

ASA

TOPIC UPDATE

SURVEY RESPONSE RATES AND THE HEALTH OF FEDERAL STATISTICS

A Report of the American Statistical Association Project Team to Assess and Monitor the Health of Federal Statistics

Funded by the Annie E. Casey Foundation, Funders for the Future of Public Data, the Robert Wood Johnson Foundation, and the American Statistical Association. The findings and conclusions presented in this report are those of the authors alone and do not necessarily reflect the opinions of these foundations, nor views of any host organization of the project team members.

November 2026

Michelle Crosby
American Statistical Association

Constance Citro
National Academies of Sciences, Engineering, and Medicine, and
Independent Consultant

Claire McKay Bowen
NORC at the University of Chicago

Daniel Cork
Massive Data Institute, McCourt School, Georgetown University

Jennifer Park
Senior Consultant, American Statistical Association

Steve Pierson
American Statistical Association

Nancy Potok
NAPx Consulting (former Chief Statistician of the United States)

Zachary Seeskin
NORC at the University of Chicago

ACKNOWLEDGEMENTS

We thank the Annie E. Casey Foundation, Funders for the Future of Public Data, and the Robert Wood Johnson Foundation for their support of this work, as well as the Alfred P. Sloan Foundation and the California Community Foundation for their past support. Our project content does not necessarily reflect the opinions of these funders. We are also grateful for the document review by statistical agency leadership and staff, our Scientific Advisory Board, and David S. Johnson, Jennifer Madans, and Mark Mather; the expert editing of the report by Kerri Kennedy; and the report's design by Megan Murphy.

The Nation's Statistical System Is Losing Its Respondents

Our ability to manage the economy, workforce, health, education, crime, and other vital areas of national life depends on accurate measurement. For many of these measures, the federal government relies on surveys of households and establishments.

That foundation is under growing strain. Response rates to government and private-sector surveys have been falling for years in the United States and around the world.[1] A National Academies of Sciences, Engineering, and Medicine (NASEM, 2023b) report concluded (p. 22) that the "US statistical agencies' reliance on sample-survey data and census data is unsustainable" and urged a new data infrastructure centered on combining survey data, where possible, with administrative records and other sources. A companion report (NASEM, 2023a, p. 7) recognized that surveys are necessary for some kinds of information—for example, people's personal experiences with health problems, whether they have been a victim of crime, or whether they are looking for work.

Declining Response Rates Are a Canary in the Coal Mine

A survey's response rate is more than a technical measure of survey administration. A decline in the response rate raises the risk to the quality of that survey and, because agencies must spend more to reach the same precision, to its cost and sustainability, even when the headline numbers still look sound.[2]

When fewer households and businesses participate in surveys, statistical agencies often are still able to produce estimates. But the foundation underneath those estimates is changing. The effective sample size is smaller than planned, which means that detail for geographic areas and population groups may need to be reduced and that estimates may become less precise and the margin of error widen. Respondents may also increasingly differ from nonrespondents, and the risk of bias may increase. The process to produce a published number has become more fragile, even when the published figure looks unchanged. The distinction matters. A falling response rate does not automatically mean that a survey's estimates are inaccurate. It increases the risk that estimates do not remain as accurate and representative as they have been in the past.

Declining response rates also increase the costs of producing statistical estimates. With a modest investment, statistical agencies may increase the sample size to try to sustain the number of respondents. A more expensive approach is to devote more resources to urge the yet-to-respond people to respond—that is, conduct "nonresponse follow up," or NRFU. Voluntary response by individuals or establishments to a survey via a paper or electronic questionnaire, perhaps with a postcard or email reminder, is generally cost-effective. When phone or in-person visits are used, whether for initial collection or for NRFU or both, response may improve but costs also increase dramatically.

The appropriate response, therefore, is not simply to chase a higher response rate for any individual survey. It is to address the declining participation to the extent possible (considering such factors as declining public trust, increasing survey burden, cost-benefit tradeoffs for different collection modes, and constrained budgets and staffing); to adapt survey methodologies, given the changed survey climate; and to consider blending survey data with other data sources.

[1] See, e.g., Jabkowski and Cichocki (2025); König et al. (2021); Luiten et al. (2020); Williams and Brick (2018).
[2] See, e.g., Groves and Peytcheva (2008); Hedlin (2020).

Such efforts at what is often termed "modernization" and the resources to make modernization possible are critical.[3] A modern statistical system will have more efficiently designed surveys, make responsible use of administrative records and other data sources, and invest in infrastructure and expertise needed to maintain data quality as survey response continues to decline. Without such modernization, agencies risk managing symptoms rather than addressing the underlying problem: patching individual surveys as their response rates deteriorate rather than building a statistical system resilient enough to produce a wide range of trustworthy information over the long term.

There is no technological shortcut around this challenge. Better tools still require good data as their foundation.

Why the Issue Is Becoming More Urgent

The urgency of declining response rates was underscored in early 2026 by reports of record low response rates to the National Agricultural Statistics Service (NASS) March 2026 Prospective Plantings Survey. The problem has drawn attention among the agricultural community and has contributed to efforts by NASS to rethink how some information is collected.[4]

Congress has also increasingly raised concerns about declining response rates and the need to modernize federal surveys. The 2025 Senate appropriations bill report language for the Departments of Labor, Health and Human Services, and Education, called for a modernization plan:

> The [Appropriations] Committee remains concerned by declining response rates facing all survey programs and other challenges which necessitate actions by BLS and the Census Bureau to modernize the operations of the Current Population Survey [CPS] and maintain this resource. *The Committee believes steps must be taken to modernize the CPS.* [emphasis added]

Congressional concern is not limited to economic statistics. In summer 2026, language in a House appropriations subcommittee report, accompanying an appropriations bill (not yet enacted) for the Departments of Labor, Health and Human Services, and Education, expressed concern about declining response rates for for the National Health and Nutrition Examination Survey (NHANES) of the National Center for Health Statistics (NCHS).[5]

The issue has also received increasing attention from researchers and policy organizations. Czajka and Beyler (2036) reviewed response rates for eight surveys of interest to the Department of Health and Human Services; Johansson, Effland, and Coble (2017) discussed response rates for NASS surveys; Williams and Brick (2018) analyzed response rates for nine in-person surveys in the government and academic sectors for the period of 2000–2014; and Taylor, Madans, and Chapman et al. (2023) focused on declining response rates and other challenges for the future of NHANES. The American Statistical Association's 2024 Nation's Data at Risk report (Auerbach, Bowen, Citro et al., 2024) identified declining survey response rates as one of the challenges facing federal statistics. In spring 2026, researchers at the Brookings Institution reported on declining response rates across a range of federal economic surveys (Johnson, Meinhardt, and Sabelhaus, 2026).

The business press has focused on declining response rates to the early rounds of the Bureau of Labor Statistics (BLS) monthly Current Employment Statistics (CES) program, which feed into the earliest estimates of payroll jobs gains and losses. BLS revises its estimates when information arrives from late responders and other sources, and sometimes the revisions are substantial.[6] Moreover, even after accounting for late responses, the overall response rate for the CES declined from 60% to 42% over the past 10 years (see Figure 3a and Appendix A).

[3] See, e.g., Modernizing the Federal Statistical System: A Roadmap for Action, American Statistical Association (2026).
[4] See, e.g., Farmer Survey Response Decline a Growing Problem | Farm Bureau Intel Markets | American Farm Bureau Federation.
[5] Committee Print of Report, Departments of Labor, Health and Human Services, and Education, and Related Agencies Appropriations Bill, 2027, U.S. House of Representatives, June, 2026, pp. 82-83.
[6] See, e.g., Answers Don't Come Easy | Richmond Fed; Why the B.L.S. Regularly Revises Jobs Data - The New York Times

A wider look at response rate trends across the federal statistical system, however—including both household and establishment surveys—has not been undertaken since work by the Federal Committee on Statistical Methodology (FCSM) and interagency working groups on nonresponse 20–25 years ago.[7] That work and the passage of the Information Quality Act of 2002 led to standards for calculating survey response rates in Statistical Policy Directive No. 2 (OMB, 2006). Yet there are no standardized, user-friendly protocols for agencies to post response rates, and agencies' practices vary in this regard. Consequently, policymakers and data users are less able to compare this measure of quality across surveys, agencies, and time periods. The modernization needs of a survey depend on its subject matter, collection methods, available alternative data, and the resources required to maintain quality. Tracking response rates across surveys and agencies, as an early warning system, provides an important basis for identifying where modernization is most urgent and where resources should be prioritized.

