

Multivariate regressions

Lecture 9

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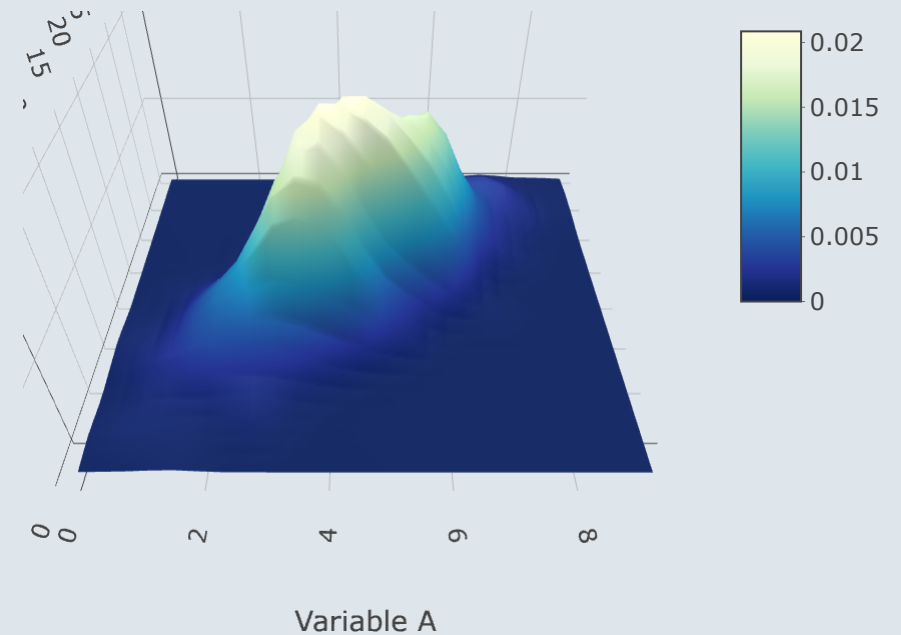
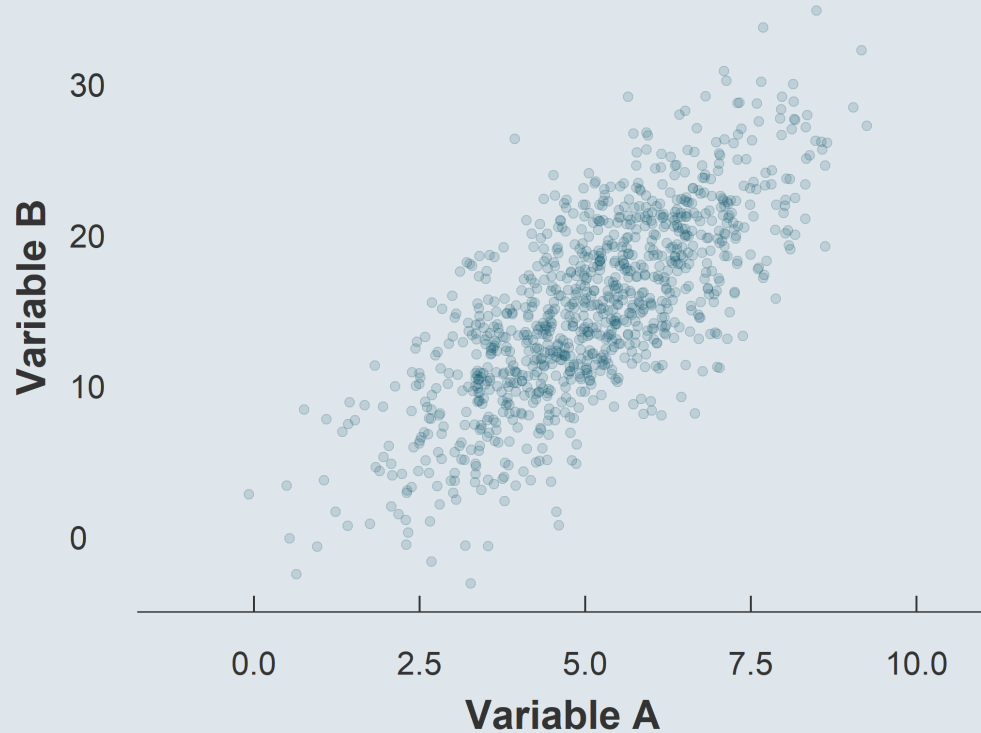
CPES 2 - Fall 2022



Quick reminder

1. Joint distribution

The **joint distribution** shows the possible **values** and associated **frequencies** for **two variables** simultaneously



Quick reminder

1. Joint distribution

→ *When describing a joint distribution, we're interested in the relationship between the two variables*

- The **covariance** quantifies the joint deviation of two variables from their respective mean
 - It can take values from $-\infty$ to ∞ and depends on the unit of the data

$$\text{Cov}(x, y) = \frac{1}{N} \sum_{i=1}^N (x_i - \bar{x})(y_i - \bar{y})$$

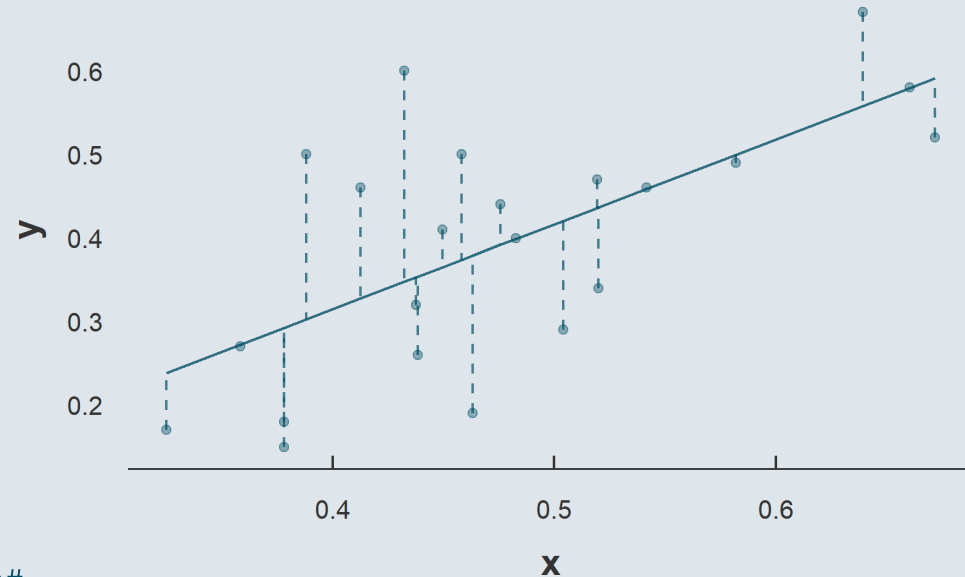
- The **correlation** is the covariance of two variables divided by the product of their standard deviation
 - It can take values from -1 to 1 and is independent from the unit of the data

$$\text{Corr}(x, y) = \frac{\text{Cov}(x, y)}{\text{SD}(x) \times \text{SD}(y)}$$



