ANALYSIS OF DATA/PRODUCTION OF ESTIMATES OR PROJECTIONS

5-1 Statistical Analysis, Inference, and Comparison

5-2 Variance Estimation

5-3 Rounding

5-4 Tabular and Graphic Presentations

SUBJECT: STATISTICAL ANALYSIS, INFERENCE, AND COMPARISON

NCES STANDARD: 5-1

PURPOSE: To ensure that statistical analyses, comparisons, and inferences included in NCES products are based on appropriate statistical procedures.

KEY TERMS: effect size, estimation, hypothesis testing, Minimum Substantively Significant Effect (MSSE), power, rejection region, simple comparison, statistical inference, survey, tail, Type I error, and Type II error.

STANDARD 5-1-1: Statistical analyses must be approached from an analysis plan that considers relevance to policy, prior findings in existing literature, and/or results of previous survey research. The analysis plan must specify the main research questions, and justify the choice of statistical methodology. Include the following elements in the analysis plan:

1. An introduction that describes the purpose, the research question and relevant literature, data sources (including a brief description of the survey data and any limitations of the data), key variables to be used in the analysis, type of analysis and statistical methodology to be used.
2. Table and figure shells that support the analysis.
3. A framework for technical notes, including as appropriate, the history of the survey program, data collection methods and procedures, sample design, response rates and the treatment of missing data, weighting methods, computation of standard errors, instructions for constructed variables, limitations of the data, and sources of error in the data
4. Target completion dates for program draft, NCES review draft, and IES review draft.

STANDARD 5-1-2: Analyses of sample survey data based on a stratified sample design must use appropriate case weights to correct for the unequal probabilities of selection (see Standard 4-5). In the case of a stratified sample design with disproportionate sample allocation, the use of appropriate case weights will reduce the biases in means and totals, but will not necessarily correct biases in standard errors.

STANDARD 5-1-3: The criterion for judging statistical significance in all reported hypothesis tests should not exceed α =0.05 (0.95 for confidence intervals). Reports will indicate an observed difference as statistically significant when an appropriate hypothesis test rejects the null hypothesis at α =0.05 or less. When estimates are compared to one another based on exploratory research and presented in descriptive reports, observed deviations in either direction are of interest and the rejection region lies within both tails of the distribution of the test statistic. The conclusions stated in the text are to be supported by two-tailed tests of significance (such as *t* tests or *z* tests).

GUIDELINE 5-1-3A: If statistically significant results are labeled in tables, place an asterisk beside the significant coefficient and include a table note indicating "* p<0.05."

GUIDELINE 5-1-3B: When the sample size is large, consideration should be given to setting the criterion for judging statistical significance in reported hypothesis tests at $\alpha = 0.01$ (0.99 for confidence intervals). In which case, reports will indicate an observed difference as statistically significant when an appropriate hypothesis test rejects the null hypothesis at $\alpha = 0.01$.

GUIDELINE 5-1-3C: If the survey purpose or prior research indicates that only differences between estimates in a specific direction are of interest or an established trend is to be updated with a new year of data, one-sided tests (in tests such as *t* tests or *z* tests) may be used to optimize power. In this case the region of rejection of the null hypothesis H_O, is contained in only one tail of the sampling distribution of the test statistic.

STANDARD 5-1-4: Reported analyses must focus on differences that are substantively important (i.e., it is not necessary, or desirable, to discuss every statistically significant difference). Statistical analysis techniques must be used that are appropriate for the specific research question. The rationale for the analytic approach must be described. The efficacy of individual statistical approaches depends on the assumptions of the techniques having been met; therefore, the assumptions underlying the techniques must be discussed.

GUIDELINE 5-1-4A: When conducting multiple comparisons, appropriate procedures should be considered to control the level of Type I error for simultaneous inferences. Multiple comparison procedures include, for example, Bonferroni, False Discovery Rate (FDR), Scheffe, and Tukey tests (see, for example, Hochberg and Tamhane 1987; Benjamini and Hochberg 1995).

GUIDELINE 5-1-4B: If the estimates being compared are not independent, the covariance between the two estimates should be taken into consideration in testing.

GUIDELINE 5-1-4C: Alternative presentation of the results, such as confidence intervals, should also be considered as appropriate.

GUIDELINE 5-1-4D: In tabular presentations, flag all estimates where the ratio of the standard error to the estimate expressed as a percent (i.e., the coefficient of variation, or the variation ratio) is in excess of 30 percent. An exclamation point beside the estimate should be used to flag these cases, with a table note indicating "! Interpret data with caution. Estimate is unstable because the standard error represents more than 30 percent of the estimate." Use caution in reporting or interpreting results from flagged estimates, and consider whether or not to include variables where this ratio exceeds 50 percent. If estimates with ratios over 50 percent are suppressed, replace the estimate with a double dagger and use a table note indicating "‡ Reporting standards not met. The standard error represents more than 50 percent of the estimate."

