medium. Like Options 2 and 3 above, ongoing production under this option would involve continued use of multiple questionnaire versions, depending on the availability of source data and the case- or geography-based determination of eligibility for use of administrative records data. For that aspect of the operational impacts, the detailed impacts are similar to Option 2. Once implemented, the ongoing production work for this option should be stable and easily manageable. The systems should be able to continually merge the administrative records data and response data from data collection activities to the extent that the records data sources are stable. However, if administrative data sources or uses change, there would be impacts similar to the initial implementation phase. There may be periodic increases in the level of effort to renew contracts with vendors and/or data usage agreements. The ongoing impact to data product production would be low after initial implementation. There would be periodic changes to systems as coverage of administrative records improve or processes improve the use of administrative records. There will be some ongoing impacts due to the likelihood of additional reviews and security requirements related to the use of administrative data (e.g., Title 26 data).

Summary Assessment of the Options

The assessment of each of the options to reduce respondent burden through asking questions less frequently or of fewer respondents is summarized in Table 10 below. These assessments are designated with "low," "medium," or "high" impact based on the professional judgment of the team members, and not on empirical criteria.

Table 10: Summary Impact Assessment for Options to Reduce Burden

Options	Operational and Processing Complexity	Impact on the Accuracy of the Data	Impact on Data Availability for Small Geographies and Groups	Estimated Burden Reduction	Impact on Richness of the Data Products
1. Periodic Inclusion	Medium	Low	High	Low	Low
2. Subsampling	High	Medium	High	Low	Medium
3. Matrix Sampling	High	High	High	Medium	High
4. Administrative Records Hybrid	High	Medium	Low	Medium	Low

Option 4, Administrative Records Hybrid, appears to achieve the best balance between burden reduction and impacts on data accuracy, data availability for small geographies and groups, and richness of the data products.

Although Option 1 has a low impact on the accuracy of the data and the richness of the data products, it does have a high impact on the data availability for small geographies and groups for the affected topics, while achieving only a small reduction in burden. Each option would add significant additional operational and processing complexity to the ACS program, though Option 1, Periodic Inclusion, introduces less complexity than the others.

Option 2, Subsampling, also does not achieve a significantly higher burden reduction (given the set of questions proposed that met our initial criteria), and has higher impacts on data accuracy and the richness of the data products than Option 1.

Option 3, Matrix Sampling, does achieve higher burden reduction for individual households, but has high impacts on data accuracy, data availability for small geographies and groups, and the richness of the data products.

Table 11 provides a summary assessment of additional costs and resources required by operation, and by initial implementation versus ongoing production. Although these assessments do not attempt to estimate actual cost impacts, they do provide a relative assessment of the resources needed to implement and maintain each option.

Table 11: Summary Assessment of Additional Costs and Resources Required by Operation

Options	Data Collection	Data Processing	Statistical Application & Modeling	Statistical Support	Tabulation & Review
1. Periodic Inclusion: Initial Implementation	Low	Low	Low	Low	Low
1. Periodic Inclusion: Ongoing Production	Low	Low	Low	Low	Low
2. Subsampling: Initial Implementation	High	High	Medium	Medium	High
2. Subsampling: Ongoing Production	Medium	Medium	Medium	Medium	Medium
3. Matrix Sampling: Initial Implementation	High	High	High	Medium	High
3. Matrix Sampling: Ongoing Production	Medium	Medium	High	Medium	Medium
4. Administrative Records Hybrid: Initial Implementation	High	High	High	Medium	High
4. Administrative Records Hybrid: Ongoing Production	Medium	Medium	Medium	Low	Low

It is important to note that costs for data collection operations account for roughly three quarters of the overall ACS program budget, therefore, impacts on data collection costs are more significant than impacts to costs for other operations. Option 1, periodic inclusion clearly has the lowest costs across the operations both initially and in ongoing production. Options 2, 3, and 4 would all require significant additional resources to prepare for initial implementation, although Option 4, administrative records hybrid, requires slightly less resources in ongoing production.

Recommendations and Future Research

The Census Bureau carried out a preliminary study of how changes to survey design could potentially strike a reasonable balance between reducing respondent burden and providing communities and businesses with the necessary information to make informed decisions, but further study is required to draw responsible and actionable conclusions. Given the assessments outlined in this document, the Census Bureau team that evaluated these options makes the following recommendations, and describes necessary additional research:

1.) **Pursue Periodic Inclusion.** As an initial step, the team recommends only periodically including any questions where the frequency and geographic needs for the data can be supported through asking some questions less frequently than every year. This option requires a comparatively low level of both effort and negative impacts.
    a. This document identifies three questions on the ACS that, while known to contain Federal mandatory and required usages, might meet the criteria for periodic inclusion. The Census Bureau will engage in further discussion with the impacted Federal agency stakeholders in order to clarify their needs.
    b. The Census Bureau will also engage Federal and non-Federal data users to deepen its understanding about the impact of including these questions only periodically.
    c. The Census Bureau will explore the possibility of expanding the list of potential questions for periodic inclusion by confirming with other Federal data users the timing of their needs for data, as well as the geographic levels necessary. Once this is confirmed, the Census Bureau will seek input from non-Federal data users to understand the impact of including any additional identified questions only periodically.
2.) **Pursue options for incorporating Administrative Records.** Preliminarily speaking, it appears that using administrative records either as a substitute for survey data collection for some topics included in the ACS, or via a hybrid approach with partial survey data collection, could significantly reduce respondent burden. When compared with subsampling and matrix sampling, using administrative records also seems to involve fewer potential undesireable impacts.

a. It would not be possible to pursue using administrative records until the availability and suitability of the data within them is evaluated. The Census Bureau has outlined a research program[18] to carry out this evaluation.
b. Because it is possible that the research program will reveal that hybrid approaches including some partial survey data collection will be necessary, the Census Bureau should continue researching how the ACS could operationalize multiple questionnaires into data collection and processing operations.
c. Pursuit of the research program will be dependent on sufficient FY16 resourcing.