Quick reminder

2. Regression



```
##  
## Call:  
## lm(formula = y ~ x, data = data)  
##  
## Coefficients:  
## (Intercept)          x  
##    -0.09129      1.01546
```

- This can be expressed with the **regression equation**:

$$y_i = \hat{\alpha} + \hat{\beta}x_i + \hat{\varepsilon}_i$$

- Where $\hat{\alpha}$ is the **intercept** and $\hat{\beta}$ the **slope** of the **line** $\hat{y}_i = \hat{\alpha} + \hat{\beta}x_i$, and $\hat{\varepsilon}_i$ the **distances** between the points and the line

$$\hat{\beta} = \frac{\text{Cov}(x_i, y_i)}{\text{Var}(x_i)}$$

$$\hat{\alpha} = \bar{y} - \hat{\beta} \times \bar{x}$$

- $\hat{\alpha}$ and $\hat{\beta}$ minimize $\hat{\varepsilon}_i$

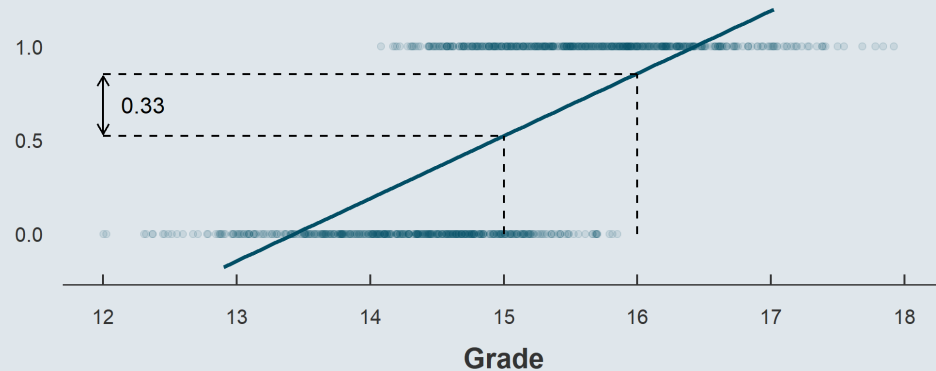


Quick reminder

3. Binary variables

Binary **dependent** variables

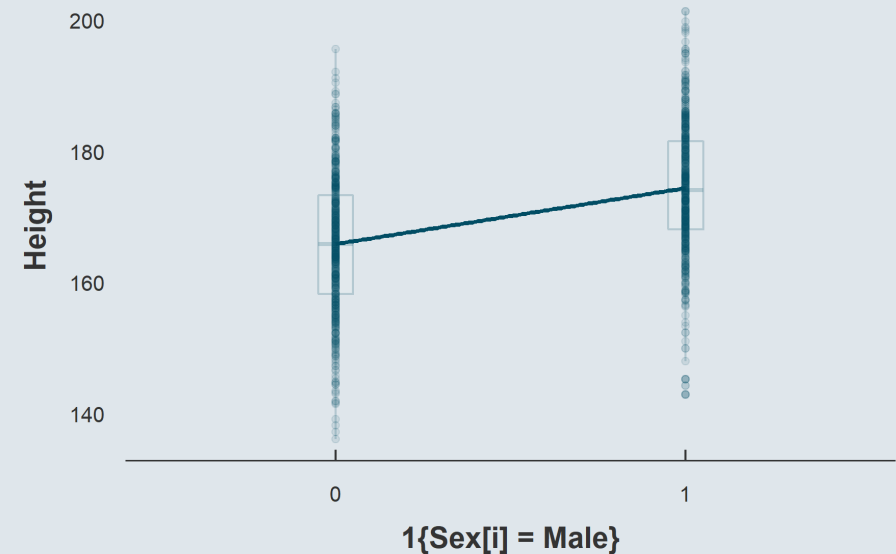
- The **fitted values** can be viewed as **probabilities**
 - $\hat{\beta}$ is the expected increase in the probability that $y = 1$ for a one unit increase in x



- We call that a **Linear Probability model**

Binary **independent** variables

- The x variable should be viewed as a **dummy 0/1**
 - $\hat{\beta}$ is the difference between the average y for the group $x = 1$ and the group $x = 0$



Warm up practice

10:00

- 1) Open the `asec.csv` data containing sex, race, weekly work hours, and annual earnings (\$)
- 2) Regress the earnings variable on the sex variable
- 3) Check that the slope coefficient is equal to the difference between male and female average earnings

You've got 10 minutes!

Solution

1) Open the `asec.csv` data containing sex, race, weekly work hours, and annual earnings (\$)

```
asec <- read.csv("asec.csv")
```

2) Regress the earnings variable on the sex variable

```
lm(Earnings ~ Sex, asec)
```

```
##  
## Call:  
## lm(formula = Earnings ~ Sex, data = asec)  
##  
## Coefficients:  
## (Intercept)      SexMale  
##      50915      21612
```

Solution

3) Check that the slope coefficient is equal to the difference between male and female average earnings

```
asec %>%  
  
  # Group the data by sex  
  group_by(Sex) %>%  
  
  # Summarise mean earnings -> 2x2 dataset  
  summarise(Mean = mean(Earnings)) %>%  
  
  # Put means in columns instead of rows -> 1x2 dataset  
  pivot_wider(names_from = Sex, values_from = Mean) %>%  
  
  # Compute the difference in means  
  mutate(Difference = Male - Female)
```

```
## # A tibble: 1 x 3  
##   Female   Male Difference  
##   <dbl> <dbl>     <dbl>  
## 1 50915. 72527.     21612.
```




