

# *On Simple Linear Regression*

# ***Why Linear Regression ?***

- LR is a fundamental tool in the data scientist's kit.
- Practically speaking, using it is one or two lines of code.
- But it's crucial for us to understand the theory underlying it:
  - Building block for more complex tools
  - We are better data scientists if we understand both HOW and WHY

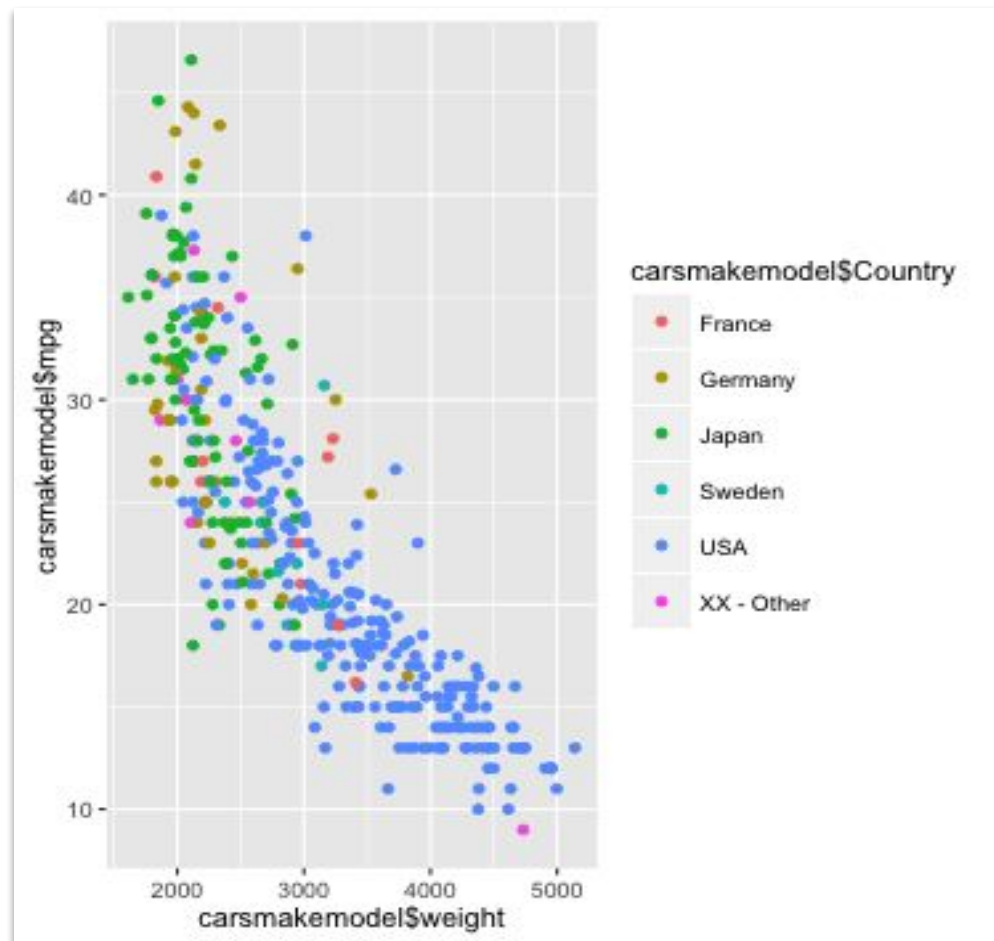
## Simple Linear Regression

- Simple: functions of a single variable:  $Y = f(X)$
- Linear: models are lines
- Regression: dependent variable is continuously-valued

