Lecture 2b: Survey weights

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Outline

- Inferential statistics

- Survey weights

- Weight options in Stata

- Complex sample cluster design

- Weights in the General Social Survey (GSS)

- Examples of descriptive statistics

Inferential statistics

- Social scientists need inferential statistics

  - They almost never have the resources or time to collect data from every case in a population

- Inferential statistics uses data from samples to make generalizations about populations

  - **Population** is the total collection of all cases in which the researcher is interested

  - **Samples** are carefully chosen subsets of the population

- With proper techniques, generalizations based on samples can represent populations

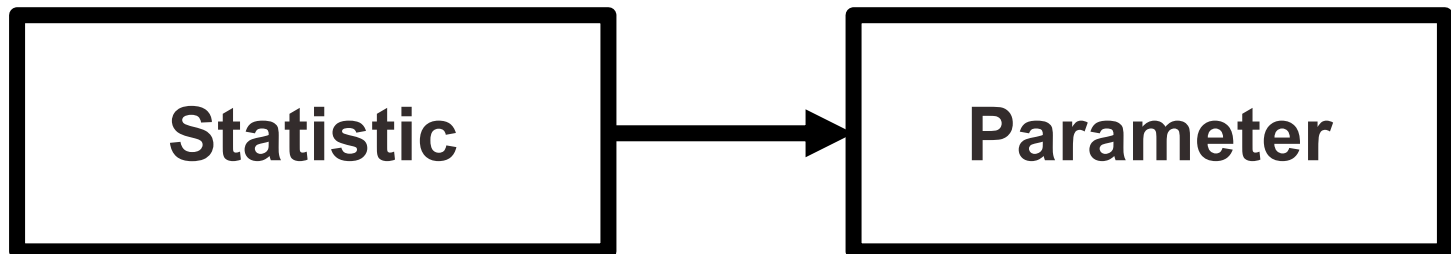# Basic logic and terminology

- Information from samples is used to estimate information about the population
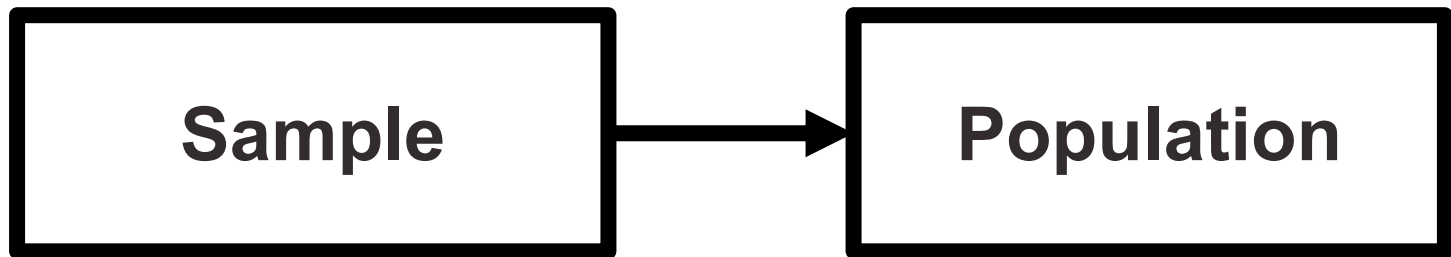
Sample	→	Population

- Statistics: characteristics of samples
- Parameters: characteristics of populations

- Statistics are used to estimate parameters

Statistic	→	Parameter

Survey weights

Name	Number of observations collected in the survey	Weight to expand to population size	Weight to maintain sample size
José	1	4	0.8
Maria	1	6	1.2
Total	2	10	2

**Survey weight =
Population weight * (Sum of survey weights / Sum of population weights)**

Weights for tables

- When we use a sample to estimate the absolute number of people

  – For an area

  – For a specific sub-group

  – We use weights to expand to population size

- If we use a sample to estimate the proportion of people in a specific sub-group

  – And we are not concerned with the absolute value

  – We use weights to maintain the sample size (we focus on percentages)