GUIDELINE 5-1-4E: When testing for structure in the data over time, a trend test or other suitable procedure should be performed (e.g., regression, ANOVA, or non-parametric statistics), and the amount of variation in the data over time should be evaluated. In conducting analyses of data over time, possible changes in population composition should be considered.

GUIDELINE 5-1-4F: When it is appropriate, the use of multiple regression and multivariate analysis techniques should be considered to examine associations between a dependent variable (e.g., test score) and a set of independent variables (e.g., race, sex, and family background). Such techniques can provide an integrated approach to testing many simultaneous relationships.

GUIDELINE 5-1-4G: In general, standardized regression coefficients should be used. When the units of measurement are meaningful (e.g., number of years of schooling), unstandardized regression coefficients or mean differences should be provided.

GUIDELINE 5-1-4H: When the results of an analysis are statistically significant, it is useful to consider the substantive interpretation of the size of the effect. For this purpose, especially in instances where the units of measurement are not easily interpretable, the observed difference can be converted into an effect size to allow the interpretation of the size of the difference.

For a *t* test of the mean difference, for example, the estimated effect size is the observed difference between the two observed means relative to a measure of variability, such as the standard deviation.

In correlation analysis, *r* is the effect size. Consult Cohen (1988) for measures of effect size using additional statistical procedures.

Cohen's (1988) convention for interpreting effect sizes may be used. Empirical evidence has shown that for *t* tests or *z* tests, an effect size of 0.2 is small, 0.5 is medium, and 0.8 is large. As for correlations, an *r* of 0.1 is small, 0.3 is medium, and 0.5 is large.

GUIDELINE 5-1-4I: Another approach to considering the substantive importance of a significant difference is to compare the size of the difference to the minimum substantively significant effect (MSSE) size that is determined *a priori.*

GUIDELINE 5-1-4J: When reporting on the significance of important findings, confirmatory and corroborative statistical methods and significance tests should be used. For example, if the original significant finding is based on a simple comparison *t* test, *t* tests adjusted for multiple comparisons could also be used if appropriate. Another example would be to confirm important findings obtained with one analytic approach with a second analysis conducted using an alternative approach.

STANDARD 5-1-5: Failure to reject the null hypothesis does not imply acceptance of the null hypothesis. When the null hypothesis is not rejected, the following options are available:

1. Do not report on this test.
2. Report that there were no statistically significant differences, or that statistically significant differences or effects were not observed/measured.
3. If the significance is between .05 and .10, and the observed differences are believed to be real, based on research or other evidence, but the failure to find a significant difference is associated with small sample sizes and large standard errors, this may be noted.
4. If the estimate is "unreliable," the reader may be informed that the standard error is sufficiently large that the observed large differences are not statistically significant.
5. If a statistically significant difference for a total group under study is observed, but similar subgroup differences of the same magnitude are associated with smaller sample sizes and larger standard errors and are not statistically significant, this may be noted.
6. If there are large apparent differences that are not significant, associated with small sample sizes and large standard errors, this may be noted.
7. Use a 95 percent confidence interval to describe the magnitude of the possible difference or effect.

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SUBJECT: VARIANCE ESTIMATION

NCES STANDARD: 5-2

PURPOSE: Given that most NCES sample designs have one or more of the following three characteristics: unequal probabilities of selection, stratification, and clustering, it is important to ensure that appropriate techniques for the estimation of variance in sample surveys are identified, implemented and documented.

KEY TERMS: clustered samples, confidentiality, On-line Analysis Tool (OAT), DEFT, design effect (DEFF), estimation, imputation, point estimate, raking, replication method, Simple Random Sampling (SRS), strata, survey, Taylor-series linearization, and variance.

STANDARD 5-2-1: Variance estimates must be derived for all reported point estimates whether reported as a single descriptive statistic (e.g., 6 percent of 1988 eighth-graders dropped out of school by 1990) or used in an analysis to infer or draw a conclusion (e.g., more 12th-graders took advanced-level mathematics courses in 1998 than in 1982).

STANDARD 5-2-2: Variance estimates must be calculated by a method appropriate to a survey's sample design (e.g., unequal probabilities of selection, stratification, clustering, and the effects of nonresponse, post-stratification, and raking). These estimates must reflect the design effect resulting from the complex design.