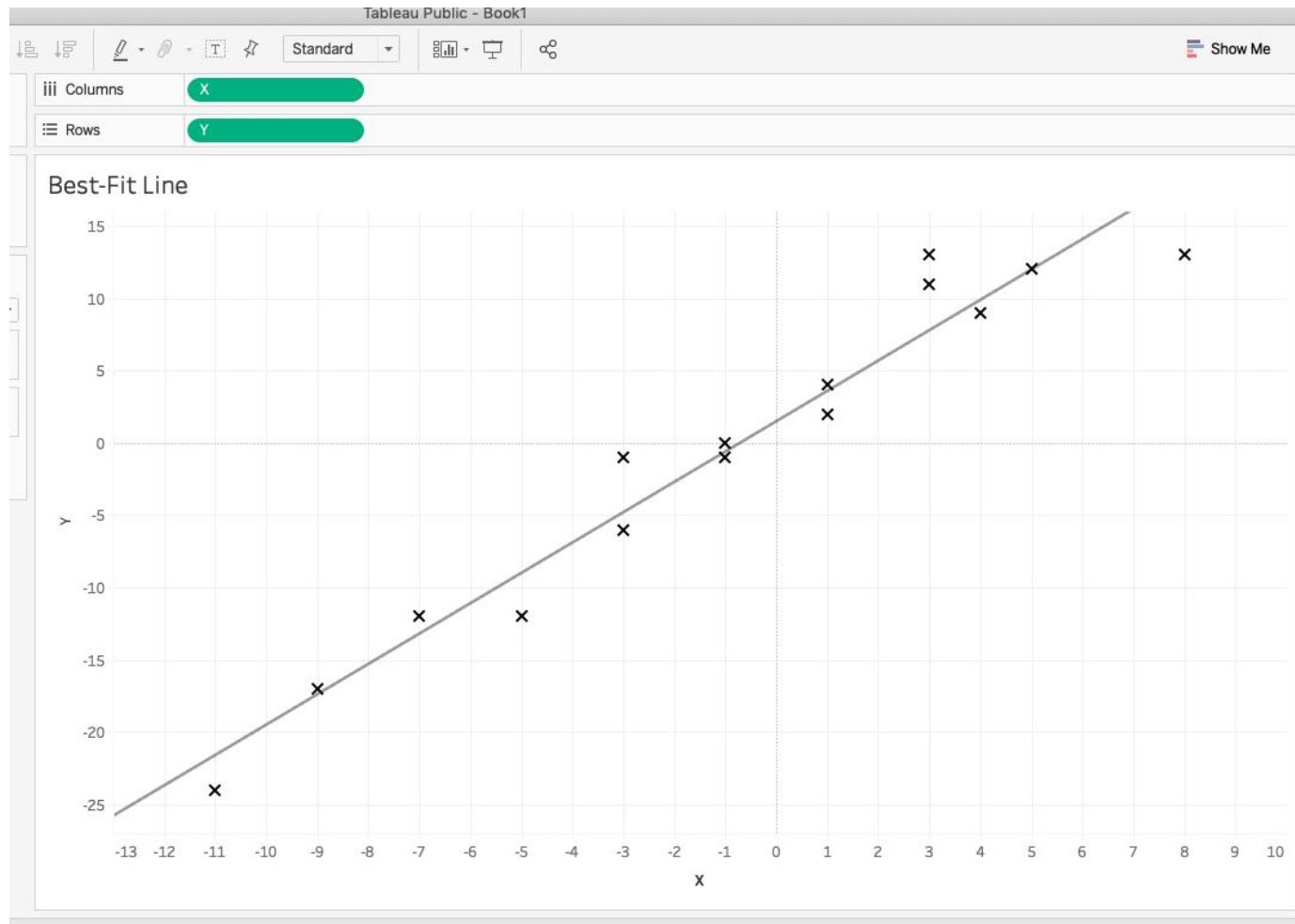
## Inference and Prediction

- As population density increases, so do housing prices.
- As the number of trees decreases, the concentration of  $\text{CO}_2$  goes up.