3.) **Seek additional input on efficient possibilities for Matrix Sampling or topical subsampling.** Matrix sampling and topical subsampling could yield benefits such as expanding overall survey content while simultaneously reducing individual household respondent burden. However, they also present potentially costly impacts on survey operations and the accuracy and richness of survey estimates. Therefore, the Census Bureau is seeking input that may help to develop research into efficient and effective designs for matrix sampling.
   a. The Census Bureau is working with the National Academies of Science Committee for National Statistics (CNSTAT) to conduct a public workshop that will include this topic among others.
   b. The Census Bureau is also planning an expert meeting with CNSTAT focused on this subject.

Finally, all-inclusive consideration of the nature of the design change, the degree of respondent burden reduction associated with the change, as well as the statistical challenges and operational context should drive further research and decision-making about changes to the design of the ACS. Because they are interdependent, viewing any of these four factors in isolation from the others does not provide enough context for responsible decision-making about any of the potential changes the team identified.

[18] U.S. Census Bureau. (2015) "Evaluating the Availability and Suitability of External Data Sources for Use in the American Community Survey." (see http://www.census.gov/programs-surveys/acs/operations-and-administration/2015-16-survey-enhancements/external-data-sources.html)

Appendix 1: Matrix Sampling Literature Review

Introduction

Matrix sampling, also referred to as split-questionnaire design, has received a fair amount of attention in the past few years as a possible method to reduce respondent burden. However, outside of educational measurement, it has not been frequently used in practice. We identify in the literature three examples of matrix sampling implementation.

First, the 1970 decennial census long form had a nested sample, with 15 percent receiving a smaller set of questions, and 5 percent receiving additional questions (Navarro and Griffin, 1993). Second, the Informed Medical Decisions Foundation implemented matrix sampling in its National Survey of Medical Decisions (Raghunathan, 2010). All survey respondents received screening questions, whose responses then determined eligibility for ten more detailed, decision-specific modules. To limit burden, respondents were randomly assigned a maximum of two such modules. Lastly, the National Center for Educational Statistics (part of the Department of Education) implements the National Assessment of Educational Progress (2015) on an ongoing basis. Each child answers a common set of core questions relating to demography and home living conditions. Then each is randomly selected to answer a set of questions which focus on one subject area, for example, math, reading, or history. The only cross-tabulations that can be created involve the core questions with those of the subject areas.

Literature Review

In addition to these examples of actual implementation of matrix sampling, we find that several government centers and nongovernmental research centers have investigated its use in their data collection programs. These are discussed below. We proceed more or less chronologically, starting with research papers released in the 1990s. We note first that matrix sampling had already been developed by the 1970s for use in educational measurement (Shoemaker, 1974).

Navarro and Griffin (1993) proposed five matrix-sampling designs for the 1990 Decennial Census long form or sample data. Ultimately, matrix sampling was not used in the 1990 Decennial Census.

Raghunathan and Grizzle (1995) described how to use multiple imputation to impute for subsampled-out data in a matrix sampling survey. By assigning modules of questions at random, one has subsampled-out data which is missing at random, fulfilling a key assumption for multiple imputation.

The authors proposed categorical variables be modeled by loglinear models and that the continuous variables are normally distributed conditioned on the categorical cells they are in. They assumed flat priors for parameters and used Gibbs sampling to produce the multiple imputations. They tried this method on a simulated matrix sampling survey based on real data from the Cancer Risk Behavior Study at the Fred Hutchinson Research Center. The results were only moderately encouraging in terms of reducing variances, but the authors discussed ways to improve the method for future work.

Thomas et al. (2006) continued investigating the method of Ragunathan and Grizzle. They made an evaluation of matrix sampling methods using data from the National Health and Nutrition Examination Survey. They simulated matrix sampling by deleting collected data and used multiple imputation for the subsampled-out data. While they found only a modest variance reduction, they also found a tolerably small bias. They pointed out that the grouping of questions was not optimized based on the correlations between the variables, and suggested they could have done better with more judicious selection and groupings of questions to be subsampled.

Adiguezel and Wedel (2005) discussed using a modified Federov algorithm to exploit correlations between questions to find optimal creation of modules of questions. They gave an example with simulated business data using multiple imputation to fill in subsampled-out data. It demonstrated that the designs created by their algorithm were more efficient than the designs obtained with heuristic procedures.

Gonzalez and Eltinge (2007) gave an overview of matrix sampling methods. One of the studies they discussed was an IRS experiment conducted in 1983. This experiment simulated matrix sampling based on deleting data from real IRS data and imputing for the subsample-out data with hot-deck imputation. They reported that the hot-deck imputation allowed for the creation of a complete data file without damaging the results.

Hall and Smith (2011) analyzed the 2010/2011 British Crime Survey Intimate Personal Violence Split-Sample Experiment and found reduced respondent burden with matrix sampling led to better data quality. They did not take statistical measures to mitigate the loss of data or to create a complete data file.

Chipperfield and Steel (2009 and 2011) and Chipperfield et al. (2013) developed Best Linear Unbiased Estimators (BLUE) for certain matrix-sampling designs. These methods optimally exploit the correlations between the questions to be subsampled to reduce the variance of the estimates. These

papers also discussed matrix sampling designs in the context of the Australian Census and the New South Wales Population Health Survey. The Australian Bureau of Statistics has investigated a Census with three modules, with each respondent receiving only two of three modules. The New South Wales Population Health Survey has explored questionnaires that would be grouped into 43 modules, 31 of which would be asked of all respondents. Only nine of the last 12 would be asked of each respondent.

