Gov 50: 23. Inference with Mathematical Models

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Roadmap

1. Central limit theorem
2. Normal distribution
3. Using the Normal for inference

1/ Central limit theorem

Sampling distribution, in pictures

population distribution

estimator

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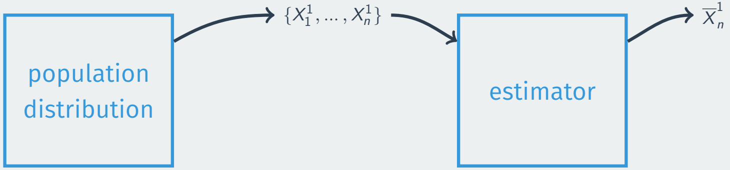

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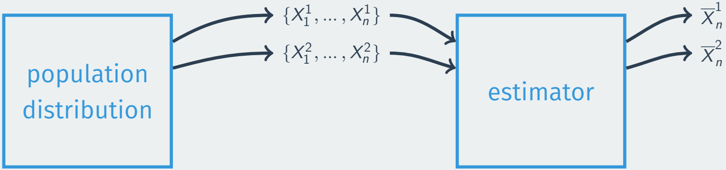

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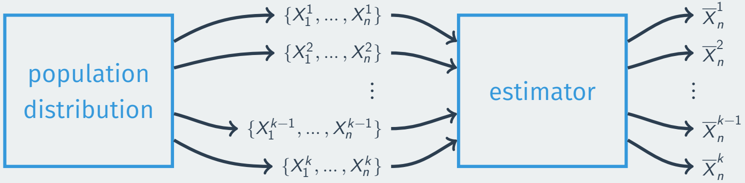

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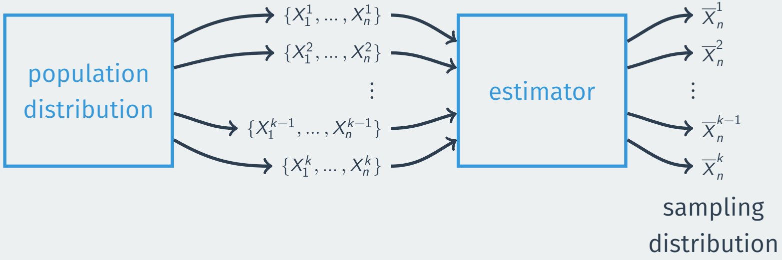

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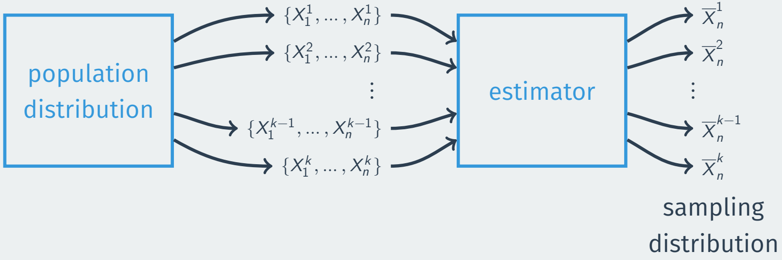

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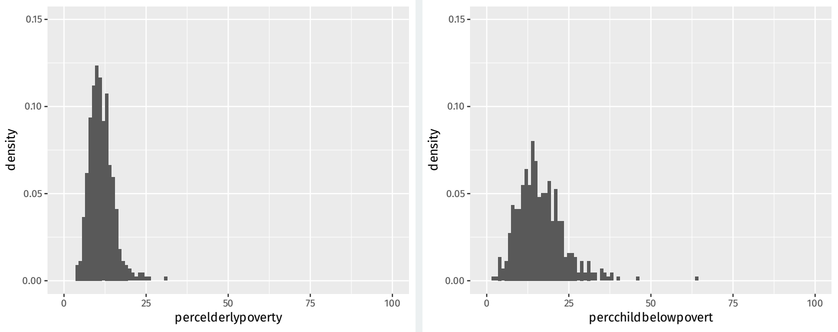
    - Size of the sample: larger sample → smaller spread of the sample means

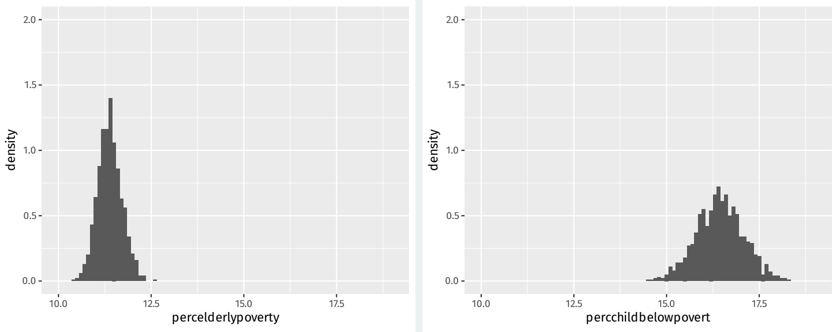
Midwest counties

Population distributions:



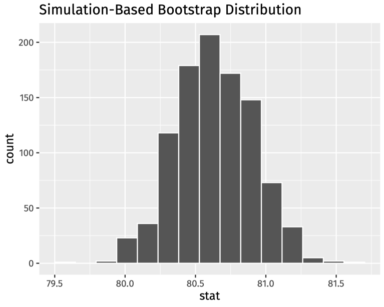
Midwest counties

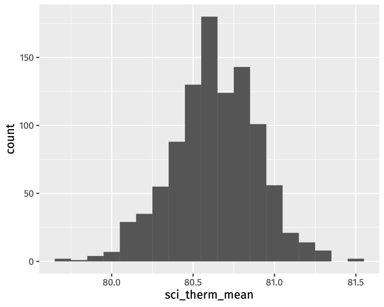
Sampling distributions with $n = 100$

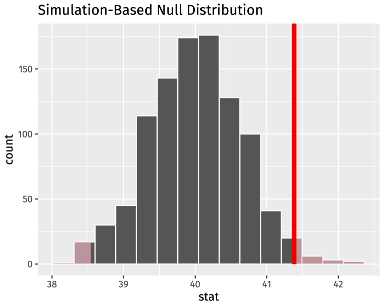


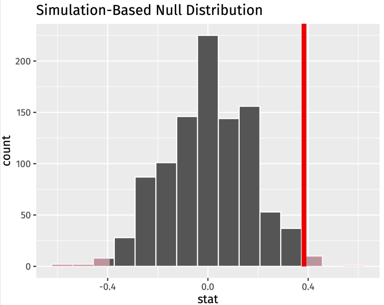
More population spread → higher SE

Similarity in the bootstrap/null distributions

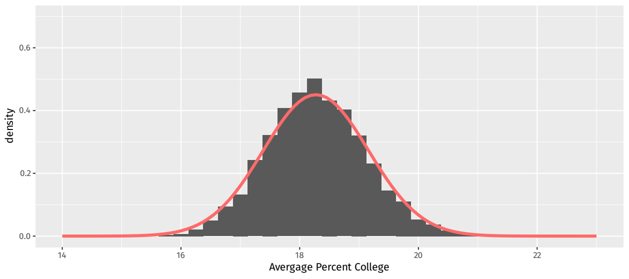








Conditions for the CLT



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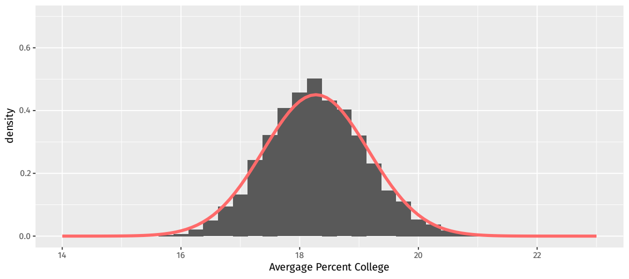

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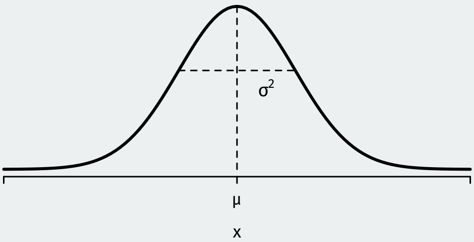
Many, many estimators will follow the CLT and have a normal distribution and will be easier to use this to do inference rather than doing increasingly complicated simulations.

2/ Normal distribution

Normal distribution



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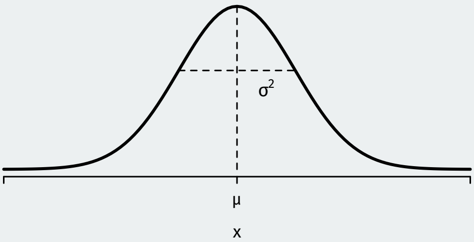

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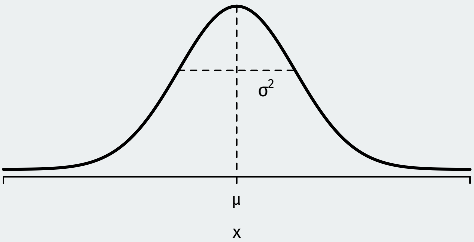