Weights for regressions

- In a simple linear regression, the test of statistical significance for a β coefficient (t-test) is estimated as

$$t = \frac{\hat{\beta}}{SE_{\hat{\beta}}} = \frac{\hat{\beta}}{\sqrt{\dfrac{MSE}{S_{xx}}}} = \frac{\hat{\beta}}{\sqrt{\dfrac{RSS}{df * S_{xx}}}} = \frac{\hat{\beta}}{\sqrt{\dfrac{\sum_i (y_i - \hat{y}_i)^2}{(n-2)\sum_i (x_i - \bar{x})^2}}}$$

- SE_β: standard error of β

- MSE: mean squared error = RSS / df

- RSS: residual sum of squares = $\sum_i (y_i - \hat{y}_i)^2$ = $\sum_i \hat{e}_i^2$

- df: degrees of freedom = n–2 for simple linear regression

  - 2 statistics (slope and intercept) are estimated to calculate sum of squares

- S_{xx}: corrected sum of squares for x (total sum of squares)

Weights for regressions

- If we use a weight that expands to the population size (*N*) on regressions

  - We would be incorrectly informing the statistical software that we have a sample with enormous size

 - This would artificially increase the test of statistical significance for the coefficient

$$t = \frac{\hat{\beta}}{SE_{\hat{\beta}}} = \frac{\hat{\beta}}{\sqrt{\dfrac{MSE}{S_{xx}}}} = \frac{\hat{\beta}}{\sqrt{\dfrac{MSE}{S_{xx}}}} = \frac{\hat{\beta}}{\sqrt{\dfrac{\sum_i (y_i - \hat{y}_i)^2}{(n-2)\sum_i (x_i - \bar{x})^2}}}$$

  - We have to inform the weight related to the sample design, but we should maintain the sample size (*n*)

t distribution (*df* = 2)

- **Bigger the *t*-test**
  - **Stronger the statistical significance**

- **Smaller the *p*-value**
  - **Smaller the probability of not rejecting the null hypothesis**
  - **Tend to accept alternative (research) hypothesis**