Lastly, Merkouris (2010 and 2015) advanced the BLUE methods developed by Chipperfield and Steel. This included developing a method which is simpler to calculate though not as efficient, and which results in a GREG calibration of weights. As with the BLUE, it exploits correlations among interview questions to improve the precision of the estimates based on subsampled questions. It is approximately BLUE for large samples.

Summary

Matrix sampling has been implemented at least starting in the 1970s, though we have no examples (outside of simulations) of methods used to complete the data file or to mitigate the loss of precision. In research simulations, the mass imputation methods with hot-deck and multiple imputation were found to produce estimates with acceptably small bias. The degree to which multiple imputation reduced the variance of estimates was disappointing, though researchers held that they could achieve greater efficiency with better use of correlations to group the questions into modules. Chipperfield and Merkouris' methods, while promising in theory, have not been applied to real data, nor to simulations based on real data such as those described in Raghunathan's papers.

References

Adiguezel, F., and Wedel, M. (2005). "Split Questionnaire Design". Working Paper No. 966, University of Michigan, Ross School of Business. http://deepblue.lib.umich.edu/handle/2027.42/41215

Chipperfield, J., and Steel, D. (2009). "Design and Estimation for Split Questionnaire Surveys". *Journal of Official Statistics*. *Vol. 25, No. 2, 2009.* http://www.jos.nu/Articles/abstract.asp?article=252227

Chipperfield, J., and Steel, D. (2011). "Efficiency of Split Questionnaire Surveys". *Journal of Statistical Planning and Inference. Vol. No. 141, 2011*. http://www.sciencedirect.com/science/article/pii/S0378375810005458

Chipperfield, J., Barr, M., and Steel, D. (2013). "Split Questionnaire Designs: are they an efficient design choice?" Presented at the 59th World Statistics Congress of the International Statistical Institute,

Hong Kong, China, 25–30 August 2013. http://www.statistics.gov.hk/wsc/IPS033-P1-S.pdf

Gonzalez, J., and Eltinge, J. (2007). "Multiple Matrix Sampling: A Review". *2007 Joint Statistical Meetings. Section on Survey Research Methods.* http://www.bls.gov/osmr/pdf/st070070.pdf

Hall, P., and Smith, K. (2011). "Analysis of the 2010/2011 British Crime Survey Intimate Personal Violence Split-Sample Experiment". *Home Office Methodology Report.* https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/116718/analysis-bcs-ipv-2011.pdf

Merkouris, T. (2010). "An Estimation Method for Matrix Sampling". *2010 Joint Statistical Meetings. American Statistical Association.* https://www.amstat.org/sections/SRMS/Proceedings/y2010/Files/308769_61580.pdf

Merkouris, T. (2015). "An Efficient Estimation Method for Matrix Survey Sampling". *Survey Methodology, Vol. 41, No. 1, June 2015.* http://www.statcan.gc.ca/pub/12-001-x/2015001/article/14174-eng.htm

National Center for Educational Statistics (2015). *National Assessment of Educational Progress (NAEP).* http://nces.ed.gov/nationsreportcard/

Navarro, A., Griffin, R. (1993). "Matrix Sampling Designs for the Year 2000 Census". *1993 American Statistical Association, Section on Survey Research Methods.* http://www.amstat.org/sections/SRMS/proceedings/papers/1993_078.pdf

Raghunathan, T., and Grizzle, J. (1995). "A Split Questionnaire Survey Design; Cancer Risk Behavior Survey". *Journal of the American Statistical Association. Vol. 90, No. 429, March 1995.* http://www.jstor.org/stable/2291129?seq=1#page_scan_tab_contents

Raghunathan, T. (2010). "Split Questionnaire Design for Consumer Expenditure Surveys Program". *Bureau of Labor Statistics Workshop December 8-9, 2010.* http://www.bls.gov/cex/methwrkshp_pp_raghunathan.pdf

Shoemaker, D. (1973). *Principles and Procedures of Multiple Matrix Sampling.* Cambridge, MA: Ballinger Publishing Company.

Thomas, N., Raghunathan, T., Schenker, N., Katzoff, M., and Johnson, C. (2006). "An Evaluation of Matrix Sampling Methods Using Data from the National Health and Nutrition Examination Survey".

Survey Methodology, Vol. 32, No. 2, December 2006. http://www.statcan.gc.ca/pub/12-001-x/2006002/article/9555-eng.pdf

Appendix 2: Expanded Discussion of Statistical Challenges and Tools

Expanded Discussion of Statistical Challenges

This section expands the discussion of statistical challenges presented earlier in the main report. Note that Challenge #6 is a discussed only in this appendix. We remind the reader that the direct substitution of administrative records data leads to some additional challenges particular to that method, which are not discussed here. The creation of an administrative records database and its match to the ACS sampling frame are being investigated by other groups at the Census Bureau and are out of scope of this report.

Challenge #1: Loss in Precision of Estimates

The most obvious limitation of matrix sampling is a reduction in the precision of the estimates of those questions which are subsampled. These increases in variances of estimates entail scaling back the ACS mission to produce estimates for the smallest geographies. A central consideration affecting how much we can subsample particular items is the required precision for a characteristic at a particular geographic area. What benchmark is used will drive many of our recommendations. The subsampling rate would depend on the targeted level of precision for a particular characteristic at the planned tabulation area (e.g., state or county). In some geographies, we may not be able to subsample, whereas in larger counties and states we may be able to subsample more substantially. We would need to ensure that we meet the target precision for the entire hierarchy of published areas since Metropolitan Statistical Areas (MSA) are built from counties, etc.