Today: Multivariate regressions

1. Adding variables

- 1.1. Continuous variables
- 1.2. Discrete variables

2. Control variables

- 2.1. Motivation
- 2.2. Discrete controls
- 2.3. Continuous controls

3. Interactions

- 3.1. Motivation
- 3.2. Discrete interactions
- 3.3. Continuous interactions

4. Wrap up!



Today: Multivariate regressions

1. Adding variables

1.1. Continuous variables

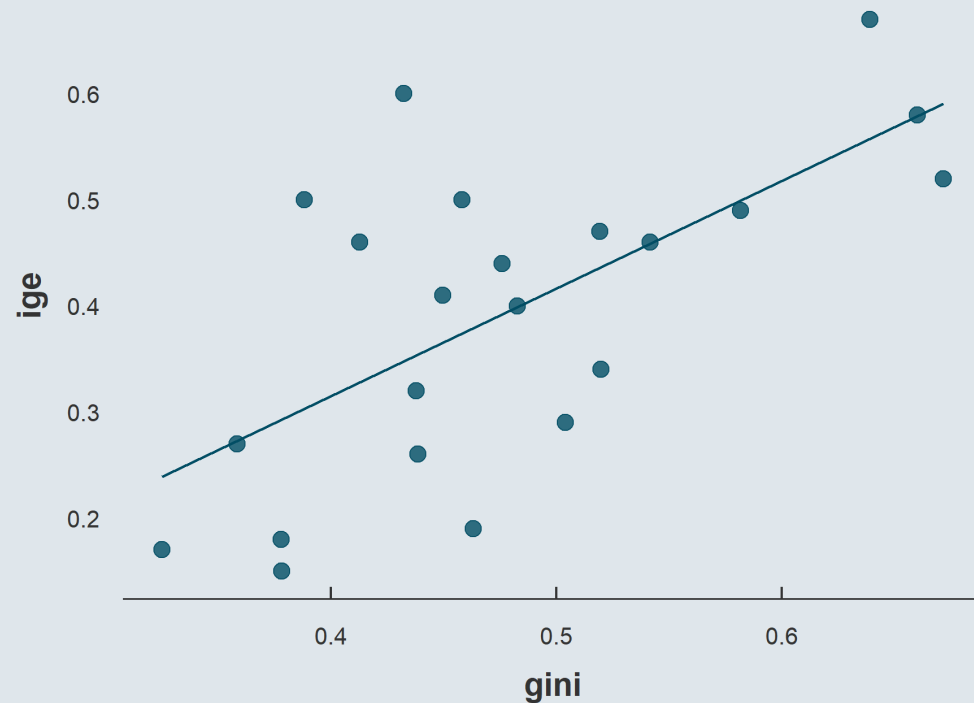
1.2. Discrete variables



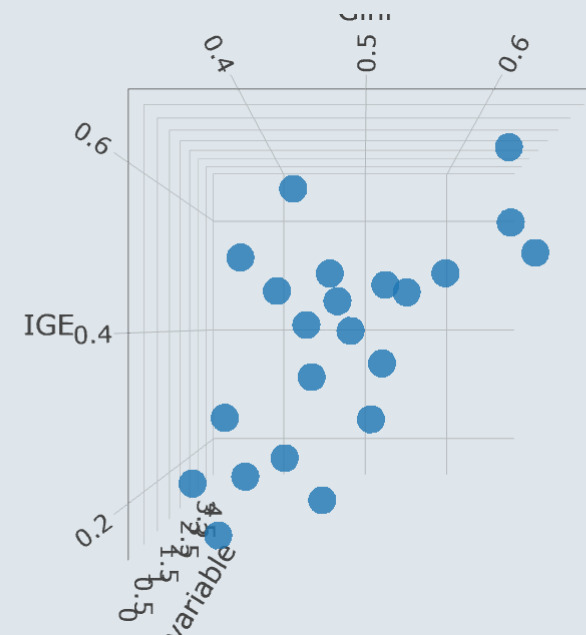
1. Adding variables

1.1. Continuous variables

- So far we focused on two-variable relationships



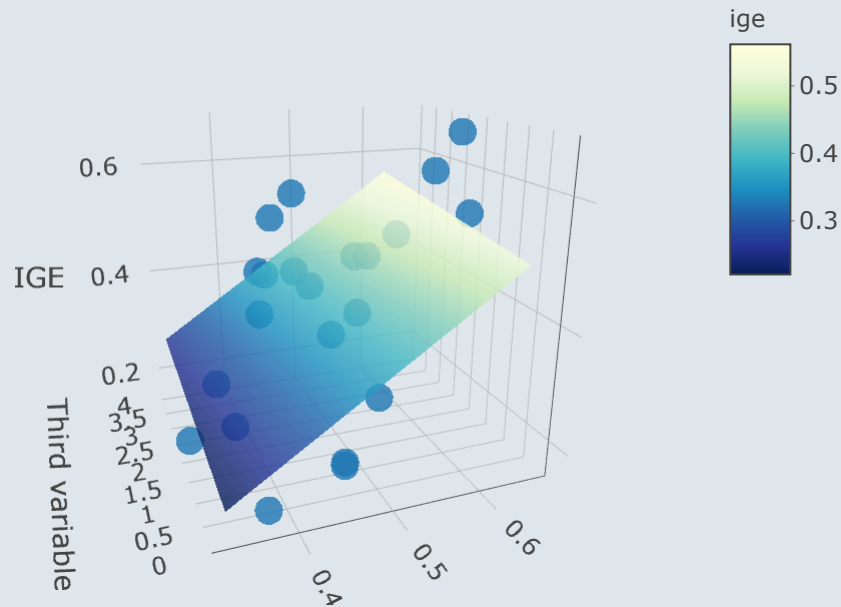
- What about three variable? (*pivot the plot*)





1. Adding variables

1.1. Continuous variables



- In this case we must fit a **plane**
 - It is characterized by **3 parameters**
 - And can be expressed as:

$$y_i = \hat{\alpha} + \hat{\beta}_1 x_{1,i} + \hat{\beta}_2 x_{2,i} + \hat{\varepsilon}_i$$

- $\hat{\alpha}$ is still the **intercept**
 - The value of \hat{y} (height) when $x_1 = x_2 = 0$
- And now there are **2 slopes**
 - $\hat{\beta}_1$ along the x_1 axis and $\hat{\beta}_2$ along the x_2 axis



1. Adding variables

1.1. Continuous variables

- The **same** applies with **more than 2** independent variables
 - We would fit a **hyperplane** with as many dimension as x variables
 - We would obtain one intercept and one slope per x variables

$$y_i = \hat{\alpha} + \hat{\beta}_1 x_{1,i} + \hat{\beta}_2 x_{2,i} + \dots + \hat{\beta}_k x_{k,i} + \hat{\varepsilon}_i$$