Example of an estimated *t*

p-value

-4.0   -3.0   -2.0   -1.0   0.0   1.0   2.0   3.0   4.0
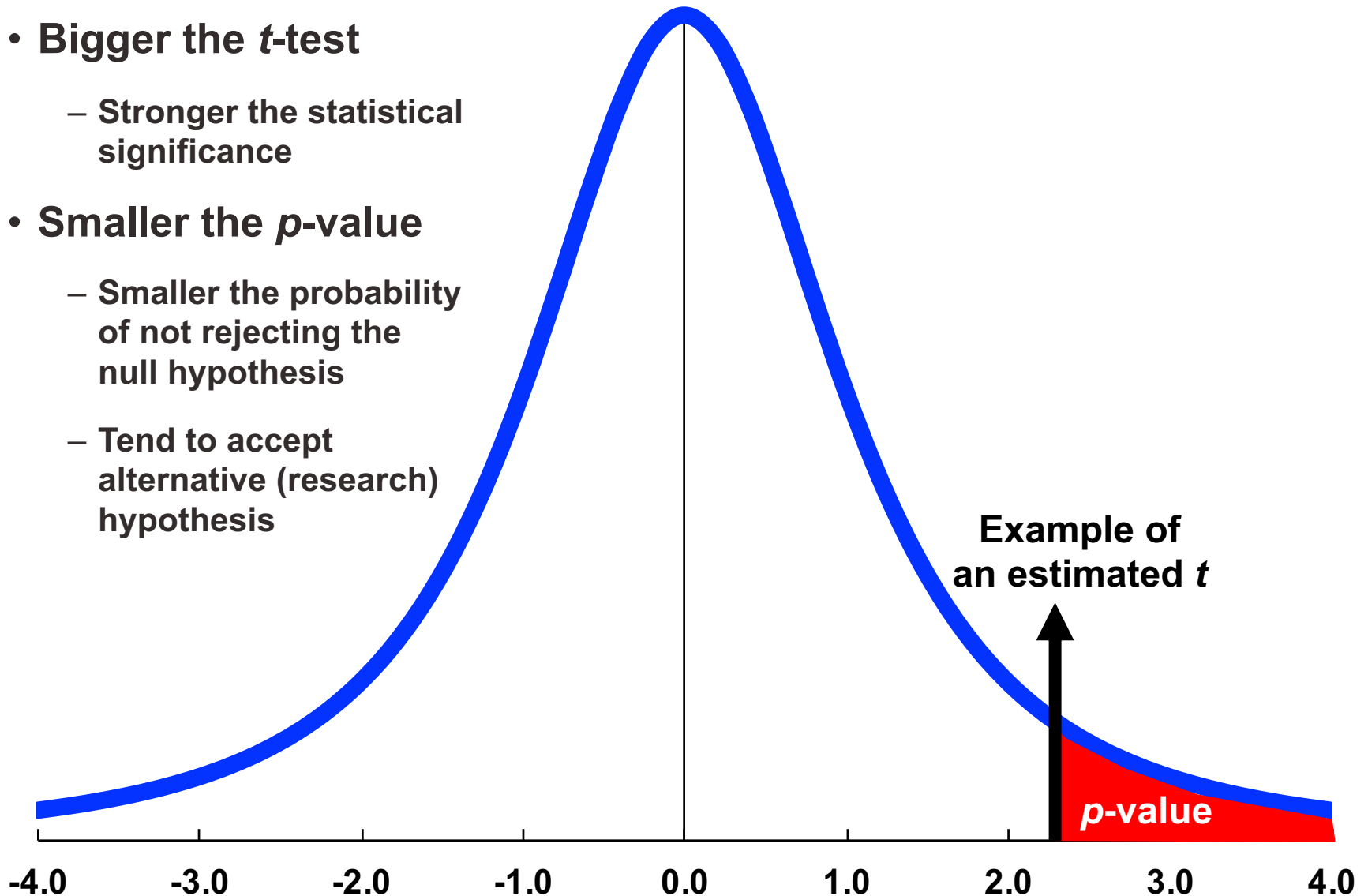
Decisions about hypotheses

Hypotheses	$p < \alpha$	$p > \alpha$
Null hypothesis (H_0)	Reject	Do not reject
Alternative hypothesis (H_1)	Accept	Do not accept

- *p*-value is the probability of not rejecting the null hypothesis

- If a statistical software gives only the two-tailed *p*-value, divide it by 2 to obtain the one-tailed *p*-value

Significance level (α)	Confidence level (success rate)
0.10 (10%)	90%
0.05 (5%)	95%
0.01 (1%)	99%
0.001 (0.1%)	99.9%

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Weight options in Stata

- Frequency weight (fweight)

- "Importance" weight (iweight)

- Analytic weight (aweight)

- Sampling weight (pweight)

Extract of 2018 ACS microdata

	year	strata	cluster	perwt	hhwt	sex	age	income
1	2018	360248	2.018012e+12	56.00	56.00	Male	46	28000
2	2018	360248	2.018012e+12	51.00	51.00	Male	20	5000
3	2018	360248	2.018012e+12	76.00	76.00	Female	84	0
4	2018	360248	2.018012e+12	55.00	55.00	Female	18	1200
5	2018	360248	2.018012e+12	143.00	143.00	Female	56	1500
6	2018	360248	2.018012e+12	198.00	198.00	Male	31	10000
7	2018	360248	2.018012e+12	48.00	48.00	Female	19	2000
8	2018	360248	2.018012e+12	48.00	48.00	Male	25	7000
9	2018	360248	2.018012e+12	65.00	65.00	Female	18	0
10	2018	360248	2.018012e+12	53.00	53.00	Female	18	15000
11	2018	360248	2.018012e+12	17.00	17.00	Male	63	0
12	2018	360248	2.018012e+12	39.00	39.00	Female	18	4000
13	2018	360248	2.018012e+12	104.00	104.00	Male	21	1000
14	2018	360248	2.018012e+12	200.00	200.00	Male	40	80000
15	2018	360248	2.018012e+12	20.00	20.00	Male	33	0
16	2018	360248	2.018012e+12	59.00	59.00	Male	19	2900
17	2018	360248	2.018012e+12	56.00	56.00	Male	55	0
18	2018	360248	2.018012e+12	77.00	77.00	Male	18	9000
19	2018	360248	2.018012e+12	16.00	16.00	Female	41	1100
20	2018	360248	2.018012e+12	46.00	46.00	Male	33	0