Approximate variance estimation methods that adjust for most of the impact of clustering and stratification include replication methods (bootstrap, jackknife, Balanced-Repeated Replication (BRR)) and Taylor-series linearization. Replication methods (bootstrap, jackknife, and BRR) can also adjust for the impact of nonresponse, post-stratification, and raking. When replication methods are used, the number of replicates should be large enough to enable stable variance estimation and small enough for efficient calculation.

GUIDELINE 5-2-2A: The preferred way to derive appropriate variance estimates for totals, means, proportions and regression coefficients is to use a statistical package that does not assume simple random sampling (SRS). Such packages include SUDAAN, SAS/WesVar, On-line Analysis Tool, SPSS, R, or Stata, and use such techniques as Taylor-series linearization or one of the replication methods mentioned above.

GUIDELINE 5-2-2B: Consideration should be given to incorporating an adjustment for imputations in variance estimation procedures.

GUIDELINE 5-2-2C: In some cases, alternative approximation strategies can be used to produce variance estimates. For example, software for multilevel models can be used to produce estimates that take into account some aspects of complex survey design. Care must be taken to include any clustering of the sample as a level in the model(s). In addition, any design variables and weights, such as those associated with strata or measures of size, should be taken into account.

STANDARD 5-2-3: Data files must include all weighting and survey design information necessary for point estimation and variance estimation (e.g., probabilities of selection, weights, stratum and PSU codes), subject to confidentiality constraints (see Standard 7-1 on Machine Readable Data Products and Standard 4-2 on Maintaining Confidentiality).

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SUBJECT: ROUNDING NUMBERS AND PERCENTAGES FOR REPORTING IN TEXT AND DISPLAYING IN SUMMARY TABLES AND FIGURES

NCES STANDARD: 5-3

PURPOSE: To ensure consistent practices for rounding and displaying numbers and percentages in text and tables/figures.

KEY TERMS: precision, survey, and universe.

STANDARD 5-3-1: Calculations performed to produce summary data, and computations performed to estimate standard errors, must be done on numbers and percentages that are carried out to at least four decimal places (i.e., not on proportions). The final rounded value must be obtained from the original figure available, not from a series of roundings (e.g., 7.1748 can be 7.175 or 7.17 or 7.2 or 7 but not 7.18). Specifically, when rounding percentages that are reported in supporting tables in tenths of a percent to full percents to be used in text or graphics, use the original unrounded values that were used to produce the rounded estimates in the tables.

STANDARD 5-3-2: Sums of column or row counts in a table must be derived using unrounded numbers, with appropriate rounding of the total after its derivation. All tables that should logically sum to either 100 percent, or to a numeric total, must include a note that states: NOTE: Detail may not sum to totals because of rounding.

STANDARD 5-3-3: For presentation purposes the following specific rules for rounding must be used:

If the first digit to be dropped is less than 5, the last retained digit is not changed.

6.1273 is rounded to 6.127

If the first digit to be dropped is greater than or equal to 5, the last digit retained is increased by 1.

6.6888 is rounded to 6.69
5.451 is rounded to 5.5

STANDARD 5-3-4: In multiplying or dividing numbers using data from secondary sources, the resulting precision cannot be more precise than that of any of the component numbers. (For example, if 4.5 and 12,200 are rounded numbers, the product can be stated only as 55,000 (not 54,900), with 4.5 having two significant digits and 12,200 having three.)

STANDARD 5-3-5: Before rounding numbers for publication, a decision must be made about the appropriate number of decimal places to be reported using the following rules:

1. Percentages appearing in text must be rounded to whole numbers unless small differences require finer breakdowns. Summary tables must be rounded to no more than one decimal place.
1. Percentages appearing in reference and methodological tables must be rounded to no more than two decimal places except in certain methodological tables where finer breakdowns may be necessary.
2. Standard errors must be rounded to one decimal place more than the estimates for which they are computed.
3. Universe data may be reported unrounded. Sample survey data must be rounded.
4. A measured zero in a universe survey (i.e., none of something) must always appear in a table or a figure as 0. If rounding is used in a universe survey, numbers that round to zero must be represented in tables and figures by the symbol #, with a table note indicating "# Rounds to zero."
5. When dealing with small values in sample surveys, zero and numbers that round to zero must be represented in tables and figures by the symbol #, with a table note indicating "# Rounds to zero." When this is done, the standard errors for estimates that round to zero are not applicable and should be denoted by the symbol †, with a table note indicating "† Not applicable."
6. When it is logically impossible to have a response in a cell, that must be denoted by the symbol †, with a table note indicating "† Not applicable."