For that reason, the ASA project "Assessing and Monitoring the Health of Federal Statistics" (ASA FedStat Health) has expanded its efforts to document response rate trends across the federal statistical system by creating an ASA Response Rates Online Resource. See Box 1 for a description of the resource and Box 2 on defining response rates.

In what follows, we briefly review the role of surveys in federal statistics and how survey response rates relate to data quality. We then provide an overview of response rate trends for selected federal household and establishment surveys for illustrative purposes, describe strategies statistical agencies use to sustain participation and limit the effects of nonresponse on data quality, and discuss the need to improve survey response rate documentation and archiving. We end with a summary conclusion. Appendix A provides response rate trends for all of the surveys currently in the online resource, by agency.

BOX 1. About the New ASA Response Rates Online Resource

It is well established that survey response rates are declining. Lower response rates can drive up costs and affect data quality by making survey estimates less certain and potentially less representative of the population being measured. It is not easy, however, to locate response rates across time for many federal household and establishment surveys.

To support research and evidence-based statistical policy, the ASA FedStat Health project is building and maintaining an open repository of survey response rates and sources for the principal federal statistical agencies that are conducting surveys. We have included some censuses and mandatory surveys: Even mandatory surveys can see declining compliance, so mandatory status does not by itself prevent decline.

The ASA Response Rates Online Resource is available here and at https://bit.ly/FedStatHealth. The rates in the resource are unit rates—that is, the percentage of eligible units in a survey sample (e.g., households, establishments) that respond with sufficient information to be usable by the statistical agency. Response rates to individual question items, while another important quality indicator, are not in the ASA resource.

Currently, the online resource includes response rates for surveys of 10 of the 13 statistical agencies: the Bureau of Justice Statistics (BJS), Bureau of Labor Statistics (BLS), Bureau of Transportation Statistics (BTS), Census Bureau, Energy Information Administration (EIA), Economic Research Service (ERS), National Agricultural Statistics Service (NASS), National Center for Education Statistics (NCES), National Center for Health Statistics (NCHS), and National Center for Science and Engineering Statistics (NCSES). ASA intends to maintain and expand the online resource to include additional surveys for the agencies already included. ASA also intends to search for past response rates to make longer time series for as many surveys as possible.

There are no surveys included for the Office of Research, Evaluation, and Statistics (ORES) or the Statistics of Income (SOI) Division, which are not conducting surveys. The Bureau of Economic Analysis (BEA) conducts mandatory surveys on foreign direct investment in the United States, US direct investment abroad, and international trade in services, which provide inputs to the National Income and Product Accounts and which are not included in the online resource.

Should you have an historical set of unit response rates for one or more surveys not already part of the resource, or for which rates in the resource are incomplete, or have questions about the resource, please contact Steve Pierson at ASA: spierson@amstat.org.

[7] See FCSM (2001) and the papers listed for the Interagency Household Survey Nonresponse Group at FCSM | Interagency Household Survey Nonresponse Group (IHSNG) and Measuring and Reporting Sources of Error in Surveys. There was also an Interagency Establishment Survey Nonresponse Group.

BOX 2. Defining Response Rates

Response rates, or completed interviews as a percentage of eligible units in the sample, estimate the extent to which a survey obtains usable data from its original sample. The American Association for Public Opinion Research (AAPOR) specifies six response rate definitions, depending on whether and what kinds of partial interviews are counted as responses in the numerator and whether and what kinds of nonresponding sample cases of unknown eligibility are included in the denominator.[8]

Statistical Policy Directive No. 2 (OMB, 2006) requires agencies to calculate unweighted and weighted "overall unit" response rates using AAPOR definition RR3. Specifically, the calculation in SPD #2 is:

RRU = C / [C + R + NC + O + *e* (U)], where

RRU = unweighted response rate,

C = number of completed cases (or plus sufficient partial completions),

R = number of refusal cases,

N = number of noncontacted sample units known to be eligible (e.g., for a household survey, addresses that are occupied and not vacant or nonresidential),

O = number of eligible sample units not responding for other reasons than refusal,

U = number of sample units of unknown eligibility, not completed, and

e = estimated proportion of U that are eligible.

The guidance in SPD #2 leaves it up to the statistical agency to determine such elements in the formula as "sufficient partial completions" and the parameter *e*. Available documentation is not always clear on the response rate calculations for a particular survey. Moreover, agencies vary in their terminology (e.g., "response rates," "overall unit response rates," "completion rates").

Agencies also may use response rate terminology when, according to AAPOR, they are presenting "cooperation" (i.e., conditional) rates: for example, the cooperation of adults selected to answer additional questions in participating households. For data quality in terms of variability and potential bias, the unconditional response rate is most relevant—which, for households, equals responding households as a percentage of estimated eligible households as above. In surveys with a household screener and a set of person questions, the person-level unconditional response rate is the household response rate times the person cooperation rate.

This analysis and the ASA Response Rates Online Resource depend on information from the statistical agencies, which differ in details of calculating rates and in the extent of documentation provided. The online resource includes technical notes on specific surveys' response rate calculations to the extent they are known, and its README sheet explains how survey-specific response rate labels differ.

The Role of Surveys in Federal Statistics

For almost 150 years, censuses (population, agriculture, manufacturing, and others) and administrative records from government operations, supplemented by non-probability surveys, were the primary sources of federal statistics.[9] The Great Depression made it imperative to have accurate, more frequent, and less costly data on unemployment, prices, and other subjects; in response, agencies introduced new probability sample-based methods, which made it possible to represent the population and estimate the variability from sampling. Probability sampling began to be adopted around 1937 when a 2% sample survey of households gave a better estimate of national unemployment than an attempt to reach everyone (Duncan and Shelton, 1978, p. 44). The 1940 census asked six questions of a 5% sample of the population to test the method as a way to obtain additional data at far lower cost than asking everyone. Subsequent censuses through 2000 asked a small number of basic demographic questions of most people on a "short form," while using a "long form" to obtain the basic demographic information plus much more (e.g., employment, income, education, housing characteristics) from a large sample of households (sampling percentages ranged from 5% to 25%).[10]

[8] The American Association for Public Opinion Research (AAPOR) has published Standard Definitions: Final Dispositions of Case Codes and Outcome Rates for Surveys (AAPOR, 2023, 10th edition) since 1998 and regularly updates it for changes in sample frame construction and data collection methods. It includes a large number of case disposition codes (e.g., partial interview, unknown eligibility), varying by the type of survey (e.g., mail list or in-person area frame). Besides response rates, it defines cooperation rates, refusal rates, and contact rates.

[9] Records included customs records from the imposition of tariffs in the 18th and 19th centuries; federal income tax records dating to 1913 upon the adoption of the 16th amendment to the Constitution, with the Revenue Act of 1916 establishing the requirement for annual publication of income tax statistics; and state birth and death records—the newly established Census Bureau was charged in 1902 to work with states on a national vital statistics system (under NCHS since 1960). Newly formed statistical offices on agriculture (1863), education (1867), and labor (1884) also obtained records from state agencies and establishments. BLS early in its history conducted nonprobability sample surveys of workers and establishments.

[10] The decennial census long-form sample stopped after 2000. Starting in 2005, the American Community Survey (ACS) surveyed large samples of housing units each month to produce annual and five-year estimates that take the place of the long form (Citro, 2016, p. 358).

Post–World War II, probability sampling took root as the primary data collection method for federal statistical agencies, as well as underpinning robust survey enterprises in academia and the private sector. The simultaneous adoption of computer processing by the statistical agencies made it possible for surveys to provide frequent, timely, relevant, and voluminous information much more easily and inexpensively compared with censuses. Over the decades, statistical agencies pioneered cost-effective, innovative survey designs, data collection, processing, and estimation methods, and dissemination mechanisms, including making public-use microdata files of survey responses available for policy and research analysis.