- We can estimate the parameters of these hyperplanes in **lm()**
 - **Additional variables** must be introduced after a **+** **sign**

```
lm(ige ~ gini + third_variable, ggcurve)
```

```
##  
## Call:  
## lm(formula = ige ~ gini + third_variable, data = ggcurve)  
##  
## Coefficients:  
##      (Intercept)           gini  third_variable  
##      -0.09536       0.98153       0.01122
```



1. Adding variables

1.2. Discrete variables

- **So far** we've been working with **binary** categorical variables:
 - Accepted vs. Rejected, Male vs. Female
 - But what about discrete variables with **more than two categories**?
- Take for instance the **race variable**:

```
asec %>%  
  group_by(Race) %>%  
  tally()
```

```
## # A tibble: 3 x 2  
##   Race      n  
##   <chr> <int>  
## 1 Black  6835  
## 2 Other  6950  
## 3 White 50551
```

*How can we use this variable
as an independent variable
in our regression framework?*



1. Adding variables

1.2. Discrete variables

- Remember how we converted our **2-category** variable into **1 dummy** variable
 - We can convert an **n-category** variable into **n-1 dummy** variables

Sex	Male		Race	Black	Other
Female	0		White	0	0
Female	0		White	0	0
Female	0		Black	1	0
Male	1		Black	1	0
Male	1		Other	0	1
Male	1		Other	0	1

→ *But why do we omit one category every time?*

- Because it would be redundant
- We only need 2 dummies for 3 groups:
 - White:** Black = **0** & Other = **0**
 - Black:** Black = **1** & Other = **0**
 - Other:** Black = **0** & Other = **1**

$\hat{\alpha}$ is the expected \hat{y} when $x_k = 0 \forall k$

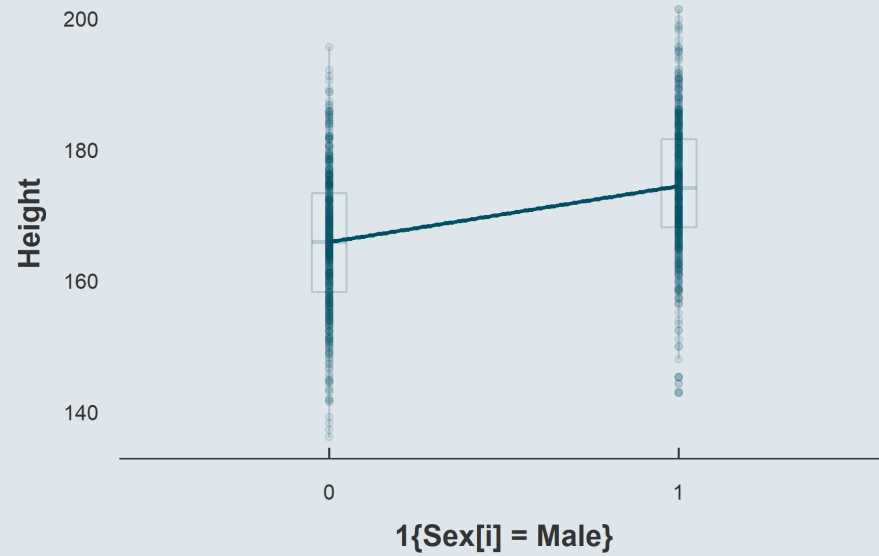
- Thus it does the job for the omitted groups!
- This group is called the **reference group**
- $\hat{\beta}_k$ are interpreted **relative** to that group



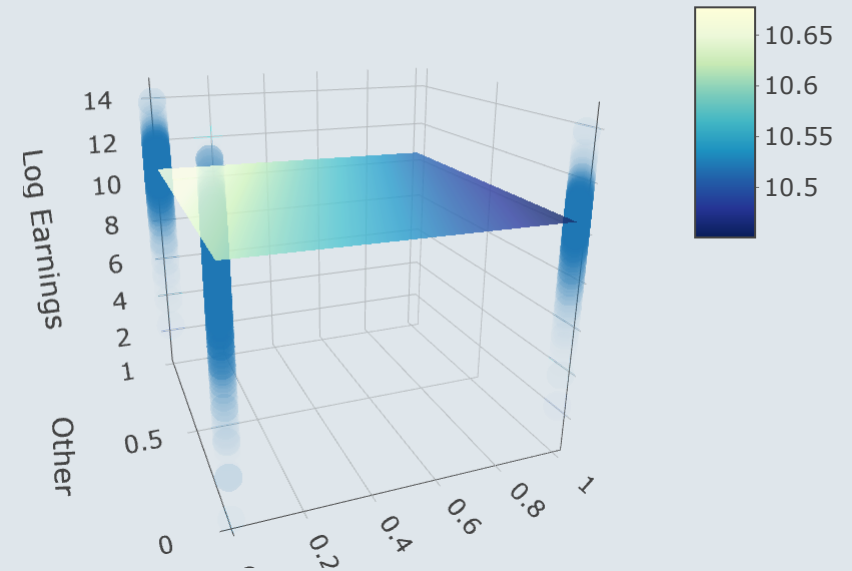
1. Adding variables

1.2. Discrete variables

2-category variable



3-category variable



1. Adding variables

1.2. Discrete variables

- This **plane** can be expressed as:

$$\text{Earnings}_i = \hat{\alpha} + \hat{\beta}_1 1\{\text{Race}_i = \text{Other}\} + \hat{\beta}_2 1\{\text{Race}_i = \text{White}\} + \hat{\varepsilon}_i$$

- And the **average** incomes for each group equal:

- **Black:** $\hat{\alpha} + 0\hat{\beta}_1 + 0\hat{\beta}_2 = \hat{\alpha}$
- **Other:** $\hat{\alpha} + 1\hat{\beta}_1 + 0\hat{\beta}_2 = \hat{\alpha} + \hat{\beta}_1$
- **White:** $\hat{\alpha} + 0\hat{\beta}_1 + 1\hat{\beta}_2 = \hat{\alpha} + \hat{\beta}_2$

```
##
## Call:
## lm(formula = Earnings ~ Race, data = asec)
##
## Coefficients:
## (Intercept)      RaceOther      RaceWhite
##          50577          17477          12303
```

Average by group	
Race	Mean earnings
Black	50577.49
Other	68054.63
White	62880.49