## Car Weight and MPG



# Best-Fit Line

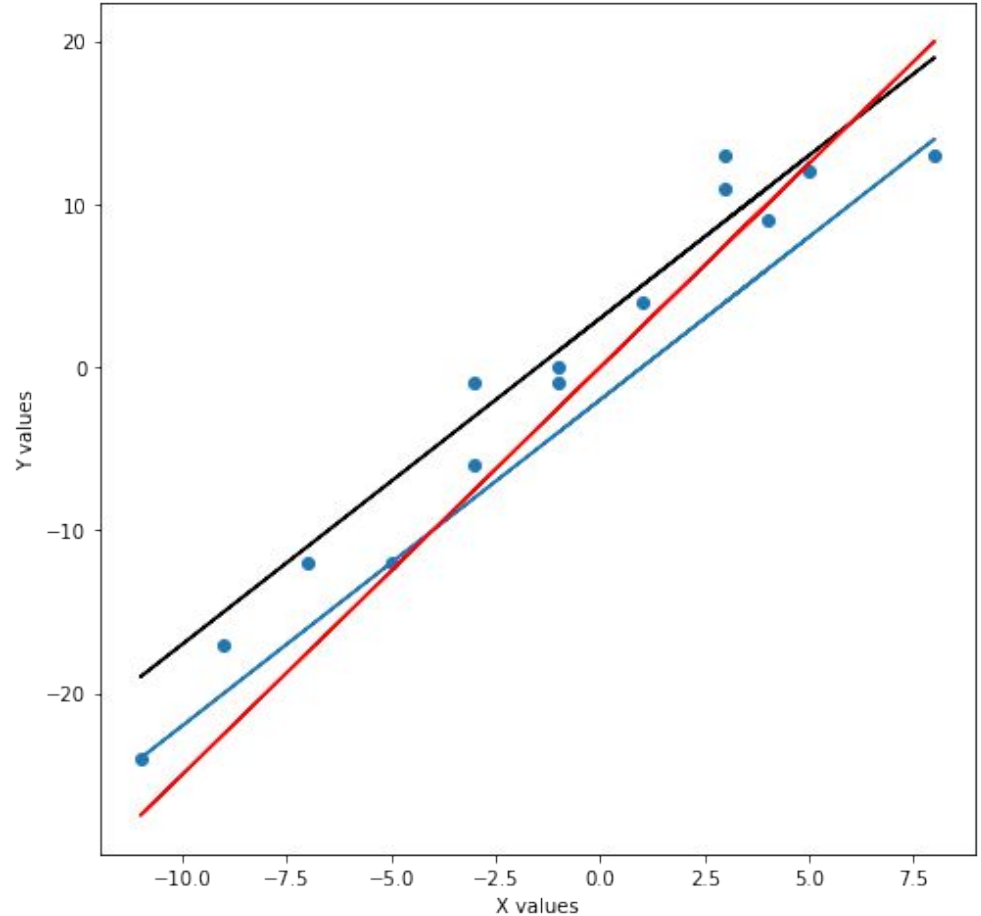


## A Line as a Model

- Predictions for *all* values of the X variable
  - Model shape:  $\hat{y} = \beta_1 x + \beta_0$
- Error as the distance between real and predicted values  
$$E = y - \hat{y}$$
$$E^2 = (y - \hat{y})^2$$

## Goal: Minimize Error

- Which of these lines fits the data best?





## How to Construct the Best-Fit Line

$$r_P = \frac{\sum_i (x_i - \bar{x})(y_i - \bar{y})}{\sqrt{\sum_i (x_i - \bar{x})^2} \sqrt{\sum_i (y_i - \bar{y})^2}}$$

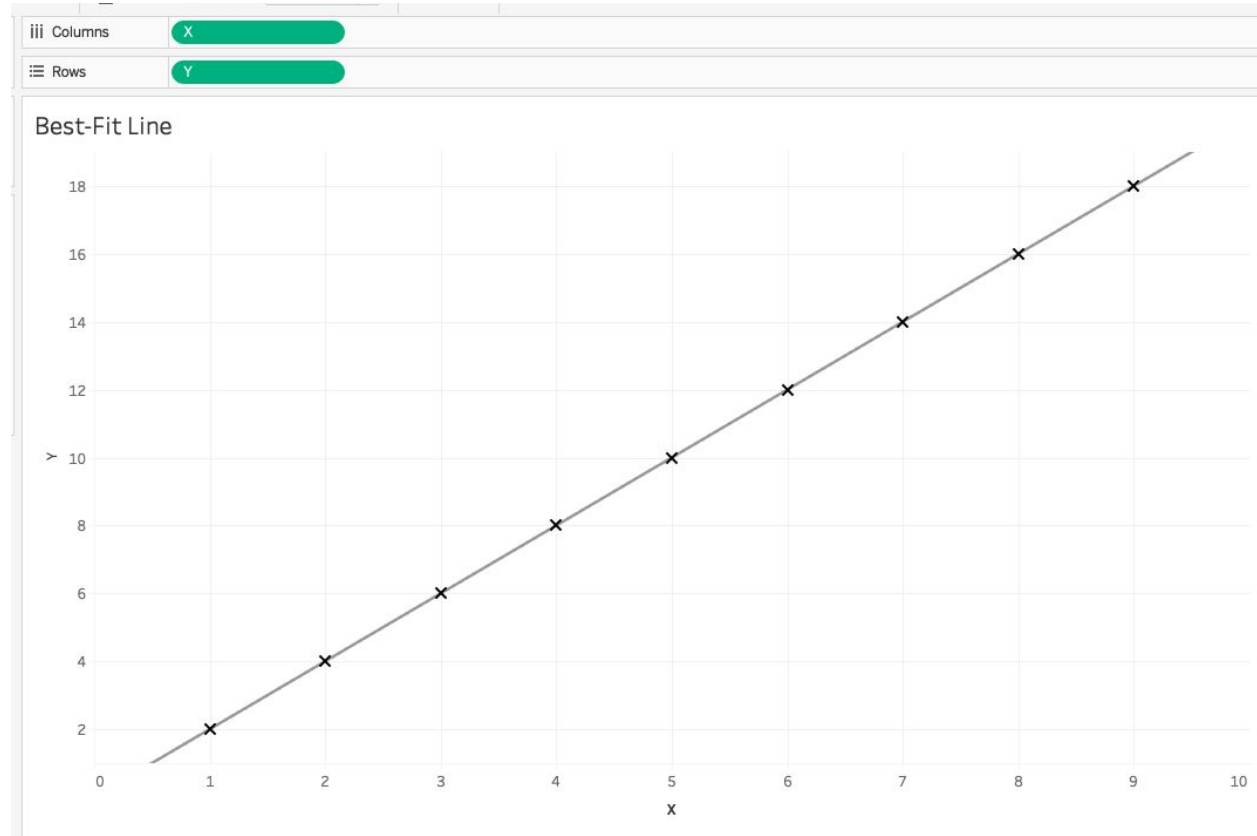
$$\beta_1 = r_P \frac{\sigma_y}{\sigma_x}$$