Federal surveys today cover a wide range of topics, from crime victimization to agricultural practices to educational outcomes to income and spending. They provide data for such uses as:

- Estimation of headline federal economic indicators (e.g., consumer and producer price indexes, retail trade, unemployment and payroll employment, median income and poverty rates);
- Federal, state, and local government planning (the ACS is a workhorse for these and other uses—see NASEM, 2013a);
- Private-sector planning (e.g., site location and workforce availability analysis);
- Congressional oversight, policy formulation, and constituency services;
- Media reporting; and
- Research and policy analysis (e.g., the deleterious effects of lead in water and gasoline on children's development from NHANES; the beneficial effects of Head Start programs from the National Longitudinal Surveys of Youth—see Bowen et al., 2025, Supporting Materials: H).

Factors in Survey Nonresponse

Over the past 40–50 years, the public, in America and abroad, has become harder to reach and, in some settings, less willing to respond to public or private survey inquiries. Research on nonresponse to face-to-face household surveys for the period 2000–2014 showed that refusals continued to be the largest percentage of nonresponse, refusal rates increased for some surveys but not others, and making contact became harder (Williams and Brick, 2018). Many factors play a role in decreasing survey participation, although it is difficult to credit specific factors with declines in response for individual surveys. A review about a decade ago (NASEM 2013b) identified three perspectives on response to household surveys: social capital theory, leverage-salience theory, and social exchange theory.[11] Presciently, the report commented (p. 36) that "as demands on the time of respondents grow, increasing the cost of responding, and distrust of institutions multiplies, the social exchange theory would posit that nonresponse would grow unless perceived benefits of responding also increase."

NASEM (2013b) points out that rigorous research linking these theories to nonresponse in particular surveys and to the general increase in survey nonresponse is lacking. Surveys vary in so many dimensions that such research is difficult and costly to conduct. Research has also shown that the reasons respondents give for nonresponse (no time, worried about privacy) have not changed over time, although the percentages for each reason very likely have changed. In that regard, a recent study of reasons for refusals to respond to NHANES, a survey involving an in-person physical health examination, between 2017 and 2022 (Fink et al., 2024) found that "too busy/avoidance" accounted for about 45% of refusals by households and sample persons in responding households over the period, and that "too busy/too long" accounted for 5% of refusals by households and 20% of refusals by sample persons in responding households over the period. Only one reason showed a substantial time trend, and that was "general distrust of

[11] A comparable review of household and person survey nonresponse covering ~2012 to 2026—a period with steeper declines in response, particularly during the COVID-19 pandemic (see below)—has not been conducted. Reviews of nonresponse to establishment surveys are also lacking.

surveys or government." Refusals for this reason increased for households from about 6% of refusals in 2017–2019 to 10% in 2021 and 15% in 2022, and for sample persons in responding households from 4% of refusals in 2017–2019 to 14% in 2021 and 18% in 2022.

Federal surveys still achieve much higher response rates than most private-sector surveys—for example, telephone-based public opinion polls often obtain usable responses from 5% or fewer of their sample cases.[12] Pollsters and survey practitioners everywhere rely on federal data to weight their own results, so declines in federal response affect far more than the federal surveys themselves.

How Response Rates Relate to Quality

Declines in response rates are worrisome for the quality of survey information along two dimensions: (1) variability due to reduced sample size; and (2) bias when survey respondents differ on one or more important characteristics from nonrespondents.[13]

1. ***Variability.*** Lower response rates for a fixed sample size increase the sampling variability of survey estimates, which—in turn—makes the margin of error wider and the estimates less certain.[14] It takes a big drop in response to have a substantial effect on variability, particularly because statistical agencies have methods to reduce variability from nonresponse. Yet response rates to some federal surveys have declined to the point that the agency decided to publish fewer detailed estimates (see, e.g., Bowen et al., 2025, p. 28).

2. ***Bias.*** Estimates that derive from surveys with lower response rates may—or may not—be less representative of the population on some or all characteristics than surveys with higher response (see, e.g., Davern, 2013).[15] SPD #2 (OMB, 2006) requires agencies to analyze nonresponse and to conduct a nonresponse bias analysis when response rates or other factors suggest potential bias; its guidelines call for such an analysis when the unit response rate falls below 80%. FCSM (2020b) conducted a systematic review of 165 bias studies carried out by statistical agencies following the issuance of SPD #2, examining the method of nonresponse bias assessment and the characteristics of surveys. The report found (p. 6) that "a majority of studies reported bias in some variables prior to weight adjustment but noted that bias was reduced in at least one of the variables after weighting." Groves and Peytchev (2006) conducted a meta-analysis of 59 studies of nonresponse bias. They concluded (pp. 23–24) that:

    (1) Large nonresponse biases can happen in surveys. High response rates can reduce the risks of bias. They do this less when the causes of participation are highly correlated with the survey variables. Indeed, in the studies we assembled, some surveys with low nonresponse rates have estimates with high relative nonresponse bias.

    (2) The search for mechanisms that link nonresponse rates and nonresponse bias should focus on the level of individual measures not on the level of the survey. The meta-analysis shows much variability in nonresponse differences within surveys, across estimates.

[12] As an example, the PEW American Trends Panel Survey reported a 3% unconditional response rate to a survey in June 2021, accounting for cumulative response, from agreeing to participate in a panel to completing the particular survey (see issue-polling-methodology.pdf).

[13] As an example, nonresponse in the CPS Annual Social and Economic Supplement (ASEC) since the 2020 survey has been estimated to bias median income statistics upward by 2 to 3 percentage points and official poverty rates downward by a fraction of a percentage point (see Using Administrative Data to Evaluate Nonresponse Bias in the 2026 Current Population Survey Annual Social and Economic Supplement).

[14] In a simple random sample (surveys invariably have more complex designs), the standard error (*se*) of a proportion p is the square root of $p(1-p)/n$, where n is the sample size. For the same proportion, the *se* decreases with the square root of the sample size, so a sample must have 4 times the number of cases to cut the *se* in half. The same relationship holds for estimates of numbers. In published estimates, the *se* is typically expressed as the estimate +/- the margin of error (*se* × confidence level factor).

[15] Mathematically, the nonresponse bias for a common statistic—namely, an unadjusted respondent mean—is Bias = $(1 - RR) \times$ (mean among respondents − mean among nonrespondents), where *RR* is the unit response rate. As an example, say that income in a sample with a 90% response rate has a mean value of $50,000, while research determines that the mean value for nonrespondents is $25,000. The mean with 100% response would be only $47,500 ($0.9 \times \$50{,}000 + 0.1 \times \$25{,}000$), so the survey, without any adjustment for bias, would overestimate mean income by 5%. How much a lower response rate would add to that bias depends on the income levels of the current respondents who move into the nonrespondent group.

For other measures of survey quality, see Box 3.

BOX 3. Select Survey Quality Measures

Statistical agencies regularly assess a variety of indicators of survey quality, often using a framework developed by the FCSM (2020a). Response rates are an important indicator because declining response rates directly affect the available sample size for estimates and may introduce bias, but they are only one indicator (see, e.g., Meyer et al., 2026).

Other important quality indicators include:

- Differences in the coverage of population groups in a survey compared to census information (actually a form of bias)—for example, coverage of Black men in many household surveys is much lower than that of other groups. Statistical agencies typically reweight sample cases to census-based population controls, which is essential to adjust for coverage differences.
- Differences in response rates to individual items (e.g., most people provide their age, sex, and race/ethnicity, but many do not report their income or wealth). Statistical agencies typically impute values for missing items, which is important for the completeness of estimates.
- Whether the concepts the survey is measuring remain relevant (e.g., the federal statistical system regularly updates industry and occupation codes).

Trends in Response Rates

Federal statistical agency surveys of both households and establishments have experienced declines in response rates. We treat them separately in this report, given their different respondent types (individuals versus corporate entities) and that we could more readily locate longer response rate times series for household surveys.