STANDARD 5-3-6: When reporting counts and weighted estimates in text and summary tables the following rules must be followed:

1. Round four- and five-digit numbers to hundreds (e.g., 1,255 is rounded to 1,300; 56,789 is rounded to 56,800);
2. Round six-digit numbers to thousands (e.g., 156,789 is rounded to 157,000); and
3. Round millions and larger numbers to no more than two decimal places (e.g., 1,234,567 is rounded to 1.2 or 1.23 million; 1,912,345,678 is rounded to 1.9 or 1.91 billion).
4. When one table contains numbers for the same unit of measurement of variable sizes, identify the number with the smallest number of digits and apply the rounding convention for that number to all rounded numbers in the table. If there are multiple units of measurement in one table (e.g., dollars and counts), apply the rounding rules separately within each unit of measurement.

GUIDELINE 5-3-6A: In a methodology report or a technical appendix weighted estimates may be included with no rounding.

STANDARD 5-3-7: If a publicly available on-line analysis tool is supported by a restricted use file, all publicly reported unweighted estimates must be rounded, at a minimum, to units of 10.

SUBJECT: TABULAR AND GRAPHIC PRESENTATIONS

NCES STANDARD: 5-4

PURPOSE: To ensure that tables and graphics displayed in NCES products communicate information accurately, clearly, and efficiently. This will allow the reader to easily and correctly interpret the presentation as a stand-alone display.

KEY TERMS: point estimate, reference year, survey, and survey year.

STANDARD 5-4-1: All tables must be produced in accordance with the "NCES Guidelines for Tabular Presentations" (appendix B) and the IES Style Guide (http://nces.ed.gov/statprog/styleguide/pdf/styleguide.pdf).

STANDARD 5-4-2: Graphics must highlight important points.

STANDARD 5-4-3: All tables must be understandable without reference to the text.

1. Each table must have a concise title that identifies the content and the reference period for the data shown. Do not use footnotes in table titles; put any such information in either the general note or in a footnote on the relevant element within the table. The table title should tell the reader what the table is about, how the data in the table are classified (the by statement), the geographic level of the data (where), and the time frame represented (when). For the "by statement," a definite order should be used. Excluding any items called out at the start of the title, start with the highest level of disaggregation in the column headers and then proceed through subsequent levels of column header disaggregations, and then proceed through the levels of disaggregation and characteristics down the row stubs.
2. Each table must include all notes necessary to convey information needed to understand the table content, such as notes that define acronyms, explain special terms, or define the underlying population included in the analysis.

STANDARD 5-4-4: All figures (graphs, maps, or charts) must be understandable without reference to the text.

1. Each figure must have a concise title that identifies the content and the reference period for the data shown. Do not use footnotes in figure titles; put any such information in either the general note or in a footnote on the relevant element within the figure. The figure title should tell the reader what the figure is about, how the data in the figure are classified (the by statement), the geographic level of the data (where), and the time frame represented (when). For the "by statement," a definite order should be used. Start with the outer most (i.e., the highest) level of disaggregations and proceed through subsequent levels of disaggregations, and end with the legend elements.
2. Each figure must include all notes necessary to convey information not immediately

evident from the main graphic, such as notes that define acronyms, explain special terms, or define the underlying population included in the analysis.

GUIDELINE 5-4-4A: Bar and pie charts should include point estimates for each category displayed.

STANDARD 5-4-5: All figures must be consistent with best practices for graphical display. All figures must adhere to the following:

1. Omit distracting detail. For example, avoid the use of three-dimensional effects when only two dimensions are displayed and avoid cluttering figures with lines or arrows when not needed.
2. Be easy to read. For example, all elements (font, lines, labels, symbols, segments, etc.) should be large enough to read with ease in the printed form, easily differentiated, and legible when photocopied or printed in black and white. Note that legends are not always needed; if lines or bars can be easily and clearly labeled directly that is preferred.
3. On line graphs, use lines that are dotted, dashed, or of various thicknesses to distinguish lines; avoid geometric figures (squares, diamonds, etc.) if at all possible. Geometric figures may be used on lines, however, (1) to indicate data points used as selectable targets in online interactive displays; and (2) in the rare instances when they are essential to communicating your meaning, as when the data points differ on multiple lines. Even if lines are printed in multiple colors or shades, the line styles or patterns must be distinctive when photocopied in black and white.
4. Be consistent with and prepared in the same style as other figures in the same publication or product. For example, lettering should be of similar size and font, lines of the same weight, symbols or legends should be used for the same categories.
5. Use consistent scales throughout a report with consistent spacing when presenting similar units of measurement (e.g., 0-10 percent should be the same size in all comparable figures; $0-5,000 should be the same size in all comparable figures). Further, all scales showing similar units should use the same scale increments (e.g., 10 percent increments in all figures, rather than 10 percent in some and 5 percent in others; $500 increments in all figures, rather than $500 in some and $400 in others).
6. With the exception of time-series, continuous scales should start with zero or the minimum value of the scale. If used, scale breaks should be clearly visible;
7. When using time-series data, time intervals should be plotted on a linear scale (e.g., all year intervals should be scaled consistently) and actual data points should be labeled.
8. Include labels for all variables and categories. The parts of legends corresponding to the figure (e.g., shaded boxes corresponding to shades of bars in a bar chart) may be placed vertically or horizontally in the legend, but the shaded or patterned boxes must use the same shading or patterns and be in the same order as in the figure.
9. Clearly label all axes and include tick marks on axes. Avoid vertical labels on axes. Place tick marks outside the axis. Center scale numbers on the tick marks they identify.
10. Prepare figures with patterns, screens, or colors selected to print clearly across