$$\beta_0 = \bar{y} - \beta_1 \bar{x}$$

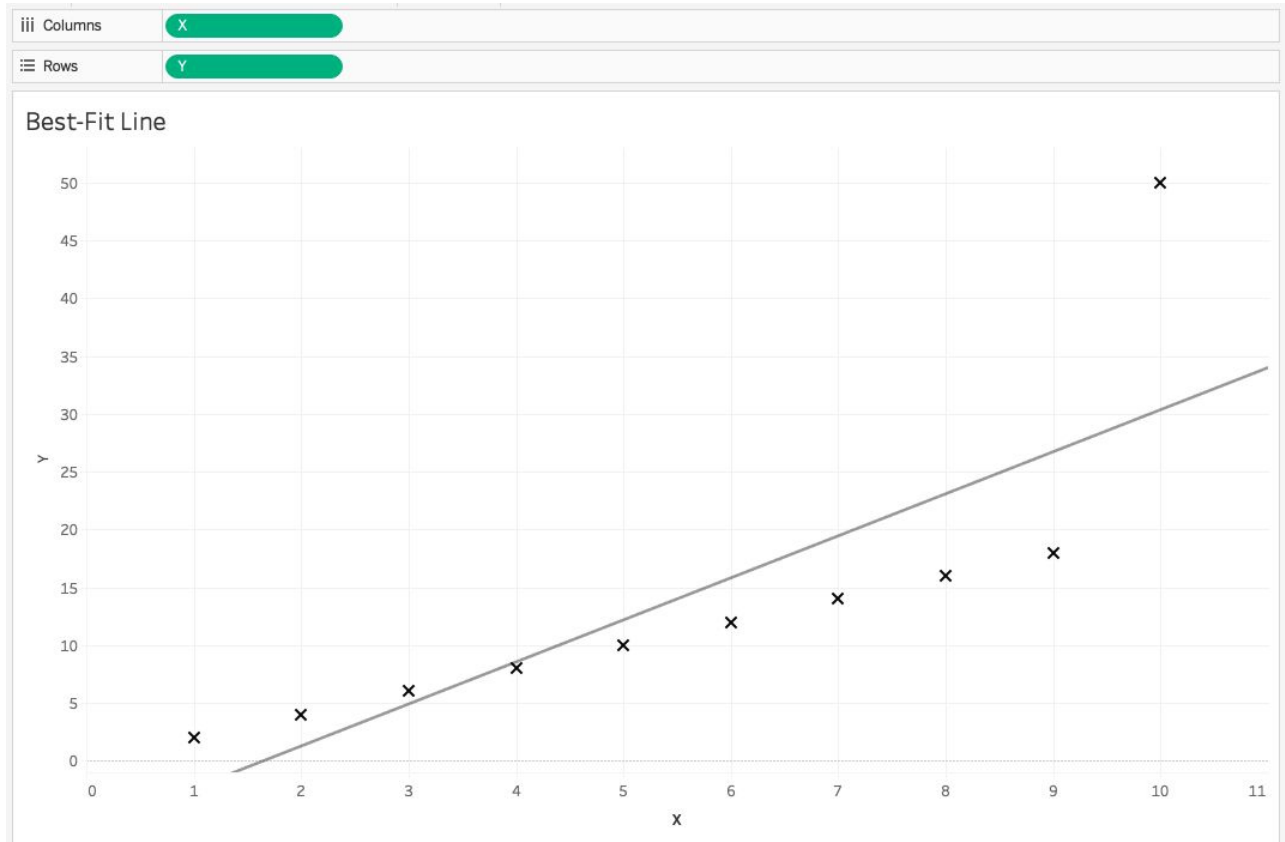
# Outliers

# Sheet1 <b>X</b>	# Sheet1 <b>Y</b>
1	2
2	4
3	6
4	8
5	10
6	12
7	14
8	16
9	18
10	50

# Dropping Outliers



# Keeping Outliers



## Example

- Construct the best-fit line for the points:

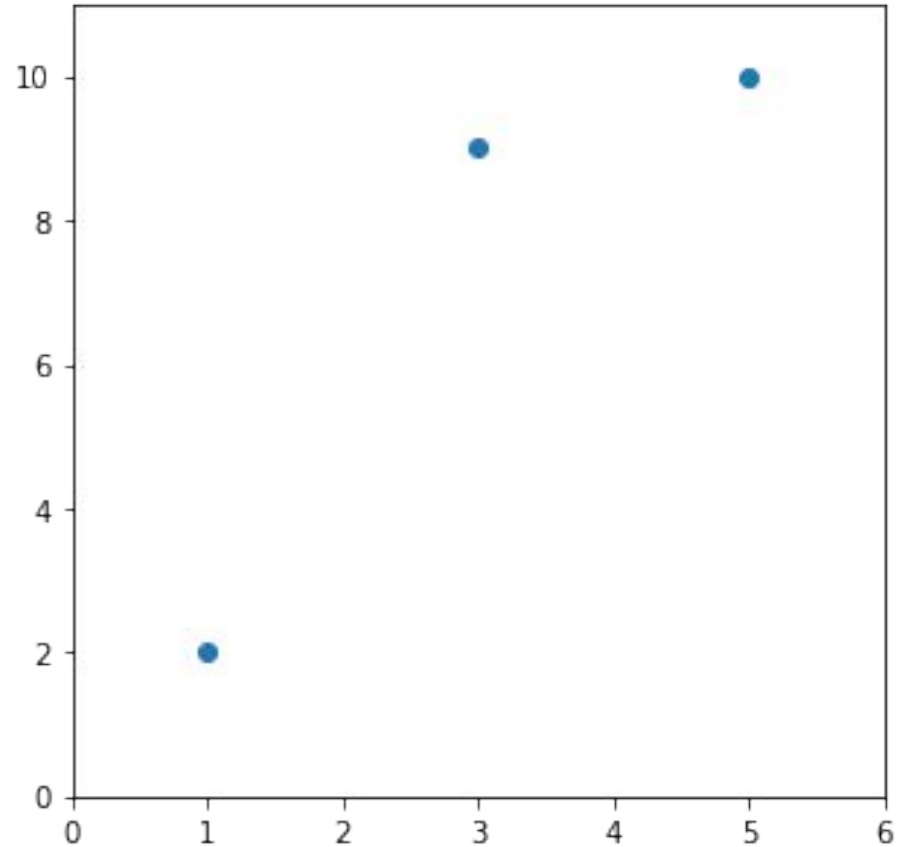
(1, 2), (3, 9), and (5, 10).

- Remember:

$$r_P = \frac{\sum_i (x_i - \bar{x})(y_i - \bar{y})}{\sqrt{\sum_i (x_i - \bar{x})^2} \sqrt{\sum_i (y_i - \bar{y})^2}}$$

$$\beta_1 = r_P \frac{\sigma_y}{\sigma_x}$$

$$\beta_0 = \bar{y} - \beta_1 \bar{x}$$



$$x_i : [1, 3, 5]$$

$$y_i : [2, 9, 10]$$

## Step 1

- Calculate  $\bar{x}$  and  $\bar{y}$ :