Federal Household Surveys

In this section, we depict overall unit response rates[16] over the period 2000–2023 for an illustrative selection of 10 household surveys (for 2 of the surveys we have rates for 2 modules—household and sample person). For readability, we separate the available response rates into Figures 1a and 1b. Both graphs show a remarkably similar pattern: namely, a slow decline in response rates from 2000–2013 (consistent with Williams and Brick, 2018), leading to a steeper decline during the 2013–2023 period. For many surveys, there was a pronounced dip in 2020 during the COVID pandemic when households that did not respond online or with a paper questionnaire could not be followed up in person. Response rebounded in 2021, but the increases were small relative to the pre-COVID declines.

Figure 2 documents this pattern in a different way. It shows the annual average percentage point change in response rates for each household survey or module in Figures 1a and 1b (except for the ACS—see Box 4) from 2000 to 2013 (blue bars) and 2013 to 2023 (orange bars).[17] Each rate is calculated as the difference between the beginning and ending rates, divided by the number of years: 13 years for the 2000–2013 series and 10 years for the 2013–2023 series.[18]

For the 2000 to 2013 period, every household survey or module in Figure 2 experienced a decline in response except for the National Survey of College Graduates (NSCG). The average decline over this span was 0.7 percentage points per year and 9 percentage points in total from the beginning of the period to its end.

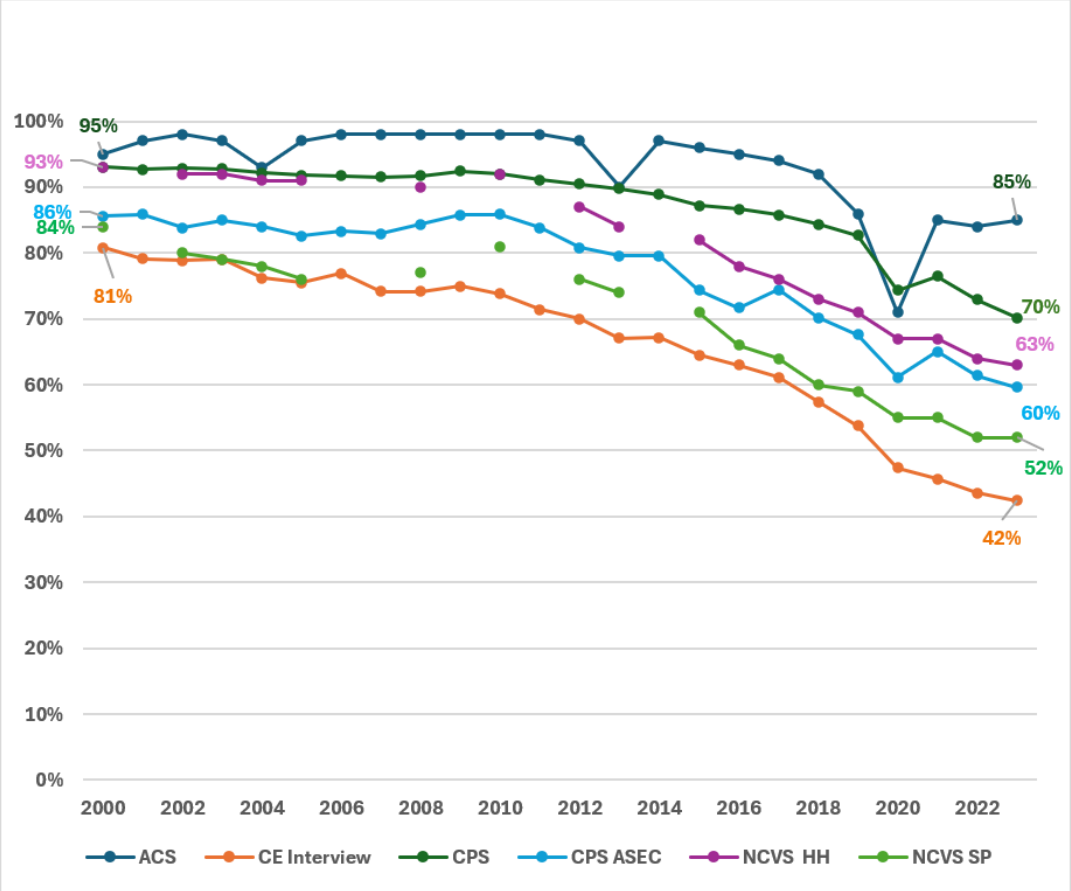
[16] The unconditional overall unit rates in this report may differ across surveys and agencies: for example, in the definitions of eligible units (see Box 2 above) and because of design differences (e.g., whether the survey draws samples separately for each interview wave or includes cases carried over from a prior wave and adds new cases in a rotation group design). Such differences should not likely affect analysis of response rate trends.

[17] For four of the surveys, the periods of observation did not exactly match the 2000–2013 and 2013–2023 periods. See notes to Figure 2.

[18] This is a simplistic analysis of response rates. It would be useful to relate trends in rates to characteristics of surveys (e.g., length of questionnaire, mode, topic), which we have not done. We hope that the new ASA Response Rates Online Resource will stimulate research inside and outside the federal statistical system, as well as serving as a reference.

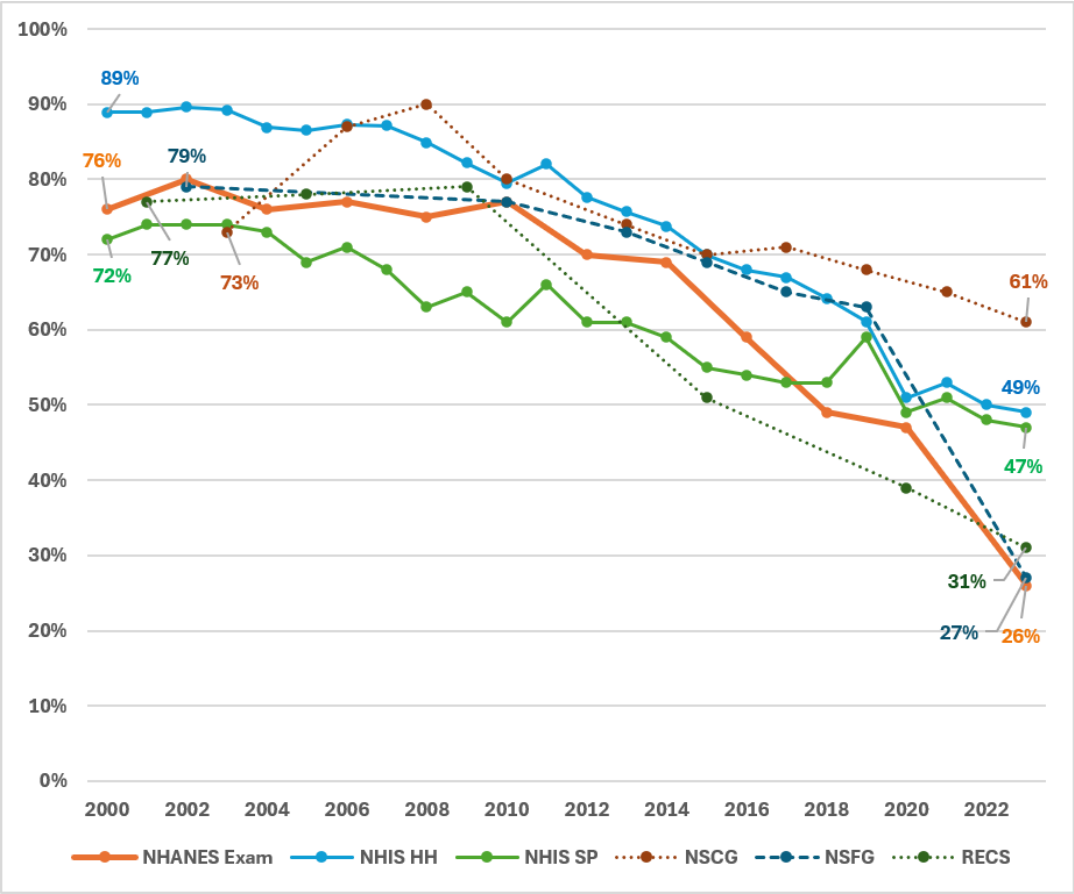
The declines in response rates from 2013 to 2023 were much steeper for most of these household surveys. The average decline over this period was 2.5 percentage points per year and 26 percentage points in total from beginning to end. The rates of decline in the 2013 to 2023 period were steepest for the NHANES exam rate and the NSFG. Some declines coincided with major methodological changes. For example, EIA changed the Residential Energy Consumption Survey (RECS) from interviewer-administered to self-administered data collection beginning in 2015. Declines may also coincide with other operational changes, such as contractor changes, survey redesigns, and shutdown: NHANES, for example, changed contractors and redesigned its sample and examination components in recent years.