Challenge #2: An Incomplete Data File

Currently, all ACS questions are asked from all respondents with the exception of built-in skip patterns, yielding a large file of respondents crossed by their reported characteristics. This file is then passed into the edit and imputation process, which checks for inconsistencies and fills in any missing or inconsistent data using either assignment, or a cold- or hot-deck imputation. The resulting file is then passed onto disclosure avoidance, weighting, and final tabulation recode processes that create the final file used for tabulation. If we ask only a subset of the full sample a particular question, we will have a

large proportion of blank responses resulting from the questions that are not asked. These blank responses result in operational challenges to the processes mentioned above.

Challenge #3: Ability to Calculate Cross-Tabulations

Matrix sampling affects the reliability of the estimates of the cells in cross-tabulations. If two characteristics to be cross-tabulated are not both collected on the same forms, their cross-tabulations cannot be produced directly from the collected data. They can only be formed from imputed data, which may be of lower quality. Without imputation, cross-tabulations of such characteristics would be impossible to produce.

Challenge #4: Producing Public Use Microdata Samples (PUMS) with Matrix Sampling

The effects of matrix sampling on the ACS would be carried over into the PUMS since the PUMS are a subsample of ACS sample records. Following the creation of the PUMS file, a series of edits is done for disclosure avoidance reasons, which includes top-coding, age perturbation, rounding of dollar values, and collapsing of categories. If we choose a matrix sampling method that does not impute, model, or otherwise fill in the subsampled data, there would be a great deal of missing data on the PUMS file. However, PUMS-specific editing would likely not change. If we used matrix sampling with content-specific weights in the ACS, any tabulations that data users make with PUMS data would likewise require using several sets of content-specific weights (currently there is only one weight per record).

If the matrix sampling option does include forming a complete data file, little would change for PUMS weighting and creation. However, it is possible that additional disclosure avoidance editing would be needed, especially if direct substitution of administrative data is done. In particular, any information regarding which records were imputed because of the subsampling cannot reveal geographic information below Public Use Microdata Area (PUMA) geography which is the smallest level of geography allowed due to disclosure avoidance reasons. Increased editing would lead to nonsampling error in PUMS estimates as well.

Challenge #5: Potentially Introduced Bias

A biased estimate is one that on average over- or underestimates the quantity that is being estimated. Modeling and imputation methods can introduce bias into estimates. A bias that is small in comparison to the variance reduction gained by a method is generally considered acceptable. It will be necessary to assess any potential bias of our methods.

Challenge #6: Estimating Variances

The margin of error, the standard error, and the variance are all estimates of the precision of an estimate. Margins of error, an essential part of the ACS data products, are calculated from estimates of variances. The variance estimation methodology used depends on the method used to produce estimates. Some statistical methods proposed for use with matrix sampling, such as imputation and modeling, would bring with them their own particular challenges in variance estimation. Others, such as content-specific weights, would not.

Expanded Discussion of Statistical Tools

There are several established tools for the statistical handling of matrix sampling which could be applied to Option #2 or #3, each with its particular strengths and demand on resources. We describe and assess these tools below. Note that we do not discuss methods for building an administrative records database nor for matching one to the ACS sampling frame. See the matrix sampling literature review in Appendix 1 for references.

Content-Specific Weights

The simplest approach for the weighting with matrix sampling is to use content-specific weights. Instead of one weight used for estimating all characteristics, each person and housing unit would have multiple weights. One of these weights would be used to tabulate any particular characteristic or to cross-tabulate two or more characteristics. It would be advantageous for tabulation to group the variables into modules which are selected together, as fewer modules would require fewer additional weights.

As simple as this approach is for weighting, it has its drawbacks. First, it is burdensome for the tabulation and data processing. The tabulation process would have to be modified to choose the

appropriate weight from two or more weights, depending on the estimate. Furthermore, content-specific weights would yield an incomplete data file, with the burdens it imposes onedit and imputation, and disclosure avoidance processes. This method does not mitigate the loss of precision due to subsampling. Depending on the matrix sampling design, some cross-tabulations may be impossible to create. The PUMS records would be less useful as they would be missing the responses to the subsampled out questions. Any tabulations data users make with PUMS data would likewise require using several sets of content specific weights. With an additional 81 weights (this includes replicate weights) for each set, the PUMS file would be bigger and harder to use.

Hot-Deck Imputation

An approach to obtaining a complete file would be to extend the current ACS production hot-deck imputation. If we choose to do this, we have to select questions for subsampling in such manner that the questions used for imputation are still in sample. For example, say we wanted to sample ACS person question 12, "Please print below the specific major(s) of any BACHELOR'S DEGREEs this person has received". Then we would need to retain the person questions 41-46, which ask, among other things, "What kind of business or industry was this?", and "What kind of work was this person doing?" These questions are used to determine the ACS occupation recode variable, which is used in the imputation of field of degree.

Extending the hot-deck imputation would be relatively simple and it may mitigate the loss of precision due to subsampling. However, we would have to revise our variance estimation methodology, because treating the imputed data as real with the current ACS variance estimation methodology would result in a gross underestimate of the total variance of estimates. Furthermore, the method might introduce significant bias. With this method we can produce cross-tabulations of subsampled-out questions which are not in the same sample, although such tabulations would consist entirely of imputed data and may not be of sufficiently sound quality. In addition, hot-deck imputation diminishes the usefulness of the PUMS data, as the subsampled out data would be missing (assuming we would not include the large-scale imputed data in the PUMS).

Multiple Imputation

Another approach to obtaining a complete data file would be multiple imputation. This method is grounded in Bayesian statistical theory and requires Monte Carlo simulations for implementation.

However, it may offer better prospects for mitigating the variance increases due to subsampling than hot-deck imputation and it lends itself to correct estimates of variance. The method requires generating not one, but several imputations (usually three or four suffice) for each missing set of responses. The values of all of the imputations are averaged to produce the estimate. From the observed variance of the multiple imputations one also obtains an estimate of the variance. The degree to which this method would mitigate the loss in precision of the subsampled questions depends on the strength of the correlations between the questions and the matrix sampling design.