1. Adding variables

1.2. Discrete variables

- By **default**, `lm()` sorts categories by **alphabetical** order
 - So every coefficient should be **interpreted relative** to the group which is first alphabetically
- But usually this is **not** the most **intuitive**
 - You may want everything to be relative to the **majority group**
 - Or to any group that has reasons to be the **reference**
- The **relevel()** function allows you to **change the reference** category
 - But it works **only on factor** variables

```
asec <- asec %>%  
  mutate(Race_fct = relevel(as.factor(Race),  
                             "White"))  
  
lm(Earnings ~ Race_fct, asec)
```

```
##  
## Call:  
## lm(formula = Earnings ~ Race_fct, data = asec)  
##  
## Coefficients:  
## (Intercept) Race_fctBlack Race_fctOther  
##          62880         -12303          5174
```



1. Adding variables

1.2. Discrete variables

- What you can also do is **create the dummies yourself**:

```
asec <- asec %>%  
  mutate(Black = as.numeric(Race == "Black"),  
         Other = as.numeric(Race == "Other"))
```

```
lm(Earnings ~ Black + Other, asec)
```

```
##  
## Call:  
## lm(formula = Earnings ~ Black + Other, data = asec)  
##  
## Coefficients:  
## (Intercept)      Black      Other  
##      62880      -12303       5174
```

→ This might be the **safest** option



1. Adding variables

1.2. Discrete variables

- But a **categorical** variable must **not** be introduced **as numeric** in `lm()`

```
asec <- asec %>%  
  mutate(num_cat = case_when(Race == "White" ~ 0,  
                             Race == "Black" ~ 1,  
                             Race == "Other" ~ 3))
```

```
lm(Earnings ~ num_cat, asec)
```

```
##  
## Call:  
## lm(formula = Earnings ~ num_cat, data = asec)  
##  
## Coefficients:  
## (Intercept)      num_cat  
##    61799.2      774.3
```

→ `lm()` used our **categorical** variable as a **continuous** variable



1. Adding variables

1.2. Discrete variables

- Use the **factor** class

```
asec <- asec %>%  
  mutate(fac_cat = as.factor(num_cat))
```

```
lm(Earnings ~ fac_cat, asec)
```

```
##  
## Call:  
## lm(formula = Earnings ~ fac_cat, data = asec)  
##  
## Coefficients:  
## (Intercept)      fac_cat1      fac_cat3  
##      62880      -12303       5174
```

→ **Converting** all your **categorical** variables into **factors** is also a **safe** option



Overview

1. Adding variables ✓

- 1.1. Continuous variables
- 1.2. Discrete variables

2. Control variables

- 2.1. Motivation
- 2.2. Discrete controls
- 2.3. Continuous controls

3. Interactions

- 3.1. Motivation
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4. Wrap up!



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2. Control variables

2.1. Motivation

- But **why** would we include **additional variables** in our regressions?
 - The main reason is to **control** for potential **confounders**
- Consider estimating the **relationship** between **income** and exposure air **pollution** in the Paris region

$$\text{Pollution}_i = \hat{\alpha}_1 + \hat{\beta}_1 \text{Income}_i + \hat{\varepsilon}_i$$

- You would probably expect that $\hat{\beta}_1 < 0$
 - Meaning that **higher income** earners live in **less polluted** areas
 - But the closer from **Paris** the higher the **rents** and the **ring-road**
 - This phenomenon might counteract this effect and pull $\hat{\beta}_1$ towards 0
- But how to **remove** the **impact** that **distance** from Paris has on the relationship?
 - **Including it** in the regression would make the corresponding coefficient **absorb the confounding effect**
 - In that case we would call distance a **control variable**

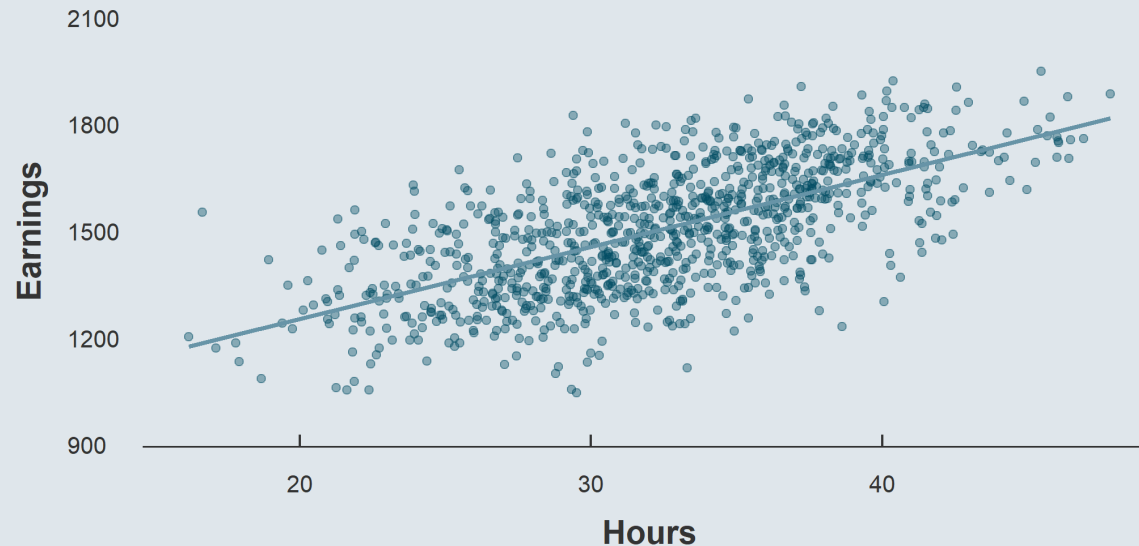
$$\text{Pollution}_i = \hat{\alpha}_2 + \hat{\beta}_2 \text{Income}_i + \hat{\beta}_3 \text{Distance}_i + \hat{\varepsilon}_i$$