FIGURE 1a. Response Rates (Percentages) for Five Federal Household Surveys and One Module from Four Statistical Agencies, 2000–2023



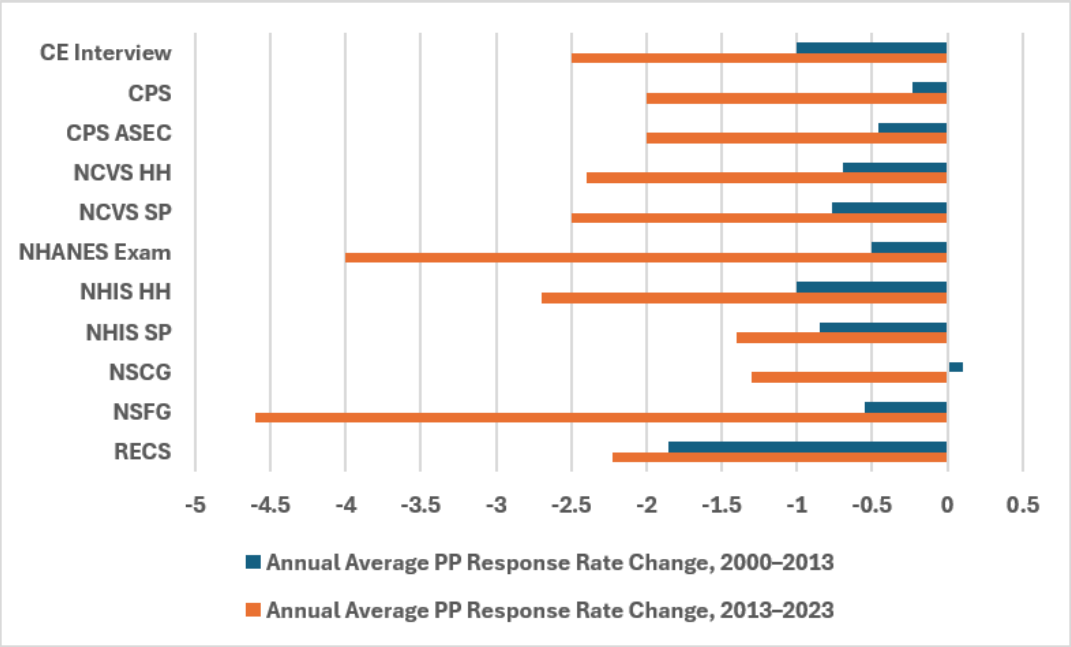
NOTES: ACS = American Community Survey (Census Bureau); CE Interview = Consumer Expenditure Survey (interview component) (BLS); CPS = Current Population Survey (BLS); CPS ASEC = CPS Annual Social and Economic Supplement (Census Bureau); NCVS HH & SP = National Crime Victimization Survey, Household & Sample Person Modules (BJS). All rates shown are unconditional (e.g., sample person rates take account of household response rates). ACS rates are weighted because of the large number of initial sampling rates and because subsamples of households that do not respond online or by mail are followed up in person. ACS rates prior to its full-scale initiation in 2005 are for smaller national samples. The ACS is mandatory.
SOURCE: ASA Response Rates Online Resource. Comparable NCVS rates for some years could not be located. The CPS response rate for 2000 (93%) is the same as the NCVS household rate shown in the graph (93%).

FIGURE 1b. Response Rates (Percentages) for Five More Federal Household Surveys and One Module from Three Statistical Agencies, 2000–2023



NOTES: NHANES = National Health and Nutrition Examination Survey; NHIS = National Health Interview Survey (NCHS); NSCG = National Survey of College Graduates (NCSES); NSFG = National Survey of Family Growth (NCHS); RECS = Residential Energy Consumption Survey (EIA). All rates are unweighted. The NCSG and RECS are collected periodically, illustrated by the dotted lines linking the response rate observations (circles). The NSFG has been collected continuously since 2006, but data are combined for multiple years for release and response rates are calculated for the combined period; hence the use of a dashed line linking the response rate observations (circles), which are for sample people in households. All rates are unconditional. The NHANES Exam rates account for response to the household screener, response by the sample person, and sample persons agreeing to take the exam. The NHIS rates are for the household module (NHIS HH) and the sample (adult) person module (NHIS SP). Different questionnaire designs were implemented for the NHIS during 1997–2018 and 2019–2024, and the calculation of the unconditional sample adult response rate differs by design.
SOURCE: ASA Response Rates Online Resource

FIGURE 2. Federal Household Survey **Annual Average Percentage Point Change** in Response Rates, 2000–2013, 2013–2023: 9 Surveys and 2 Modules from 6 Statistical Agencies



NOTES: See notes to Figures 1a and 1b. For four of the surveys, the periods of observation did not exactly match the 2000–2013 and 2013–2023 periods. For NHANES, the periods were 2000–2012 and 2012–2023; for NSCG, the first period was 2003–2013; for NSFG, the first period was 2002–2013; and for RECS, the periods were 2001–2015 and 2015–2024. This is a simplistic analysis of response rates. It would be useful to relate trends in rates to characteristics of surveys (e.g., length of questionnaire, mode, topic), which we have not done. For example, NCHS attributes the NSFG's large decline in response rates to a significant mode change.
SOURCE: ASA Response Rates Online Resource.

BOX 4. Response Rates in the American Community Survey (ACS)

As a mandatory survey (and the only mandatory household survey), the ACS would not be expected to exhibit much decline in response. Yet the decline seen in Figure 1a from 95% response in 2000 to 85% response in 2023 is concerning, given the reliance of users on the ACS for small geographic area and population group analyses. During COVID, ACS response dropped to 71%, and the Census Bureau released a smaller-than-usual set of 1-year estimates, labeled "experimental." See 2020 ACS 1-Year Experimental Data Release. Refusals, which are the primary reason for ACS nonresponse, have increased from 1% of eligible housing units in 2005 to 9% in 2025.

The ACS also illustrates the importance of examining item nonresponse rates in addition to overall unit response rates. Imputation rates have increased for many items in the ACS since its inception, such as:

- Educational attainment: imputation rates of ~4–5% (2006–2010 ACS) and ~12% (2021–2025 ACS);
- Citizenship: imputation rates of ~2–3% (2006–2010) and ~10–11% (2021–2025);
- Social Security or Railroad Retirement income: imputation rates of ~7–9% (2006–2010) and ~20% (2021–2025).

In addition, the percentage of people with some or all of their income imputed increased from ~19–22% in 2006–2010 to ~32% in 2021–2025.

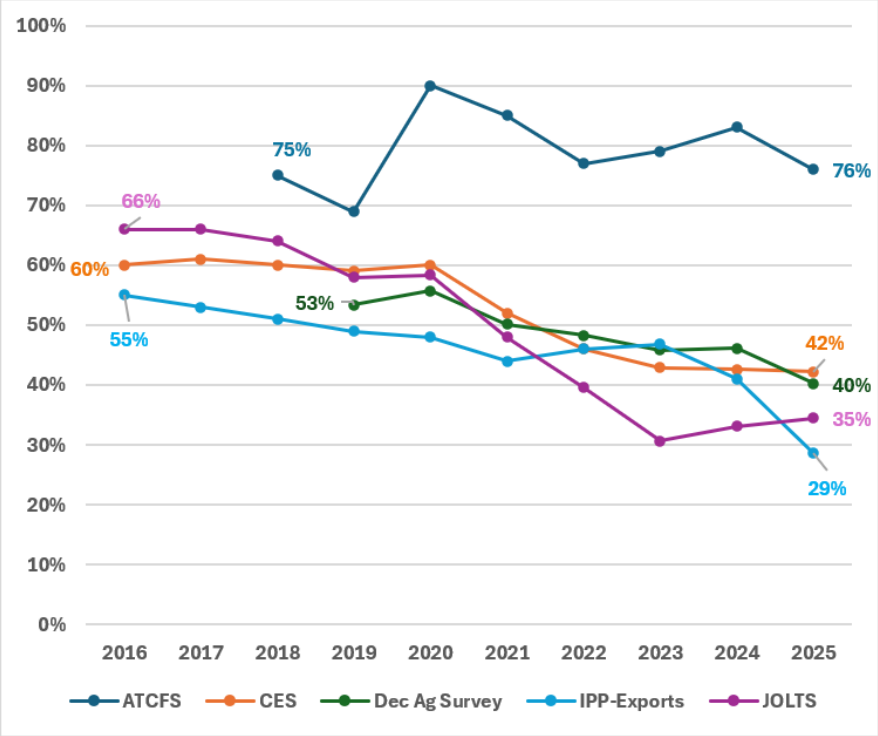
Source: Sample Size and Data Quality.