different media. In addition, all tables and figures must be in compliance with Section 508 standards that require that information on web pages be made "accessible" to people with a wide range of disabilities, including vision and hearing impairments, dexterity problems, color blindness, and even rare conditions such as photosensitive epilepsy triggered by rapidly flashing lights. For the full text of the law, see: www.cio.gov/Documents/section%5F508%5Faugust%5F1998%2Ehtml

11. Figures should be produced using the same underlying unrounded data that are used to produce tables. If rounding is required for clarity in labeling, include a table note indicating that the data shown are based on unrounded estimates. Note that rounding can result in identical labels on bars with different underlying values (e.g., two bars labeled 4 could have, one can represent 3.5 and the other 4.49).

STANDARD 5-4-6: When presenting multiple related figures on one page, a summary title must appear at top of the page and each figure must have its own title. When using multiple related figures from one source on the same page, the source note must be provided at the bottom of the page. When using multiple related figures from different sources on the same page, source notes must be provided for each figure. These source notes must follow the guidelines in Standard 5-4-6.

STANDARD 5-4-7: Supporting data for figures must be included in the publication or product. In the case of reports that are extracts that summarize existing publications, supporting data are not required, but summary products must refer to the full report. If a report is 15 pages or less, and supporting data are not included in the report, they must be available on the web and the publication must refer to the URL. (See web standards for URL format.)

STANDARD 5-4-8: All figures and tables must incorporate a complete source note. A complete source note identifies all the sources relevant to the data presented.

GUIDELINE 5-4-8A: For figures or tables based on data from one or more reports, the Source should cite the report, relevant survey(s) or subsurvey(s), data reference year, file version number, department name, and agency name. In the case of unpublished data, use the month and year of the tabulation or data file. If the data are drawn from multiple years: for 1 to 3 years, report each year; for more than 3 continuous years, use the year span; and for more than 3 noncontinuous years, use "selected years" and the year span. (Use the survey title included in the recommended citation in the data release report for each data source.)

EXAMPLES:

Data from one or more reports:
Revenues and Expenditures for National Public Elementary and Secondary Education: School Year 2009-10, Common Core of Data (CCD), "National Public Education Financial Survey" (NPEFS), 2009-10, Version 1, U.S. Department of Education, National Center for Education Statistics.

Data from unpublished tabulations and a published NCES report:
U.S. Department of Commerce, Bureau of the Census, Current Population Survey, previously unpublished tabulations (April 2011); and U.S. Department of Education, National Center for Education Statistics, *Dropout Rates in the United States*, Selected years, 1972-2010.

GUIDELINE 5-4-8B: For figures or tables based on data from a compendium report, the source note should cite the compendium report and the original survey or survey report (e.g., *2011 Digest of Education Statistics*, Integrated Postsecondary Education Data System, Fall Enrollment 2010).

GUIDELINE 5-4-8C: For figures or tables based on unpublished tabulations from surveys that are not the main focus of the report, the source note should indicate the data source followed by "previously unpublished tabulation."

GUIDELINE 5-4-8D: For figures or tables based on on-line analysis tools, the source note should cite the data source and the data tool.

STANDARD 5-4-9: Figures and tables in the executive summary must be assigned alpha characters consecutively and figures in reports must be assigned numbers. Figures and tables in appendixes must be assigned the letter of the appendix and a number suffix (e.g., figures in appendix A must be labeled A-1, A-2, etc.).

STANDARD 5-4-10: All tables that should logically sum to either 100 percent, or to a numeric total, must include a note that states: NOTE: Detail may not sum to totals because of rounding.

STANDARD 5-4-11: Data for the outlying areas must be excluded from U.S. summary totals, unless separate totals are shown.

REFERENCES:

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