Frequency weight

- **FWEIGHT**

  - Expands survey size to the population size

  - Indicates the number of duplicated observations

  - Used on tables to generate frequencies

  - Can be used in frequency distributions only when weight variable is discrete (no fractional numbers)

```
tab x [fweight = weight]
```

"Importance" weight

- **IWEIGHT**

  – Indicates the "importance" of the observation in some vague sense

  – Has no formal statistical definition

  – Any command that supports iweights will define exactly how they are treated

  – Intended for use by programmers who want to produce a certain computation

  – Can be used in frequency distributions even when weight variable is continuous (fractional numbers)

  ```
  tab x [iweight = weight]
  ```

Analytic weight

- **AWEIGHT**

  – Inversely proportional to the variance of an observation

  – Variance of the jth observation is assumed to be σ^2/w_j, where w_j are the weights

  – For most Stata commands, the recorded scale of aweights is irrelevant

  – Stata internally rescales frequencies, so sum of weights equals sample size

```
        tab x [aweight = weight]
regress y x1 x2 [aweight = weight]
```

More about analytic weight

- Observations represent averages and weights are the number of elements that gave rise to the average

```
group      x         y      n
  1       3.5      26.0     2
  2       5.0      20.0     3
```

- Instead of

```
group      x         y
  1        3        22
  1        4        30
  2        8        25
  2        2        19
  2        5        16
```

- Usually, survey data is collected from individuals and households (not as averages)
  - Thus, aweights are not appropriate for most cases

Sampling weight

- **PWEIGHT**

  – Denote the inverse of the probability that the observation is included due to the sampling design

  – Variances, standard errors, and confidence intervals are estimated with a more precise procedure

  – Indicated for statistical regressions to estimate robust standard errors

  - Obtain unbiased standard errors of OLS coefficients under heteroscedasticity (i.e., residuals not randomly distributed)

  - Robust standard errors are usually larger than conventional ones

```
regress y x1 x2 [pweight = weight]
```

Summary of Stata weights

WEIGHTS IN FREQUENCY DISTRIBUTIONS		
Weight unit of measurement	**Expand to population size**	**Maintain sample size**
Discrete	**fweight**	**aweight**
Continuous	**iweight**	

WEIGHTS IN STATISTICAL REGRESSIONS should maintain sample size	
Robust standard error	**Adjusted R^2, TSS, ESS, RSS**
pweight	**aweight**
reg *y x*, vce(robust) **reg *y x*, vce(cluster *area*)**	**outreg2**

Example of 2018 ACS weight

```
. sum perwt, d
```

                            Person weight

         Percentiles   Smallest
  1%   10   1
  5%   19   1
 10%   29   1   Obs   3,214,539
 25%   52   1   Sum of wgt. 3,214,539

 50%   80   Mean   101.7774
                           Largest   Std. dev.   83.93534
 75%   124   1916
 90%   195   1990   Variance   7045.14
 95%   263   2097   Skewness   2.845116
 99%   427   2313   Kurtosis   17.99265

Example of 2018 ACS weight

. tab sex

Sex	Freq.	Percent	Cum.
Male	1,574,618	48.98	48.98
Female	1,639,921	51.02	100.00
Total	3,214,539	100.00	

. tab sex [fweight=perwt]

Sex	Freq.	Percent	Cum.
Male	161,072,404	49.23	49.23
Female	166,095,035	50.77	100.00
Total	327,167,439	100.00	