Multiple imputation would have important implications that need considering. The tabulation process would have to change to accommodate three or more records for each one record which had subsampled out questions. With this method we can produce cross-tabulations of subsampled-out questions which are not in the same sample, although such tabulations would consist entirely of imputed data and may not be of sufficiently sound quality. In addition, the usefulness of the PUMS data is diminished as the subsampled out data would be missing. Lastly, multiple imputation works better with a smaller number of items to impute. Whether it would work well with 20 items is impossible to say at this point. Ultimately, multiple imputation would be a new method for the ACS and it would require substantial research and development for implementation.

Calibrating Weights

A method to mitigate the loss of precision with matrix sampling of modules of questions is detailed by Merkouris (2009 and 2015). His method requires the existence of subsample of housing units that has all of the questions. It uses a generalized regression to calibrate or adjust the sample weights, which exploits correlations between the variables to reduce variances of the subsampled questions. It has the additional advantage that estimates can be calculated using only those sample with all of the questions, simplifying the tabulations. This method would require an additional regression step in the weighting to adjust the weights. Multiple, content-specific weights would be needed as described in the section on content specific weights.

Administrative Records and Generalized Regression

If administrative records data related to subsampled questions are available, but direct substitution were infeasible or otherwise undesirable, we could reduce the loss of precision due to the subsampling for those questions by incorporating these administrative records into the generalized regression step of

the ACS 5-year weighting (also referred to as model-assisted estimation).[19] The ACS production GREG for the 5-year weighting makes use of both the sampling frame counts and administrative records to adjust the weights. For example, if we had a module of income related questions, and we had administrative records data on income (e.g., household income from the IRS), we could incorporate this income data in the GREG step. An important feature of the model-assisted estimation procedure is that the administrative records data are not used directly to produce ACS estimates (this is not an imputation or direct substitution of data). The published ACS estimates are formed only from weighted totals of the ACS survey data. Incorporating additional data into the GREG is a minor change.

Variance Estimation with Hot-Deck Imputation

The hot-deck imputation would require changes to our current variance methodology, successive differences replication. The imputed data would not be real sampled and interviewed data, and naively applying the successive differences replication would grossly underestimate the variances of estimates of the subsampled characteristics. Two approaches to obtain more correct variance estimation are using inflation factors and reimputation methods. Inflation factors are used in the current ACS production variance estimation for group quarters (GQ) persons to account for the mass imputation of GQ persons.[20] Replicate weights are adjusted in a manner to yield appropriately higher estimates of variances. Reimputation methods for data with imputation require a replicate-based method of variance estimation, such as the jackknife or random groups. It requires that for each replicate the imputation be conducted independently with donors drawn only from the replicate.

[19] American Community Survey: Design and Methodology. Chapter 11, page #25.
http://www2.census.gov/programs-surveys/acs/methodology/design_and_methodology/acs_design_methodology_ch11_2014.pdf
[20] American Community Survey: Design and Methodology. Chapter 11, page #2.
http://www2.census.gov/programs-surveys/acs/methodology/design_and_methodology/acs_design_methodology_ch11_2014.pdf

Appendix 3: Summary of Potential Subsampling Rates

A key consideration for Option 2 (subsampling) is what reductions in sample size we could make while still meeting programmatic requirements for reliability. The methodology and results to help answer that question will be discussed in this appendix.

Data Sources

The nine questions identified in this report as potentially meeting subsampling eligibility criteria were first split up based on the level of detail necessary for mandatory and required uses. Agricultural sales, marital status change in the past 12 months, times married and year last married have uses at the state level. Year of entry, period of service, service connected disability, and hours worked have uses at the county and place levels. State-level estimates can be made using 1-year ACS data, while complete coverage of counties and places requires 5-year ACS data. So, the four questions needing state-level data were analyzed using 2013 1-year ACS data, and the four questions needing data at lower levels of geography were analyzed using the 2009-2013 5-year ACS data. The level of detail needed for the undergraduate field of degree question was not specified, and it was included with the state-level questions using 1-year data.

For each question, the next decision was what ACS estimates would represent the question in the analysis. For two questions, the questions asked on the form are simple yes/no checkboxes: marital status change (actually three separate questions for married, widowed, and divorced), and service connected disability. Estimates of "yes" answers for those will be used in the analysis.

For two others, agricultural sales and times married, the available checkbox categories available on the form served as the basis of the individual estimates, e.g. "$1 to $999" for agricultural sales. The "$0" category for agricultural sales was omitted, as the null result did not seem a likely estimate that a program would require. For times married, "never married" was included in addition to the three checkbox options.

For period of service, the respondent marks any of the nine available checkboxes covering various time periods. A "yes" (check) for each of the nine boxes will be the nine representative estimates for this question.

The remaining four estimates, field of degree, year last married, year of entry and hours worked per week are write-in responses. For field of degree, year of entry, and hours worked per week, existing ACS data products provide ready-to-use categories.[21] Year last married is only used in ACS data products as a means to produce median duration of marriage and is not tabulated separately, so a six-category distribution was devised.

The 40 estimates for the nine questions are shown in Tables A1 and A2 at the end of this appendix, with the five state-level questions in A1 and the four lower-level questions in A2.

Calculating Sample Size Reduction Ratios

State or county estimates, as appropriate for each question, were created using the 2013 1-year ACS data or the 2009-2013 5-year ACS data for each of the 40 estimates. (Puerto Rico and its municipios were excluded from the analysis.) These estimates were population or housing unit counts, not percents. For example, the estimated number of persons married in the last year, and not the percent of persons married in the last year.