2. Control variables

2.2. Discrete

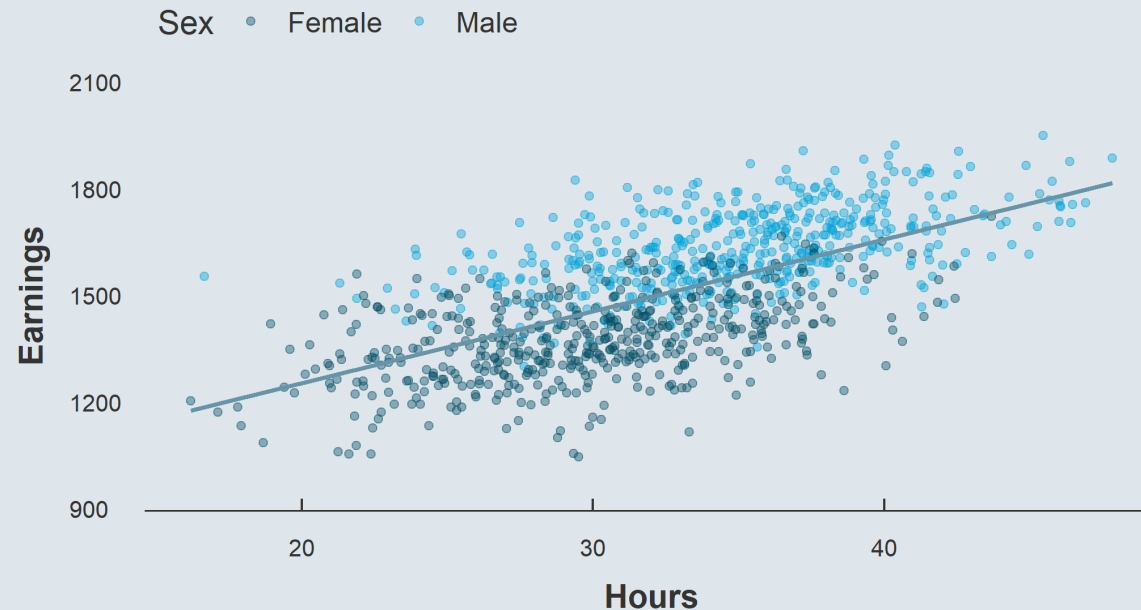
- The most **common control** variable is probably **sex/gender**
 - It may play a role in the **relationship** between **earnings** and **hours worked** for instance
 - The fact that **women** work **part time** more often and **earn less** contribute to the relationship
 - Just like distance did in the previous example



2. Control variables

2.2. Discrete

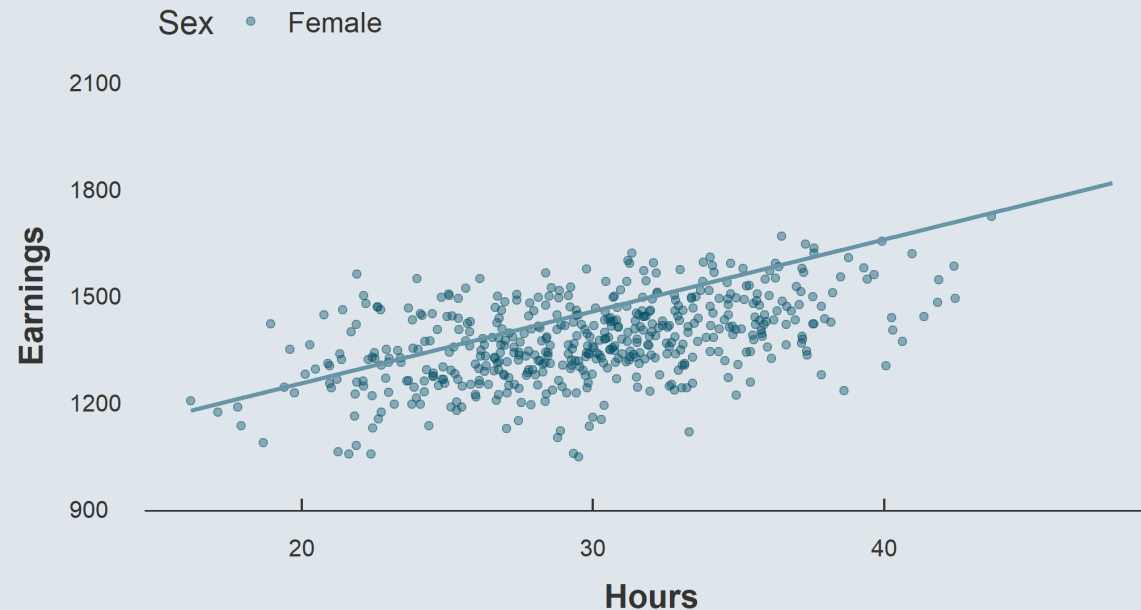
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2. Control variables

2.2. Discrete

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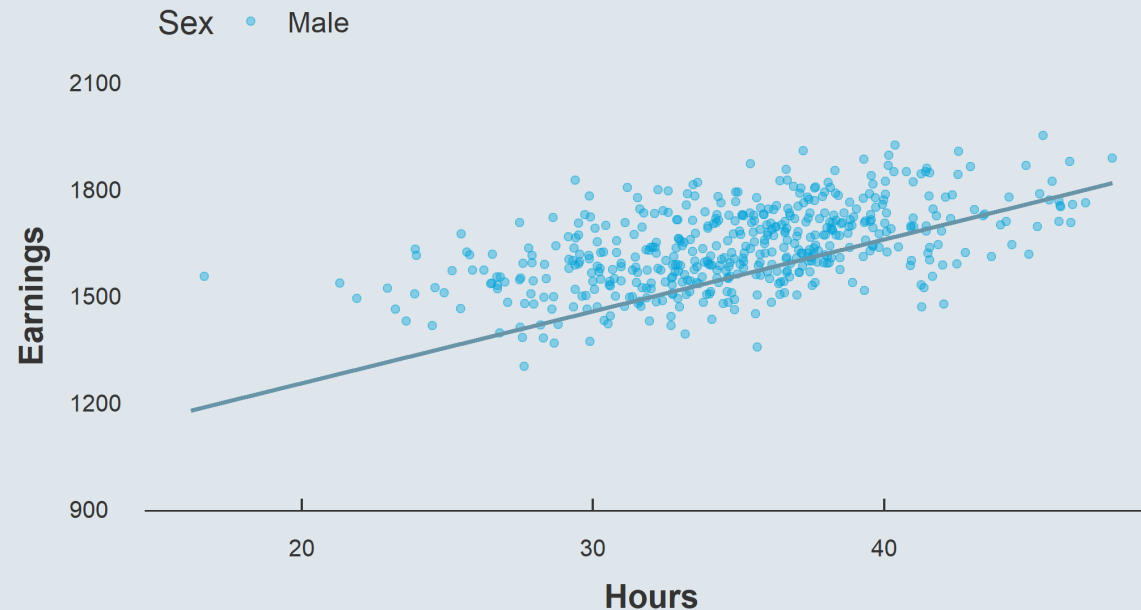