. tab sex [iweight=perwt]

Sex	Freq.	Percent	Cum.
Male	161,072,404	49.23	49.23
Female	166,095,035	50.77	100.00
Total	327,167,439	100.00	

. tab sex [aweight=perwt]

Sex	Freq.	Percent	Cum.
Male	1,582,595	49.23	49.23
Female	1,631,944	50.77	100.00
Total	3,214,539	100.00	

Example of 2021 GSS weight

```
. sum wtssnrps, d
```

person post-stratification weight, nonrespondents
adjusted

	Percentiles	Smallest		
1%	.243687	.1723802		
5%	.30024	.1738938		
10%	.4057674	.1926333	Obs	4,032
25%	.5423563	.2104285	Sum of wgt.	4,032
50%	.8183308		Mean	1
		Largest	Std. dev.	.7260472
75%	1.212269	6.51434		
90%	1.798724	6.903664	Variance	.5271445
95%	2.27083	7.218392	Skewness	2.825826
99%	3.986099	7.557038	Kurtosis	15.89999

Example of 2021 GSS weight

```
. tab sex, m
```

respondents sex	Freq.	Percent	Cum.
male	1,736	43.06	43.06
female	2,204	54.66	97.72
.i	19	0.47	98.19
.n	71	1.76	99.95
.s	2	0.05	100.00
Total	4,032	100.00	

```
. tab sex [fweight=wtssnrps], m
may not use noninteger frequency weights
r(401);
```

```
. tab sex [iweight=wtssnrps], m
```

respondents sex	Freq.	Percent	Cum.
male	1,904.2566	47.23	47.23
female	1,993.21543	49.43	96.66
.i	18.1122752	0.45	97.11
.n	113.299832	2.81	99.92
.s	3.11586052	0.08	100.00
Total	4,032	100.00	

```
. tab sex [aweight=wtssnrps], m
```

respondents sex	Freq.	Percent	Cum.
male	1,904.2566	47.23	47.23
female	1,993.21543	49.43	96.66
.i	18.1122752	0.45	97.11
.n	113.299832	2.81	99.92
.s	3.11586052	0.08	100.00
Total	4,032	100.00	

Complex sample cluster design

- To calculate standard errors correctly, variables for sample cluster design must be used

  - Without design variables, Stata will assume a simple random sample and underestimate standard errors

- Strata are created based on the lowest level of geography available in each sample

  - We use additional statistical techniques that account for the complex sample design to produce correct standard errors and statistical tests

Cluster design for tables

- If we want to estimate a confidence interval for a sample statistic (mean or proportion), we need to inform the complex survey design

- **Confidence interval** is a range of values used to estimate the true population parameter

- **Confidence level** is the success rate of the procedure to estimate the confidence interval

- Larger confidence levels generate larger confidence intervals

Confidence level, *α*, and Z

Confidence level $(1 - \alpha) * 100$	Significance level alpha (*α*)	*α* / 2	Z score
90%	0.10	0.05	± 1.65
95%	**0.05**	**0.025**	$\pm\textbf{1.96}$
99%	0.01	0.005	± 2.58
99.9%	0.001	0.0005	± 3.32
99.99%	0.0001	0.00005	± 3.90

Confidence intervals from samples

$$c.i. = sample\ estimate \pm margin\ of\ error$$
$$c.i. = sample\ estimate \pm score\ of\ confidence\ level * standard\ error$$