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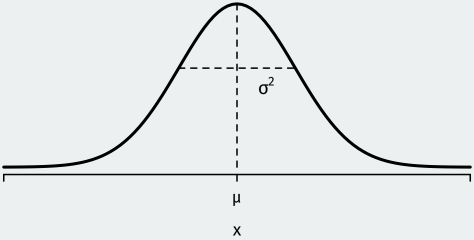

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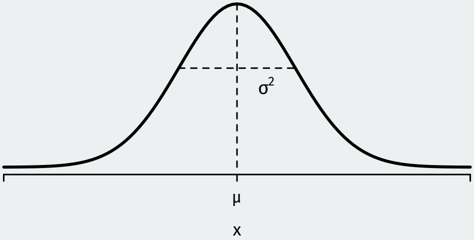

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    - **mean/expected value** usually written as μ
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- **Standard normal distribution**: mean 0 and standard deviation 1.

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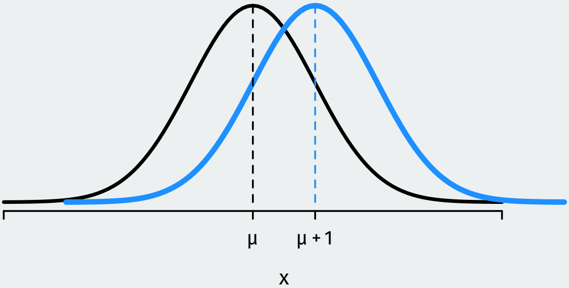
- Intuition: adding a constant to a normal shifts the distribution by that constant.



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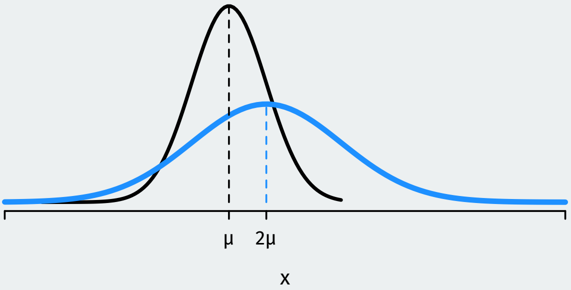

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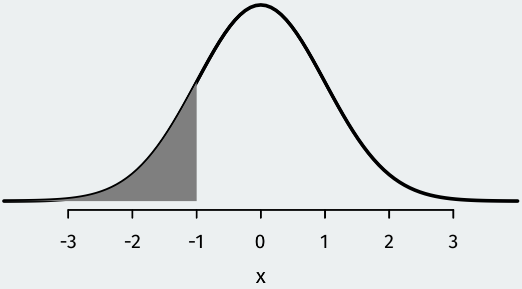
- Subtract the mean and divide by the SD $\rightsquigarrow$ standard normal.
- z-score measures how many SDs away from the mean a value of X is.

Normal probability calculations

What's the probability of being below -1 for a standard normal?



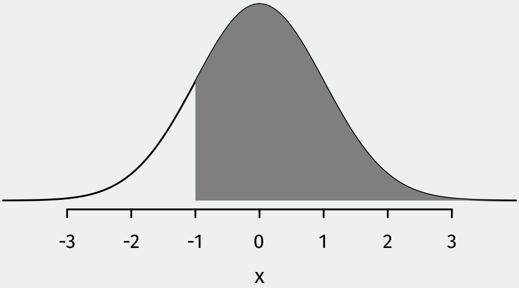
This is the area under the normal curve, which `pnorm( )` function gives us this:

```
pnorm(-1, mean = 0, sd = 1)
```

```
## [1] 0.159
```

Normal probability calculations

What’s the probability of being **above** -1 for a standard normal?



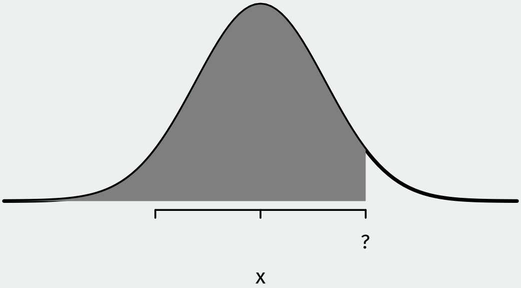
Total area under the curve (1) minus the area below -1:

```
1 - pnorm(-1, mean = 0, sd = 1)
```

```
## [1] 0.841
```

Normal quantiles

What if we want to know the opposite? What value of the normal distribution puts 95% of the distribution below it?