Federal Establishment Surveys

Figures 3a and 3b show a mixed picture for response rate trends for a selection of 10 establishment and price surveys over the period 2016–2025. The Annual Tank Car Facility Survey (ATCFS), Business Enterprise Research and Development Survey (BERD), and National Census of Ferry Operators (NCFO) show variations in response but have generally held their own at reasonably high rates of response (BERD is a mandatory survey). The other seven surveys show a marked decline in response from 2016 to 2020–2022, followed by continued decline, except for the CES and Consumer Price Index–Commodities and Services (CPI-C&S), which have stabilized, and the Job Openings and Labor Force Turnover Survey (JOLTS), which has improved. Response rates for 6 of the 10 surveys have fallen below 50%, and the rates for International Price Program–Exports (IPP-Exports), IPP-Imports, and JOLTS (even with its recent improvement) are below 40%. EIA, on the other hand, has a series of weekly and monthly mandatory censuses and surveys on electricity, natural gas, and petroleum supply for which the average annual response rate has remained consistently in the upper 90 percent range for at least the past decade.[19]

Figure 4 shows the annual average percentage point change in response rates for each establishment or price survey in Figures 3a and 3b from 2016 to 2025.[20] During this period, 8 of the 10 establishment and price surveys experienced a decline in response rates—the exceptions were the ATCFS and the NCFO, two surveys of small populations (~140 facilities for ATCFS and and ~260 operators for NCFO) with response rates that, on average, increased slightly over the period. The average decline over this span was 1.8 percentage points per year and 16 percentage points in total from beginning to end of the period. By comparison, the average decline for the household surveys in Figure 2 above was 0.7 percentage points per year from 2000 to 2013 and 2.5 percentage points per year from 2013 to 2023. Establishment and price surveys showing total declines of greater than 16 percentage points (pp) included JOLTS (31 pp), IPP-Exports (26 pp), Employment Cost Index (ECI) (24 pp), IPP-Imports (23 pp), and CES (18 pp).

FIGURE 3a. Response Rates (Percentages) for Five Federal Establishment and Price Surveys from Three Statistical Agencies, 2016–2025

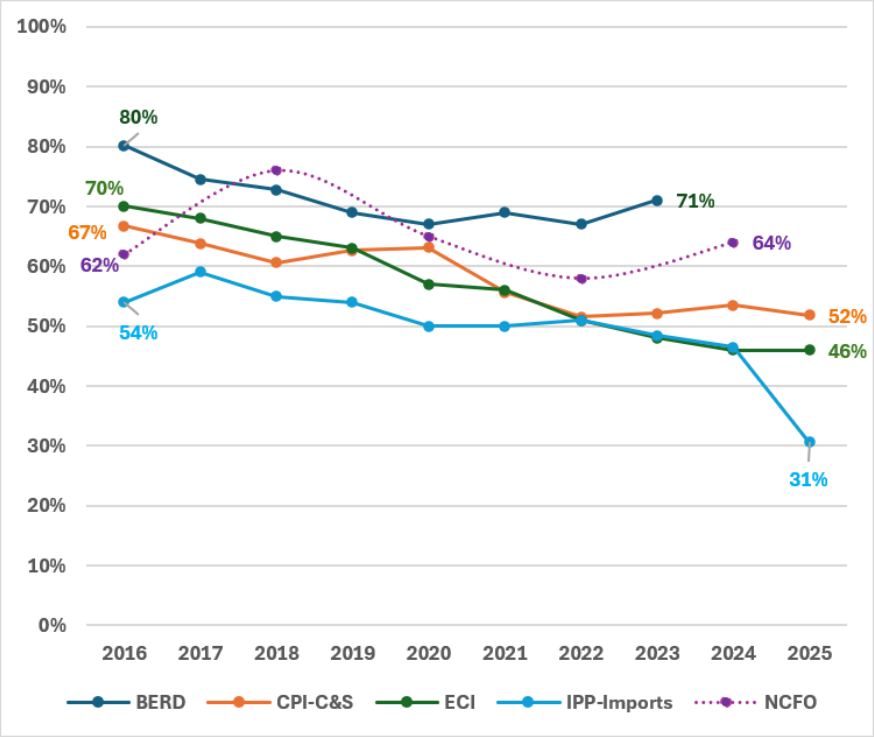


NOTES: ATCFS = Annual Tank Car Facility Survey (BTS), which began in 2018; CES = Current Employment Statistics (BLS); Dec Ag Survey = December Agricultural Survey (NASS); IPP-Exports = International Price Program-Exports (BLS); JOLTS = Job Openings and Labor Force Turnover Survey (BLS). Response rates are unconditional. For monthly surveys (CES, IPP-Exports, JOLTS), rates are for January.
SOURCE: ASA Response Rates Online Resource. Rates could not be located for the December Agricultural Survey for 2017 or 2018.

[19] See Appendix A and the EIA tab of ASA Response Rates Online Resource. Note that the general population for the censuses and surveys ranges from 40 to 12,000.

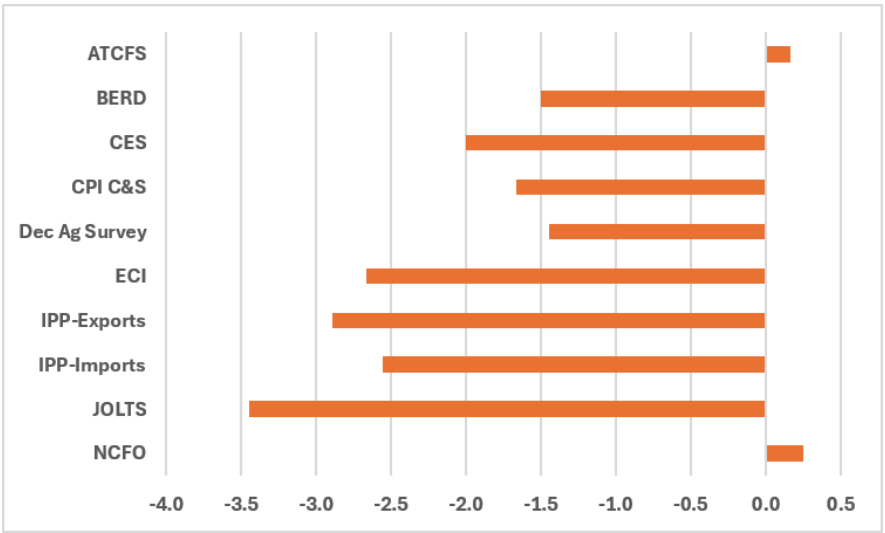
[20] For three of the surveys, the period of observation excluded one or more years between 2016 and 2025 (see notes to Figure 4).

FIGURE 3b. Response Rates (Percentages) for Five More Federal Establishment and Price Surveys from Three Statistical Agencies, 2016–2025



NOTES: BERD = Business Enterprise Research and Development Survey (NCSES; BERD is mandatory; in 2025 BERD was integrated into the Annual Business Survey, co-sponsored by NCSES and the Census Bureau); CPI-C&S = Consumer Price Index–Commodities and Services (BLS); ECI = Employment Cost Index (BLS); IPP-Imports = International Price Program–Imports (BLS); NCFO = National Census of Ferry Operators (BTS, biannual). All response rates are unconditional. For monthly surveys (CPI-C&S, IPP-Imports), rates are for January; for the quarterly ECI, rates are for March.
SOURCE: ASA Response Rates Online Resource.