The coefficient of variation (CV), the standard error of the estimate divided by the estimate itself, was calculated for each nonzero estimate. The maximum number of areas with estimates was 51 at the state level (includes the District of Columbia), and 3,143 counties. The number of nonzero values for each estimate is shown in Tables A1 and A2. Four of the five agricultural sales categories had no observations in at least one state. There were no respondents in the earliest period of service category, "Nov 1941 or earlier", in 43 percent the counties. The median CV across all the areas with nonzero estimates is also shown in Tables A1 and A2.

Separately for the state and county level questions, three "target" CVs were selected: 5, 10, and 15 percent for state questions, and 10, 20, and 30 percent for county questions. With everything now set

[21] Field of degree, detailed table C15010: http://factfinder.census.gov/bkmk/table/1.0/en/ACS/13_5YR/B23022
Year of entry, detailed table B05005: http://factfinder.census.gov/bkmk/table/1.0/en/ACS/13_5YR/B05005
Hours worked, detailed table B23022: http://factfinder.census.gov/bkmk/table/1.0/en/ACS/13_5YR/B23022

up, the key question could now be answered: for each question, how much can the sample be reduced so that the observed median CV would be increased to match the target CV?

To adjust a CV upwards, the number of cases in sample must be adjusted downwards. First, we estimate the reduction in sample (*r)* needed for each geographic area:

$$CV_{target} = \sqrt{\frac{n_{observed}}{n_{target}}} \times CV_{observed}$$

$$r = \frac{n_{target}}{n_{observed}} = \left(\frac{CV_{observed}}{CV_{target}}\right)^2$$

The ratio, *r*, is calculated for each area with a nonzero estimate. If the CV for the area is larger than the target CV, then no reduction is possible and *r* is set to 1. To get an overall sample reduction, the *r* values are multiplied with each area's initial housing unit address sample size, then summed across all areas (with a nonzero estimate), and divided by the total US (1-year or 5-year) initial housing unit address sample size.

The final reduction ratio for a given estimate is

$$\text{Final Reduction Ratio} = \frac{\sum_{non-zero\ areas} r \times SS}{\sum_{non-zero\ areas} SS}$$

where *SS* is the initial housing unit sample size, and *r* was defined above. These final ratios were calculated for each of the 40 question estimates, at each of the three target CVs for either 1-year or 5-year data. These final reduction ratios are shown in Tables A1 and A2.

The final reduction ratio can be interpreted as the percent of the initial sample that the overall sample can be reduced to, such that the observed median CV will match the target CV. The reduction ratios as applied, if this is implemented, would vary by geographic area.

Analysis of Sample Size Reduction Ratios

Tables A1 and A2 have the same layout. The median CVs and final reduction ratios described in the previous section are included. Under the column titled "Areas above Target CV" are the number of states or counties where the *r* value is one; in other words, the areas where the observed CV was higher than the target CV and no sample reduction could be taken. The last columns, the mean reduction ratios, are a summarization for each question, averaging the final reduction ratios across the question's categories. For example, the 5 percent mean reduction ratio is 17.9, an average of the 5 percent final reduction ratios of the five field of degree question categories.

Focusing on Table A1 first, with the five state-based questions, we see that the median CVs of most of the question estimates are below the lowest target CV of 5 percent. The agricultural sales categories are a notable exception. As an example of the final reduction ratios, we can look at the science and engineering category of field of degree. Its final reduction ratio is 10.1. That means the overall initial sample can be reduced to 10.1 percent of its original value in order that the median CV for the science and engineering estimate would match the target CV of 5 percent. The final reduction ratios for 10 and 15 percent target CVs are even smaller, at 2.6 and 1.1.

There are some cases where the target CV can't be met. This occurs when more than half of the geographic areas have CVs above the target value, so the median CV can never match the target. For these situations, the final reduction ratio is grayed out. For example, the final reduction ratio of 61.6 for the 10 percent target CV for the "$1 to $999" agricultural sales category is grayed out. There are 26 states with CVs above 10 percent (per the next set of columns in the table), so the median CV could never match 10 percent.

Many of the final reduction ratios are quite low, with values less than 10.0 for 16 question categories at both the 10 percent and 15 percent CV targets; for the 15 percent target, 15 of the 16 are below 4.0 (i.e. the current sample could be reduced to less than 4.0 percent of its current size to meet the target CV). The agricultural sales and marital status change categories are substantially higher. Two of the agricultural sales categories can't meet any target CV.

Looking at the county-level questions in Table A2, the final reduction ratios are not as small as those in Table A1, meaning the amount of sample reduction that could be taken is not as large as with many of

the state-level question categories. Only two of the 17 categories, both with hours worked per week, can meet the 10 percent target CV. Fourteen of the 17 categories can meet the 30 percent target CV, but only three have final reduction ratios less than 10.0.

It is worth noting that the final reduction ratio can be quite substantial even if the target CV can't be achieved. For the Vietnam Era category of period of service, the calculated final reduction ratio for the 10 percent target CV was 31.7, but 1,691 of the 3,141 nonzero counties had CVs above 10 percent, so the target could not be achieved. The substantial reduction ratio is due to the uneven distribution of sample across the counties. The 1,450 counties with initial CVs less than 10 percent contained more than 80 percent of the sample, and the sample in the largest counties had to be reduced the most to raise the CV to the target level.