This is a **quantile** and we can get it using `qnorm( )`:

```
qnorm(0.95, mean = 0, sd = 1)
```

```
## [1] 1.64
```

3/ Using the Normal for inference

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  - $\overline{Y} = 0.42$ is the sample proportion.

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Special rule for SEs of sample proportion $\overline{Y}$:

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Because we don't know p, we replace it with our best guess, $\overline{Y}$:

$$\widehat{SE} = \sqrt{\frac{\overline{Y}(1-\overline{Y})}{n}}$$

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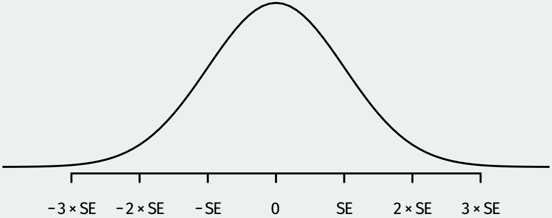
- Central limit theorem implies

$$\overline{Y} \approx N\left(p, \frac{p(1-p)}{n}\right)$$

Chance error: $\overline{Y} - p$ is approximately normal with mean 0 and SE equal to $\sqrt{p(1-p)/n}$

Chance errors



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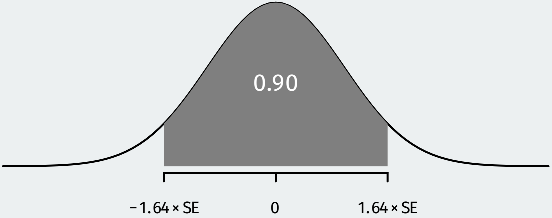

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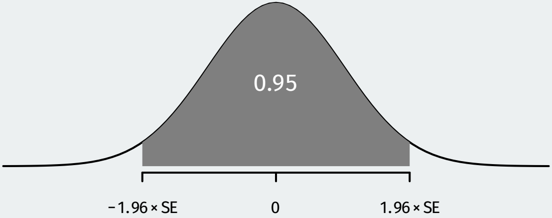

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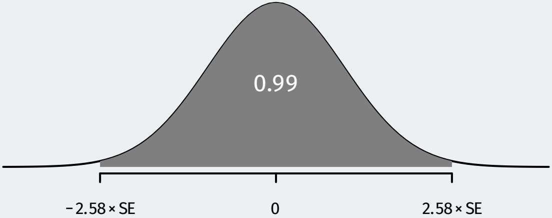

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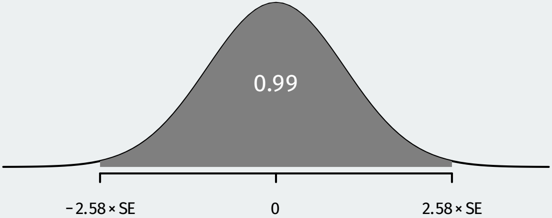

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This implies we can build a 95% confidence interval with $\overline{Y} \pm 1.96 \times SE$

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  - 90% CI $\rightsquigarrow \alpha = 0.1 \rightsquigarrow z_{\alpha/2} = 1.64$

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    - $\mathbb{P}(-z_{\alpha/2} < Z < z_{\alpha/2}) = \alpha$
    - 90% CI $\rightsquigarrow \alpha = 0.1 \rightsquigarrow z_{\alpha/2} = 1.64$
    - 95% CI $\rightsquigarrow \alpha = 0.05 \rightsquigarrow z_{\alpha/2} = 1.96$

How did we get those values?

- First, choose a **confidence level**.
  - What percent of chance errors do you want to count as “plausible”?
  - Convention is 95%.
- $100 \times (1 - \alpha)\%$ confidence interval:

$$CI = \overline{Y} \pm z_{\alpha/2} \times SE$$

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  - 95% CI $\rightsquigarrow \alpha = 0.05 \rightsquigarrow z_{\alpha/2} = 1.96$
  - 99% CI $\rightsquigarrow \alpha = 0.01 \rightsquigarrow z_{\alpha/2} = 2.58$

Standard normal z-scores in R

`qnorm(x, lower.tail = FALSE)` will find the quantile of $N(0, 1)$ that puts x in the upper tail:

```r
qnorm(0.05, lower.tail = FALSE)
```

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qnorm(0.05, lower.tail = FALSE)
```

```
## [1] 1.64
```

```r
qnorm(0.025, lower.tail = FALSE)
```

```
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```

```
## [1] 1.96
```

```
qnorm(0.005, lower.tail = FALSE)
```

```
## [1] 2.58
```