FIGURE 4. Federal Establishment and Price Survey Average Annual Percentage Point Change in Response Rates, 2016–2025: 10 Surveys from 4 Statistical Agencies



NOTES: See notes to Figures 3a and 3b. For three of the surveys, the period of observation excluded one or more years between 2016 and 2025: for ATCFS, the period was 2018–2025; for BERD, it was 2016–2023; and for NCFO, it was 2016–2024.
SOURCE: ASA Response Rates Online Resource.

Statistical Agency Strategies to Mitigate Nonresponse

Federal statistical agencies have been grappling with declining response rates for many years. They have made and continue to make important methodological improvements to maintain and improve response in a cost-effective manner and also to mitigate the potential effects of nonresponse on the variability and bias in survey estimates. We highlight many of the strategies employed by agencies as illustrations of the range of what is possible. We group these strategies in three categories. Response rates would likely be much lower without the mitigation efforts agencies already make.

- **Obtain additional sample cases**
    - *Add sample.* To maintain the precision of estimates when response rates decline, a common strategy is to increase the initial sample size to achieve the number of complete responses needed. Federal statistical agencies can rarely employ this strategy, however, because budgets are fixed by appropriation levels, which are difficult to change.
    - *Allocate additional resources to converting nonrespondents.* Agencies can increase the number of follow-up attempts, use monetary incentives, assign their best interviewers to remaining nonrespondents, and use other strategies to reduce nonresponse. Such efforts also add to costs and time needed to complete data collection.
    - *Redesign features of the survey to facilitate response and reduce costs.* Agencies can, for example, reduce the length and complexity of questions; offer additional response modes (e.g., online on laptops, tablets, and cell phones in addition to mail, telephone, and in-person, including video, with flexibility to respond when convenient); and add information about the benefits of the survey to motivate response. BLS and the Census Bureau are currently modernizing response modes and other features for the CPS along these lines, and NCHS is exploring a similar modernization for NHIS, which will require resources to test and implement. The Census Bureau is similarly pursuing multimode collection, email and text outreach, adaptive case prioritization, and nonresponse bias analyses to maintain data quality (Pickering, 2022). In the CPS, adding a web mode lets interviewers focus on hard-to-reach cases, which supports cost sustainability and may improve response.
- **Weight sample responses to minimize variability and bias**
    - *Use population controls in weighting responses to the target population.* While differential nonresponse rates across subgroups may yield a set of respondents that is not representative of the population, survey weighting seeks to adjust responses to improve representativeness and reduce bias. Weighting in federal statistical surveys is typically a multi-stage process. For the monthly CPS, for example, weighting begins with calculating each respondent's base weight (inverse of the probability of selection) and proceeds through a set of adjustments for nonresponse to a set of ratio adjustment steps, culminating in the "second-stage ratio adjustment," which substantially reduces variability by ensuring that the estimates match independent census-based estimates of the population by age, sex, and race/ethnicity (see Weighting).
    - *Use additional data and models in weighting.* The ACS, for example, uses a complex model-based approach to develop subcounty controls from administrative data for weighting small geographic areas. It also adjusts for differences in responses from the internet versus in-person follow-up (see American Community Survey Design and Methodology Ch. 11 Weighting and Estimation).

- **Integrate multiple data sources to maximize benefits and minimize costs of each source**

    - *Use administrative records and other data sources to reduce overall costs and increase quality.* Blending data sources can make it possible to reduce survey length and obtain more complete data for items that are offloaded from a questionnaire to another source. The Census Bureau's National Experimental Well-Being Statistics (NEWS) is using CPS-ASEC data together with administrative records to develop improved estimates of household income (see National Experimental Well-Being Statistics (NEWS)). The next step would be to remove corresponding survey questionnaire content from the CPS-ASEC questionnaire and use administrative records data directly in estimation. BLS has for some time been moving parts of its pricing programs from interviewers to purchase of data from aggregators, crowd-sourcing sites, and other sources (NASEM, 2022). BLS has also begun using video interviews for business respondents, lengthened the time sampled units stay in some samples, and enlarged some samples to offset lower response (BLS, 2023).

    - *For business surveys, obtain data directly from company records.* The Census Bureau is experimenting with uploading large companies' own records and analyzing them rather than having the company be responsible to go through its records to fill out questionnaires (Bowen et al., 2025, p. 44).

In the future, surveys will and must continue to play an important role because there is some information that only a person or establishment can supply. Yet surveys do not need to be as comprehensive and indeed daunting as some of them are today. A paradigm of multiple response modes and multiple data sources seems worthwhile to pursue—acknowledging the many technical and operational challenges (e.g., designing systems flows to incorporate multiple data streams; developing models to project forward from administrative records that lag in availability). This work is innovative and important and needs investment to bring it to fruition.

Administrative records and other non-survey data have their own challenges. They are generally not ready for statistical use without substantial processing, validation, and quality assurance, and their suitability depends on completeness, timeliness (how old the data are by the time they are available), consistency over time, and coherence with the concepts being measured. Tax data also carry statutory confidentiality limits on use and sharing. Blending commercial or administrative data with collected data complicates what can be said about the bias and other quality attributes of the combined estimates. That said, administrative records and other non-survey data can fill important gaps, reduce survey burden, and increase data quality, presuming they receive the necessary investment similar to how survey methods were and continue to be developed and refined through the leadership of the federal statistical agencies.

Improving Survey Response Rate Documentation and Archiving

Recognizing that response rates are only one indicator of the risk of nonresponse bias, they are nonetheless an important metric to track, yet that is easier said than done. There are some excellent examples of response rate tracking and documentation, including the BLS page on household, establishment, and price quotes survey response rates (Household and establishment survey response rates: U.S. Bureau of Labor Statistics), which provides historical rates for the previous 10 years and extensive material about each survey; the quality indicators page for the American Community Survey on the Census Bureau's website (Sample Size and Data Quality | American Community Survey | U.S. Census Bureau); the NCHS pages on selected survey response rates (e.g., NHANES Response Rates and Population Totals), and NASS's webpage for 32 survey topics that links to methodology and quality reports for each of the

respective releases. For the NCHS and NASS examples, the user must access multiple pages to build a time series. Other statistical agencies typically include response rates in yearly or less frequent publications, which presents burdens in compiling time series. Rates for some surveys appear not to be accessible except through communication with agency staff,[21] and published rates may differ in what they estimate (e.g., NCVS household response rates versus person cooperation rates, or BLS overall unit response rates versus collection rates).

We recommend that a subcommittee of the Interagency Council on Statistical Policy (ICSP) and the Federal Committee on Statistical Methodology (FCSM) develop additional guidance for Statistical Policy Directive No. 2 on best practices for estimating and reporting the AAPOR overall unit response rates stipulated in SPD #2. The subcommittee as part of its work should develop standards for making response rates available in accessible formats with permanent digital object identifiers to ensure their continued availability and accessibility. It should do the same for nonresponse rates to individual survey items. We further recommend that statistical agencies and their funders invest in research on why unit and item nonresponse is increasing, why people are harder to reach, and why they provide less complete information than in the past, so that agencies can target the design changes most likely to be effective.

Conclusion

The problem of declining survey response rates is becoming ever more pronounced and not easily resolved. Statistical agencies can and do employ many strategies to maintain, improve, and mitigate the effects of declining response rates on variability and potential bias in survey estimates. Full-scale research and development (R&D) and deployment of additional appropriate strategies, which may vary among surveys, requires that statistical agencies have sufficient resources—budget, staffing, expertise, and leadership—to maintain current survey operations while undertaking improved data collection and estimation methods for the future. An important resource for R&D in this area is consistently maintained, well-documented, and easily accessible response rate databases within the federal statistical system.