2. Control variables

2.2. Discrete

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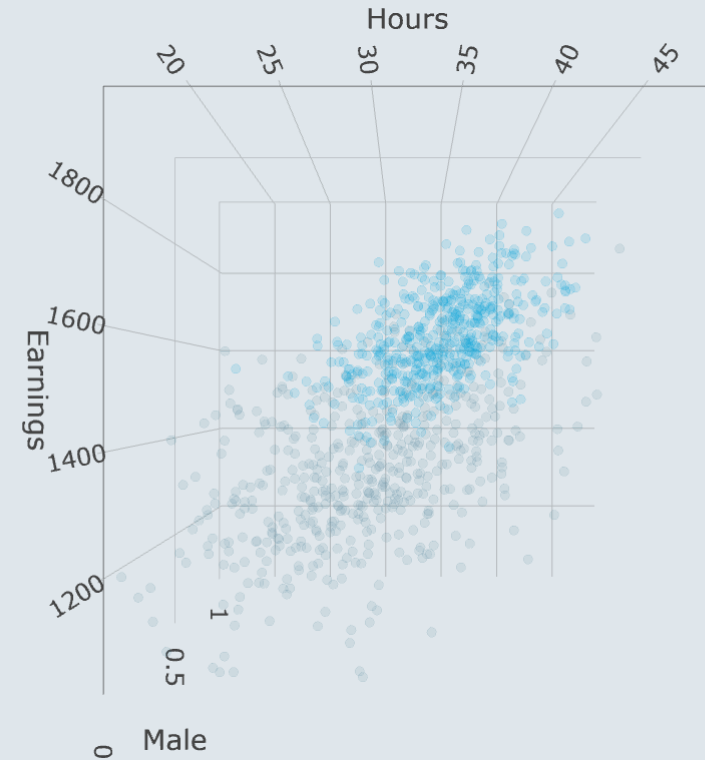


2. Control variables

2.2. Discrete

→ The **relationship** is indeed **inflated** by the sex variable

- Because being a **male** is positively **correlated** with **both** x **and** y
- **Controlling** for sex would **solve that problem** by absorbing this effect
- Controlling for a **discrete** variable amounts to allow **one intercept per category**
- Giving **two parallel fitted lines** which are the intersections of the plane and the scatterplots



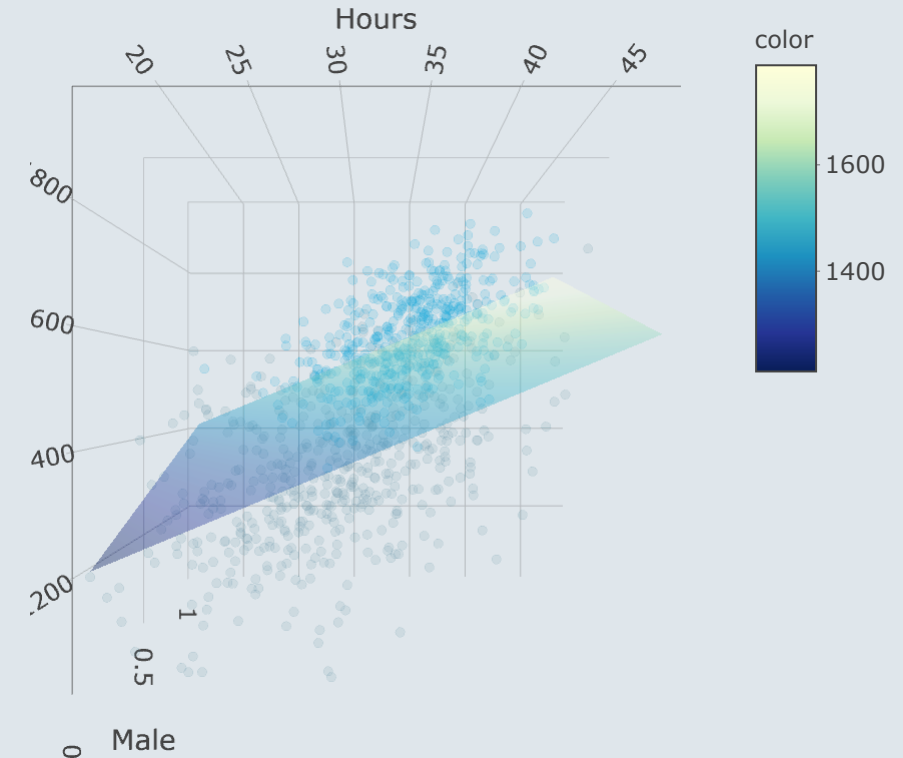


2. Control variables

2.2. Discrete

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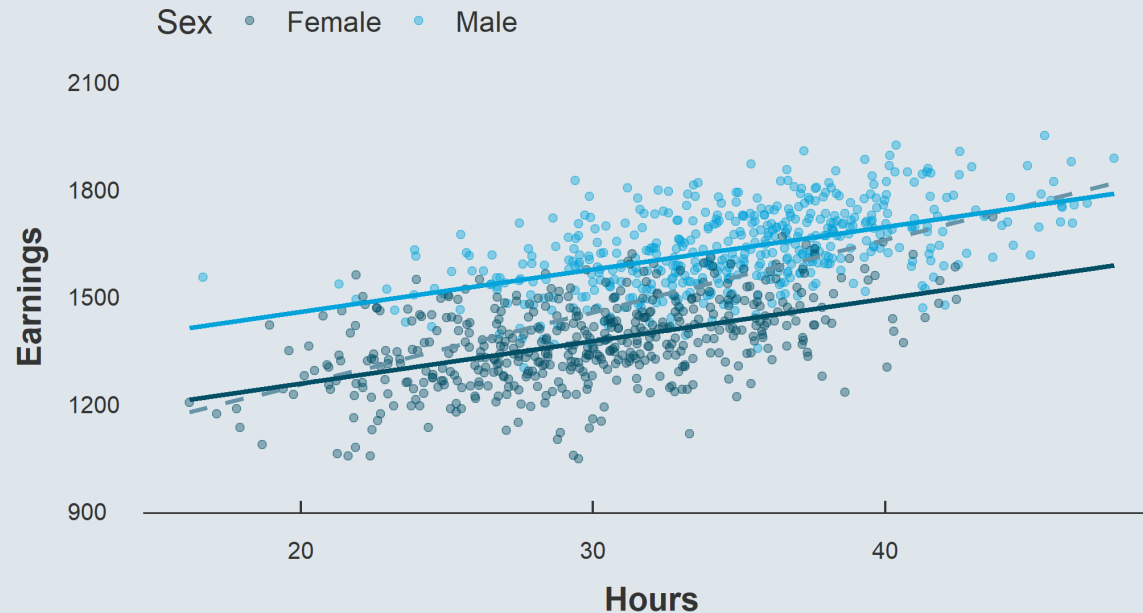