Appendix Table A1: Final Reduction Ratios and Related Measures for Questions Required at the State Level (2013 1-Year Data)

Question	Estimate	# Areas Est > 0	Median CV	Final Reduction Ratio CV=10%	Final Reduction Ratio CV=20%	Final Reduction Ratio CV=30%	Areas Above Target CV 5%	Areas Above Target CV 10%	Areas Above Target CV 15%	Mean Reduction Ratio 5%	Mean Reduction Ratio 10%	Mean Reduction Ratio 15%
Agricultural Sales	$1 to $999	50	10.2%	97.2	61.6	35.8	48	26	13	98.1	77.7	54.1
	$1,000 to $2,499	50	13.3%	100.0	85.7	55.8	50	36	22			
	$2,500 to $4,999	49	17.7%	100.0	93.2	69.8	49	43	30			
	$5,000 to $9,999	50	18.2%	100.0	91.9	72.7	50	43	33			
	$10,000 and up	51	9.6%	93.4	56.0	36.4	41	24	15			
Field of Degree	Science and Engineering	51	1.9%	10.1	2.6	1.1	2	0	0	17.9	4.8	2.1
	Science and Engineering Related Fields	51	3.4%	29.1	8.3	3.7	14	1	0			
	Business	51	2.2%	16.2	4.4	1.9	7	0	0			
	Education	51	2.6%	19.0	5.0	2.2	6	0	0			
	Arts, Humanities and Other	51	2.3%	15.1	3.8	1.7	5	0	0			
Marital Status Change	Married in the last year	51	4.9%	57.9	20.1	9.6	25	10	0	63.1	23.1	11.4
	Widowed in the last year	51	6.1%	67.5	26.0	13.2	35	13	5			
	Divorced in the last year	51	5.4%	63.9	23.1	11.4	29	11	1			
Times Married	Never married	51	0.8%	1.7	0.4	0.2	0	0	0	7.2	2.0	0.9
	Once	51	0.5%	1.0	0.2	0.1	0	0	0			
	Twice	51	1.3%	5.8	1.5	0.6	1	0	0			
	Three or more times	51	2.6%	20.5	5.7	2.6	9	1	0			
Year Last Married	2010 or later	51	2.7%	22.5	6.2	2.7	8	0	0	9.1	2.4	1.1
	2000 to 2009	51	1.4%	6.3	1.6	0.7	0	0	0			
	1990 to 1999	51	1.4%	6.6	1.7	0.7	1	0	0			
	1980 to 1989	51	1.4%	6.8	1.7	0.8	2	0	0			
	1970 to 1979	51	1.7%	8.5	2.2	1.0	1	0	0			
	Before 1970	51	1.1%	3.9	1.0	0.4	0	0	0			

Note: Shaded Final Reduction Ratio cells cannot meet the target median CV because more than half of the states have CVs larger then the target CV.

Appendix Table A2: Final Reduction Ratios and Related Measures for Questions Required at the County Level (2013 5-Year Data)

Question	Estimate	# Areas Est > 0	Median CV	Final Reduction Ratio CV=10%	Final Reduction Ratio CV=20%	Final Reduction Ratio CV=30%	Areas Above Target CV 10%	Areas Above Target CV 20%	Areas Above Target CV 30%	Mean Reduction Ratio 5%	Mean Reduction Ratio 10%	Mean Reduction Ratio 15%
Year of Entry	2010 or later	2,477	55.6%	78.1	58.9	48.0	2,372	2,181	1,945	57.2	39.2	28.9
	2000 to 2009	3,031	27.5%	53.4	36.0	25.2	2,623	1,980	1,383			
	1990 to 1999	2,991	29.1%	53.7	36.5	26.2	2,582	1,984	1,457			
	Before 1990	3,120	20.4%	43.4	25.4	16.2	2,432	1,585	966			
Period of Service	Sep 2001 or later	3,084	27.1%	67.6	40.4	26.1	2,748	2,085	1,346	61.7	37.9	26.1
	Aug 1990 to Aug 2001	3,127	21.5%	60.0	31.8	18.9	2,630	1,694	896			
	May 1975 to Jul 1990	3,138	15.8%	47.2	21.4	11.3	2,323	1,111	395			
	Vietnam Era	3,141	10.7%	31.7	11.4	5.4	1,691	391	124			
	Feb 1955 to Jul 1964	3,137	15.3%	46.7	20.1	10.4	2,271	957	344			
	Korean War	3,130	16.9%	52.7	24.6	13.3	2,488	1,215	515			
	Jan 1947 to Jun 1950	2,924	43.9%	90.1	65.0	47.7	2,874	2,581	2,151			
	World War II	3,120	22.2%	59.6	33.2	19.9	2,731	1,775	936			
	Nov 1941 or earlier	1,778	78.4%	99.4	93.4	81.8	1,777	1,759	1,663			
Service Connected Disability	Has a service-connected disability rating	3,131	18.2%	56.4	27.0	14.7	2,560	1,376	542	56.4	27.0	14.7
Hours Worked Per Week	35 hours or more	3,143	2.5%	3.0	0.8	0.4	69	7	1	21.4	8.7	4.4
	15-34 hours	3,141	7.6%	18.7	5.8	2.7	1,012	148	29			
	1-14 hours	3,137	15.1%	42.5	19.4	10.2	2,252	1,022	331			

Note: Shaded Final Reduction Ratio cells cannot meet the target median CV because more than half of the counties have CVs larger then the target CV.

Appendix 4: Edit Processing Impacts

This appendix provides insights into the ripple effects on edit processes due to changes to the set of potential items included as meeting the criteria for Option 1, periodic inclusion, and Option 2, subsampling.

The table that begins on the following page includes the short description for each item, the item number from ACS mail instrument (in parentheses), and the final edited variable name (in brackets). The table is arranged in the order that items are processed through the sequential edits rather than ordered as items appear on the instrument.

First-order impacted items are the downstream items that rely in some way on the starting item that is a candidate for possible matrix sampling (i.e., direct links). The starting item may impact the downstream item by some combination to (a) identify records for further editing, (b) inform logical edits, or (c) inform deterministic or hot-deck allocations. Second-order downstream variables are the downstream items that are affected by the first-order item (i.e., indirect links). The exact manner in which a given item impacts a subsequent item (or items) would take considerable time to untangle.