- Sample mean ($\bar{x}$), standard deviation (s), *n*<30

$$c.i. = \bar{x} \pm t\left(\frac{s}{\sqrt{n}}\right) \qquad df = n - 1$$

- Sample mean ($\bar{x}$), standard deviation (s), *n*≥30

$$c.i. = \bar{x} \pm Z\left(\frac{s}{\sqrt{n-1}}\right)$$

- Sam. proportion (P_s), pop. proportion (P_u), *n*≥30

$$c.i. = P_s \pm Z\sqrt{\frac{P_u(1 - P_u)}{n}}$$

Cluster design for regressions

- We also need to inform cluster design for regressions, because the *t*-test utilizes standard errors

$$t = \frac{\hat{\beta}}{SE_{\hat{\beta}}} = \frac{\hat{\beta}}{\sqrt{\dfrac{MSE}{S_{xx}}}} = \frac{\hat{\beta}}{\sqrt{\dfrac{RSS}{df * S_{xx}}}} = \frac{\hat{\beta}}{\sqrt{\dfrac{\sum_i (y_i - \hat{y}_i)^2}{(n-2) \sum_i (x_i - \bar{x})^2}}}$$

– SE_β: standard error of β

– *MSE*: mean squared error = *RSS* / *df*

– *RSS*: residual sum of squares = $\sum_i (y_i - \hat{y}_i)^2$ = $\sum_i \hat{e}_i^2$

– *df*: degrees of freedom = *n*–2 for simple linear regression

– S_{xx}: corrected sum of squares for x (total sum of squares)

Cluster design & standard error

- Sample cluster designs underestimate standard errors, because they tend to select individuals with more similar characteristics from the same clusters

  - Simple random samples would provide more variation (higher standard errors), because they give the same chance of selection for all individuals in the population

- When we inform the cluster design, the standard error tends to increase and statistical significance decreases

$$\downarrow t = \frac{\hat{\beta}}{\uparrow SE_{\hat{\beta}}} = \frac{\hat{\beta}}{\sqrt{\dfrac{MSE}{S_{xx}}}} = \frac{\hat{\beta}}{\sqrt{\dfrac{RSS}{df * S_{xx}}}} = \frac{\hat{\beta}}{\sqrt{\dfrac{\sum_i (y_i - \hat{y}_i)^2}{(n-2) \sum_i (x_i - \bar{x})^2}}}$$

Weights in GSS

- The General Social Survey (GSS) targets the adult population (18+) living in U.S. households

- Due to the adoption of the sub-sampling design of non-respondents, a weight must be employed when using the GSS 2004 and after

- There are three continuous weight variables
  - WTSS
  - WTSSNR
  - WTSSALL

- They all maintain the original sample size, even in frequency distributions with "iweight"

WTSS

- WTSS variable takes into consideration

  - Sub-sampling of non-respondents

  - Number of adults in the household

- In years prior to 2004, a value of one is assigned to all cases, so they are effectively unweighted

  - Number of adults can be utilized to make this adjustment for years prior to 2004

WTSSNR

- WTSSNR variable takes into consideration

  - Sub-sampling of non-respondents

  - Number of adults in the household

  - Differential non-response across areas

- In years prior to 2004, a value of one is assigned to all cases, so they are effectively unweighted

  - Number of adults can be utilized to make this adjustment for years prior to 2004

  - Area non-response adjustment is not possible

WTSSALL

- WTSSALL takes WTSS and applies an adult weight to years before 2004

- The weight value of WTSSALL is the same as WTSS for 2004 and after

- Researchers who use the GSS data before or after 2004 may consider using the WTSSALL weight variable

```
tab x [aweight = wtssall]

sum x [aweight = wtssall]
```

GSS has a cluster sample
(https://gssdataexplorer.norc.org/pages/show?page=gss%2Fstandard_error)

- First- and second-stage units are selected with probabilities proportional to size
  - Size is defined by number of housing units

- Third-stage units (housing units) are selected to be an equal-probability sample
  - This results in roughly the same number of housing units selected per second-stage sampling unit

GSS variables for cluster design

(https://gssdataexplorer.norc.org/pages/show?page=gss%2Fstandard_error)

- There are two design variables
  - VSTRAT
  - VPSU

- First-stage unit
  - VSTRAT: Variance Stratum
  - National Frame Areas (NFAs): one or more counties

- Second-stage unit
  - VPSU: Variance Primary Sampling Unit
  - Segments: block, group of blocks, or census tract