[Appendix A: Survey Response Rate Graphs and Descriptions by Agency]

[21] On that note, we gratefully acknowledge the EIA staff who, after our inquiry, compiled and posted response rates for the Commercial Buildings Energy Consumption Survey and the Residential Energy Consumption Survey

References

American Association for Public Opinion Research (AAPOR). (2023). Standard Definitions: Final Dispositions of Case Codes and Outcome Rates for Surveys (10th ed.). https://aapor.org/wp-content/uploads/2023/05/Standards-Definitions-10th-edition.pdf

Auerbach, J., Bowen, C. M., Citro, C., Pierson, S., Potok, N., and Seeskin, Z. (2024). The Nation's Data at Risk: Meeting America's Information Needs for the 21st Century. American Statistical Association, Assessing and Monitoring the Health of Federal Statistics. https://www.amstat.org/docs/default-source/amstat-documents/the-nation's-data-at-risk---report.pdf?v=0321

Bowen, C. M., Citro, C., Crosby, M., Pierson, S., Potok, N., and Seeskin, Z. (2025). The Nation's Data at Risk: 2025 Report. American Statistical Association, Assessing and Monitoring the Health of Federal Statistics. https://www.amstat.org/docs/default-source/amstat-documents/the-nations-data-at-risk-2025/The-Nations-Data-at-Risk-2025-Report.pdf?v=0126

Bureau of Labor Statistics (BLS). (2023, March 24). What is BLS doing to maintain data quality as response rates decline? BLS Blog. https://www.bls.gov/blog/2023/what-is-bls-doing-to-maintain-data-quality-as-response-rates-decline.htm

Citro, C. F. (2016). The US federal statistical system's past, present, and future. *Annual Review of Statistics and Its Application* (3):347–73. https://www.annualreviews.org/content/journals/10.1146/annurev-statistics-041715-033405

Czajka, J., and Beyler, A. (2016, June 15). Declining Response Rates in Federal Surveys: Trends and Implications. Background paper for the Office of the Assistant Secretary for Planning and Evaluation, U.S. Department of Health and Human Services.. Mathematica Policy Research, Inc., Washington, DC. https://www.aspe.hhs.gov/sites/default/files/private/pdf/255531/Decliningresponserates.pdf

Davern, M. (2013). Nonresponse rates are a problematic indicator of nonresponse bias in survey research. *Health Services Research 48*(3):905–912. https://doi.org/10.1111/1475-6773.12070

Duncan, J. W., and Shelton, W. C. (1978). *Revolution in United States Government Statistics: 1926-1976*. Office of Federal Statistical Policy and Standards. Washington, DC: U.S. Department of Commerce. https://books.google.com/books?id=pglFRByHurYC&pg=PA32&source=gbs_toc_r&cad=2#v=onepage&q&f=false

Federal Committee on Statistical Methodology. (2001). Measuring and Reporting Sources of Error in Surveys. Statistical Policy Working Paper No. 31. https://statspolicy.gov/assets/fcsm/files/docs/spwp31.pdf

Federal Committee on Statistical Methodology. (2020a). A Framework for Data Quality (FCSM-20-04). Office of Management and Budget. https://statspolicy.gov/assets/fcsm/files/docs/FCSM.20.04_A_Framework_for_Data_Quality.pdf

Federal Committee on Statistical Methodology. (2020b). A Systematic Review of Nonresponse Bias Studies in Federally Sponsored Surveys (FCSM-20-02). Office of Management and Budget. https://statspolicy.gov/assets/fcsm/files/docs/A_Systematic_Review_of_Nonresponse_Bias_Studies_Federally_Sponsored_SurveysFCSM_20_02_032920.pdf

Fink, S., Jans, M., Fleming, J., Schaar, D., Caporaso, A., Clark, J., Dixon, G., Genoversa, S., and Riddles, M. (2024). Refusal Reasons: Changes in Refusal Reasons Over Time in the National Health and Nutrition Examination Survey (NHANES), 2017-2019, 2021, 2022. PowerPoint presentation at the 2024 Federal Committee on Statistical Methodology Research and Policy Conference. https://statspolicy.gov/assets/fcsm/files/docs/2024-conference-docs/C/C1.3_Fink.pdf

Groves, R. M., & Peytcheva, E. (2008). The impact of nonresponse rates on nonresponse bias: A meta-analysis. Public Opinion Quarterly *72*(2):167–189. https://doi.org/10.1093/poq/nfn011

Hedlin, D. (2020). Is there a "safe area" where the nonresponse rate has only a modest effect on bias despite non-ignorable nonresponse? *International Statistical Review 88*(3):642–657. https://doi.org/10.1111/insr.12359

Jabkowski, P., and Cichocki, P. (2025). Survey response rates in European comparative surveys: A 20-year decline irrespective of sampling frames or survey modes. *Quality & Quantity 59*(1):635–655. https://doi.org/10.1007/s11135-024-01993-9

Johansson, R., Effland, A., and Coble, K. (2017, January 19). Falling Response Rates to USDA Crop Surveys: Why It Matters. Department of Agricultural and Consumer Economics, University of Illinois at Urbana-Champaign. farmdoc daily (7):9. https://farmdocdaily.illinois.edu/2017/01/falling-response-rates-to-usda-crop-surveys.html

Johnson, D. S., Meinhardt, M., and Sabelhaus, J. (2026). Why did people stop responding to federal economic surveys? What can be done? Commentary. Brookings. https://www.brookings.edu/articles/why-did-people-stop-responding-to-federal-economic-surveys-what-can-be-done/

König, C., Sakshaug, J. W., Stegmaier, J., and Kohaut, S. (2021). Trends in establishment survey nonresponse rates and nonresponse bias: Evidence from the 2001-2017 IAB Establishment Panel. *Journal of Official Statistics 37*(4):931–953. https://doi.org/10.2478/jos-2021-0040

Luiten, A., Hox, J., and de Leeuw, E. (2020). Survey nonresponse trends and fieldwork effort in the 21st century: Results of an international study across countries and surveys. *Journal of Official Statistics 36*(3):469–487. https://doi.org/10.2478/jos-2020-0025

Meyer, B. D., Wu, D., Mittag, N., Tatarka, A., and Langetieg, P. (2026, August). The Anatomy and Evolution of Survey Error. Working Paper 35680. National Bureau of Economic Research. https://www.nber.org/papers/w35680

National Academies of Sciences, Engineering, and Medicine (NASEM). 2013a. *Benefits, Burdens, and Prospects of the American Community Survey: Summary of a Workshop*. Washington, DC: The National Academies Press. https://doi.org/10.17226/18259

NASEM. 2013b. *Nonresponse in Social Science Surveys: A Research Agenda*. Washington, DC: The National Academies Press. https://doi.org/10.17226/18293.

NASEM. 2022. *Modernizing the Consumer Price Index for the 21st Century*. Washington, DC: The National Academies Press. https://doi.org/10.17226/26485

NASEM. 2023a. *Toward a 21st Century National Data Infrastructure: Enhancing Survey Programs by Using Multiple Data Sources*. Washington, DC: The National Academies Press. https://doi.org/10.17226/26804

NASEM. 2023b. *Toward a 21st Century National Data Infrastructure: Mobilizing Information for the Common Good*. Washington, DC: The National Academies Press. https://doi.org/10.17226/26688

Office of Management and Budget (OMB). 2006. Statistical Policy Directive No. 2. Standards and Guidelines for Statistical Surveys. https://obamawhitehouse.archives.gov/sites/default/files/omb/inforeg/statpolicy/standards_stat_surveys.pdf

Pickering, C. (2022, December 9). Nonresponse in Census Bureau surveys [Presentation]. Federal Economic Statistics Advisory Committee. https://apps.bea.gov/fesac/meetings/2022-12-09/Pickering-FESACNonresponse-in-Census-Surveys-12092022.pdf

Taylor, C., Madans, J., Chapman, N., et al. (2023, May). Critical data at the crossroads: the National Health and Nutrition Examination Survey faces growing challenges. *The American Journal of Clinical Nutrition 117*:847–858. https://ajcn.nutrition.org/article/S0002-9165(23)46262-4/fulltext?dgcid=raven_jbs_etoc_email

Williams, D., and Brick, J. M. (2018). Trends in U.S. face-to-face household survey nonresponse and level of effort. *Journal of Survey Statistics and Methodology 6*(2):186–211. https://doi.org/10.1093/jssam/smx019