The direct impact (A --> B) or indirect impact (A --> B --> C) may result in the edited value B or C being flagged as an allocated value. When considering the impact on allocation rates of removing item A, it is also necessary to consider the potential for increased allocation of variables B...Z. Whether the downstream edited value is flagged as an allocation can only be determined by looking at each specific edit condition.

Item for Potential Matrix Sampling	First Order Impacted Items[1]	Second Order or Greater Impacted Items[2]	Composite Recodes
Times Married (P22) [MARHT]	*Marital Status Change in Past 12 Months* Married in Past 12 Months (P21A) [MARHHM] Widowed in Past 12 Months (P21B) [MARHW] Divorced in Past 12 Months (P21C) [MARHD]	 none none none	
Year Last Married (P23)	*Marital Status Change in Past 12 Months* Married in Past 12 Months (P21A) [MARHHM] Widowed in Past 12 Months (P21B) [MARHW] Divorced in Past 12 Months (P21C) [MARHD]	 none none none	
Marital Status Change in Past 12 Months Married in Past 12 Months (P21 A) [MARHHM] Widowed in Past 12 Months (P21 B) [MARHW] Divorced in Past 12 Months (P21 C) [MARHD]	 none none none	 none none none	

Item for Potential Matrix Sampling	**First Order Impacted Items[1]**	**Second Order or Greater Impacted Items[2]**	**Composite Recodes**
Year of Entry (P9) [YOE]	Citizenship (P8) [CIT] Speaks another language at home (P14A) [LANX] English speaking ability (P14C) [ENG]	Language spoken (P14B) [LAN]	Linguistic isolation [LNGI]
Undergraduate Field of Degree (P12) [FOD1-FOD10]	none	none	Science and engineering flag [SCIENG] Science and engineering related flag [SCIENGRL]

Item for Potential Matrix Sampling	First Order Impacted Items[1]	Second Order or Greater Impacted Items[2]	Composite Recodes
Hours Worked Per Week (P40) [WKH]	When last worked (P38) [WKL] *Income and Earnings* Wages/salary income (P47A) [WAG] Self-employment income (P47B) [SEM] Interest, dividends, etc. income (P47C) [INT] Social security or railroad retirement (P47D) [SS] Supplemental security income (P47E) [SSI] Public assistance (P47F) [PA] Retirement income (P47G) [RET] Other income (P47H) [OI] Total income (P48) [TI] Class of worker (P41) [COW] Industry (P43) [IND] Occupation (P45,P46) [OCC]	*Disability* Hearing difficulty (P17A) [DEAR] Visual difficulty (P17B) [DEYE] Difficulty remembering (P18A) [DREM] Physical difficulty (P18B) [DPHY] Difficulty dressing (P18C) [DDRS] Difficulty going out (P19) [DOUT] Veteran status (P26) [MIL] Service connected disability status (P28A) [DRATX] Place of work (P30) Mobility status (P15A) [MIG] Migration (P15B) [MIGS,MIGC,MIGD,MIGP] *Health Insurance* Health insurance through employer/union (P16A) [HINS1] Health insurance purchased directly (P16B) [HINS2] Health insurance through Medicare (P16C) [HINS3] Health insurance through Medicaid (P16D) [HINS4] Health insurance through TRICARE (P16E) [HINS5] Health insurance through VA (P16F) [HINS6] Health insurance through Indian Health Service (P16G) [HINS6]	Employment status recode [ESR] Disability status recode [DIS] Health insurance coverage [HICOV] Food stamp recipiency [FS] Poverty status [POV]

Item for Potential Matrix Sampling	First Order Impacted Items[1]	Second Order or Greater Impacted Items[2]	Composite Recodes
Period of Service (P27) [MLPA-MLPK]	Veteran status (P26) [MIL]	*Income and Earnings* Wages/salary income (P47A) [WAG] Self-employment income (P47B) [SEM] Interest, dividends, etc. income (P47C) [INT] Social security or railroad retirement (P47D) [SS] Supplemental security income (P47E) [SSI] Public assistance (P47F) [PA] Retirement income (P47G) [RET] Other income (P47H) [OI] Total income (P48) [TI] *Health Insurance* Health insurance through employer/union (P16A) [HINS1] Health insurance purchased directly (P16B) [HINS2] Health insurance through Medicare (P16C) [HINS3] Health insurance through Medicaid (P16D) [HINS4] Health insurance through TRICARE (P16E) [HINS5] Health insurance through VA (P16F) [HINS6] Health insurance through Indian Health Service (P16G) [HINS6] VA Service Connected Disability Status (P28A) [DRATX] VA Service Connected Disability Rating (P28B) [DRAT]	Veteran period of service [VPS] Health insurance coverage [HICOV]

Item for Potential Matrix Sampling	First Order Impacted Items[1]	Second Order or Greater Impacted Items[2]	Composite Recodes
VA Service Connected Disability Status (P28 A) [DRATX]	none	none	
VA Service Connected Disability Rating (P28 B) [DRAT]	none	none	
Agriculture Sales (H5) [AGS]	*No direct effects; however, AGS informs the sort order of nearest neighbor allocation for: Work Experience [WKL,WKW,WKH]; Industry, Occupation, and Class of Worker (IND, OCC, COW); Income and Earnings [WAG, SEM, INT, SS, SSI, PA, RET, OI, TI]*	none	

1 Starting variable (A) is used to inform the edits of downstream variable (B). Variable A may be used to identify records for further editing, inform logical edits, or to inform deterministic or hot-deck allocation. Depending on how variable A is used in the edit decision, variable B may be identified as an allocated value.

2 Starting variable (A) is used to inform the edits of downstream variable (B), which in turn informs the edits of a subsequent variable (C). Variable A may be used to identify records for further editing, inform logical edits, or to inform deterministic or hot-deck allocation. Depending on how variables A and B are used in the sequence of A to B to C, variable C may be identified as an allocated value.