$$\bar{x} = \frac{1+3+5}{3} = 3$$

$$\bar{y} = \frac{2+9+10}{3} = 7$$

$$x_i : [1, 3, 5]$$

$$y_i : [2, 9, 10]$$

## Step 2

- Calculate these products:

$$\Sigma(x_i - \bar{x})(y_i - \bar{y}) = (1 - 3)(2 - 7) + (3 - 3)(9 - 7) + (5 - 3)(10 - 7) = 16$$

$$\Sigma(x_i - \bar{x})^2 = (1 - 3)^2 + (3 - 3)^2 + (5 - 3)^2 = 8$$

$$\Sigma(y_i - \bar{y})^2 = (2 - 7)^2 + (9 - 7)^2 + (10 - 7)^2 = 38$$

$x_i : [1, 3, 5]$

$y_i : [2, 9, 10]$

### Step 3

- Calculate Pearson correlation:

$$r_P = \frac{\Sigma(x_i - \bar{x})(y_i - \bar{y})}{\sqrt{\Sigma_i(x_i - \bar{x})^2} \sqrt{\Sigma_i(y_i - \bar{y})^2}} = \frac{16}{\sqrt{(8)(38)}} = \frac{4}{\sqrt{19}}$$



$x_i : [1, 3, 5]$

$y_i : [2, 9, 10]$

## Step 4

- Calculate standard deviations:

$$\sigma_x = \sqrt{\frac{8}{3}}$$

$$\sigma_y = \sqrt{\frac{38}{3}}$$

$$x_i : [1, 3, 5]$$

$$y_i : [2, 9, 10]$$

## Step 5

- Calculate the slope:

$$\beta_1 = r_P \frac{\sigma_y}{\sigma_x} = \frac{4}{\sqrt{19}} \left( \frac{\sqrt{\frac{38}{3}}}{\sqrt{\frac{8}{3}}} \right) = \frac{4}{\sqrt{19}} \left( \frac{\sqrt{38}}{\sqrt{8}} \right) = \frac{4\sqrt{2}}{2\sqrt{2}} = 2$$

$x_i : [1, 3, 5]$

$y_i : [2, 9, 10]$

## Step 6

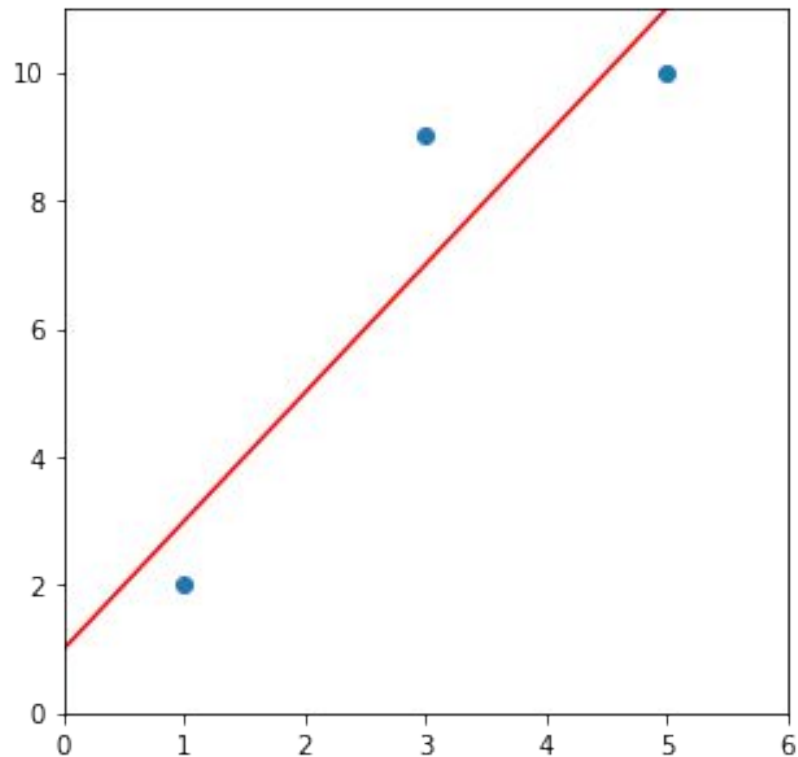
- Calculate the y-intercept:

$$\beta_0 = \bar{y} - \beta_1 \bar{x} = 7 - (2)(3) = 1$$

## Line

- We have our line!

$$\hat{y} = \beta_1 x + \beta_0 = 2x + 1$$



# Surface and Contour Plots of $SSE(m, b)$