GSS complex sample design

- Account for GSS sample design in Stata

```
svyset [weight=wtssall], strata(vstrat) psu(vpsu) singleunit(scaled)
```

- After "svyset," you should indicate survey design with the option "svy" for commands that estimate standard errors

```
svy: mean y
svy: reg y x1 x2
```

Strata with single sampling unit

(https://gssdataexplorer.norc.org/pages/show?page=gss%2Fstandard_error)

- VSTRAT and VPSU were created with a minimum of three respondents within a cell
  - If all cases are missing on a variable, you get an error message in Stata
  - "Missing standard error because of stratum with single sampling unit"
- It is recommended to utilize the "subpop" option for any subdomain analyses (e.g., for males)

```
svy, subpop(if sex==1): tab x
```

- You can also specify that strata with one sampling unit are "centered" at grand mean instead of stratum mean

```
svyset [weight=wtssall], strata(vstrat) psu(vpsu) singleunit(centered)
```

Example: 2021 GSS in Stata (nominal-level variable)

. tab sex

respondents sex	Freq.	Percent	Cum.
male	1,736	44.06	44.06
female	2,204	55.94	100.00
Total	3,940	100.00	

. tab sex [iweight=wtssnrps]

respondents sex	Freq.	Percent	Cum.
male	1,904.2566	48.86	48.86
female	1,993.21543	51.14	100.00
Total	3,897.472	100.00	

. svyset [weight=wtssnrps], strata(vstrat) psu(vpsu) singleunit(scaled)
(sampling weights assumed)

. svy: tab sex
(running **tabulate** on estimation sample)

Number of strata =   9
Number of PSUs   = 3,492
Number of obs   =   3,940
Population size = 3,897.472
Design df   =   3,483

respondents sex	proportion
male	.4886
female	.5114
Total	1

Key: proportion = **Cell proportion**

Example: 2021 GSS in Stata (ordinal-level variable)

`. tab degree`

r's highest degree	Freq.	Percent	Cum.
less than high school	246	6.14	6.14
high school	1,597	39.84	45.97
associate/junior college	370	9.23	55.20
bachelor's	1,036	25.84	81.04
graduate	760	18.96	100.00
Total	**4,009**	100.00	

`. tab degree [iweight=wtssnrps]`

r's highest degree	Freq.	Percent	Cum.
less than high school	480.972702	11.99	11.99
high school	1,891.6334	47.15	59.13
associate/junior college	452.656901	11.28	70.42
bachelor's	681.8664156	16.99	87.41
graduate	505.084448	12.59	100.00
Total	**4,012.2139**	100.00	

`. svyset [weight=wtssnrps], strata(vstrat) psu(vpsu) singleunit(scaled)`
(sampling weights assumed)

`. svy: tab degree`
(running **tabulate** on estimation sample)

Number of strata =	9
Number of PSUs =	3,543
Number of obs =	4,009
Population size =	**4,012.2139**
Design df =	3,534

r's highest degree	proportion
less tha	.1199
high sch	.4715
associat	.1128
bachelor	.1699
graduate	.1259
Total	1

Key: proportion = **Cell proportion**

Example: 2021 GSS in Stata (interval-ratio-level variable)

```
. sum conrinc
```

Variable	Obs	Mean	Std. dev.	Min	Max
conrinc	2,456	41722.79	39243.69	336	170912.6

```
. sum conrinc [iweight=wtssnrps]
```

Variable	Obs	Weight	Mean	Std. dev.	Min	Max
conrinc	2,456	2453.15509	37647.74	37376.88	336	170912.6

```
. svy: mean conrinc
(running mean on estimation sample)

Survey: Mean estimation

Number of strata =      9        Number of obs    =      2,456
Number of PSUs   = 2,241        Population size  = 2,453.1551
                                Design df        =      2,232
```

```
. estat sd
```

	Mean	Linearized std. err.	[95% conf. interval]	
conrinc	37647.74	850.3902	35980.1	39315.38

	Mean	Std. dev.
conrinc	37647.74	37376.87