2. Control variables

2.2. Discrete

$$\text{Earnings}_i = \hat{\alpha} + \hat{\beta}_1 \text{Hours}_i + \hat{\beta}_2 1\{\text{Sex}_i = \text{Male}\} + \varepsilon_i$$

##	(Intercept)	Hours	SexMale
##	1019.34269	11.86326	200.98782



Graphical counterpart

$\hat{\alpha}$: Intercept of the reference group

$\hat{\beta}_1$: Common slope

$\hat{\beta}_2$: Gap between the two lines

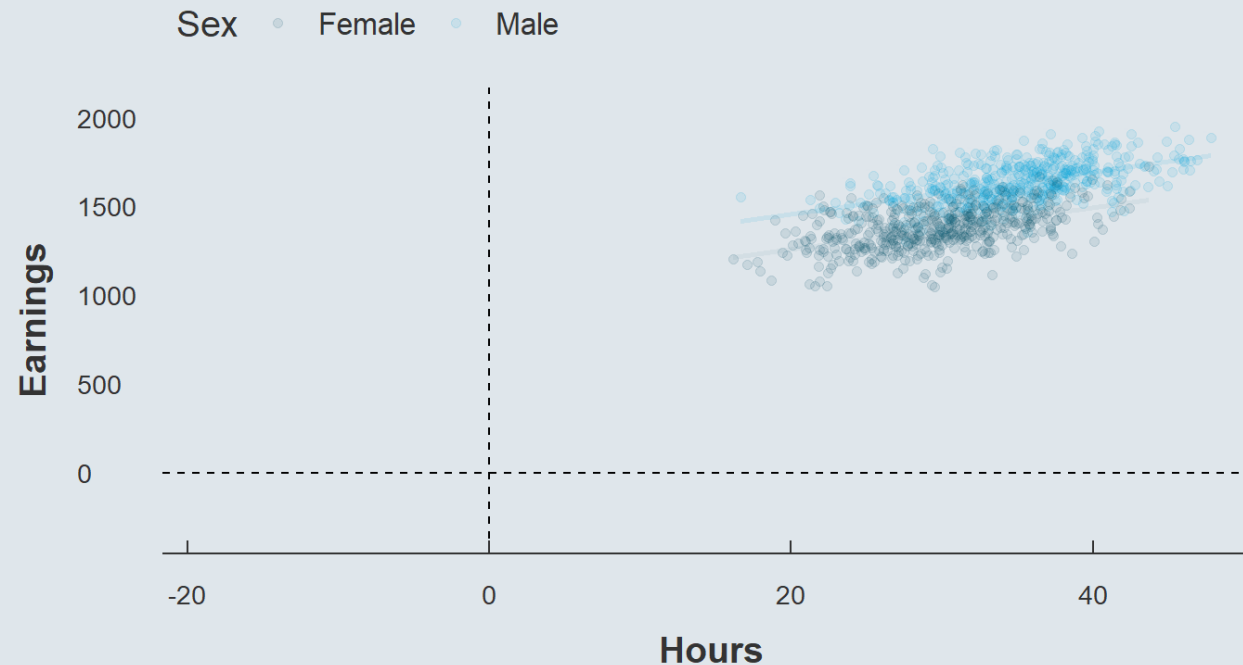
$\hat{\alpha} + \hat{\beta}_2$: Intercept of the other group



2. Control variables

2.2. Discrete

- We can **obtain** this common **slope** by:
 1. **Demeaning** earnings and hours by group
 2. **Regressing** the demeaned earnings on the hours

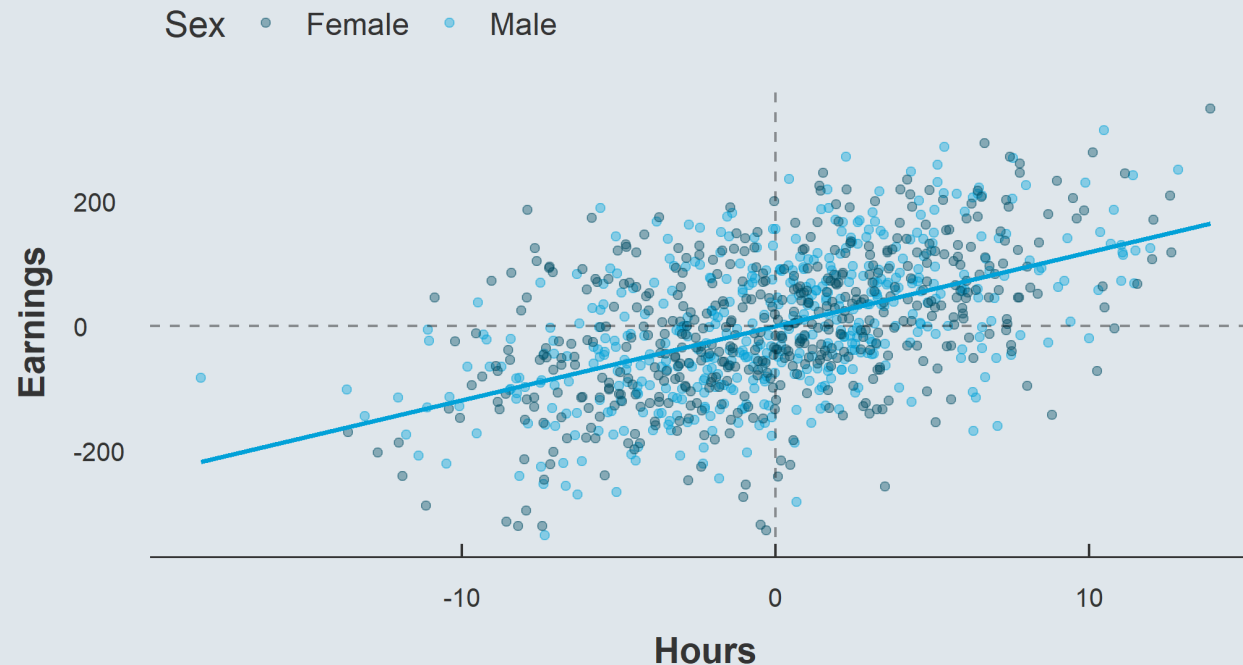




2. Control variables

2.2. Discrete

- Note that once we **control** for third variable
 1. As we move along the x axis, this **third variable remains constant**
 2. Here, as the number of **hours increases** the probability to be a **male does not** increase anymore

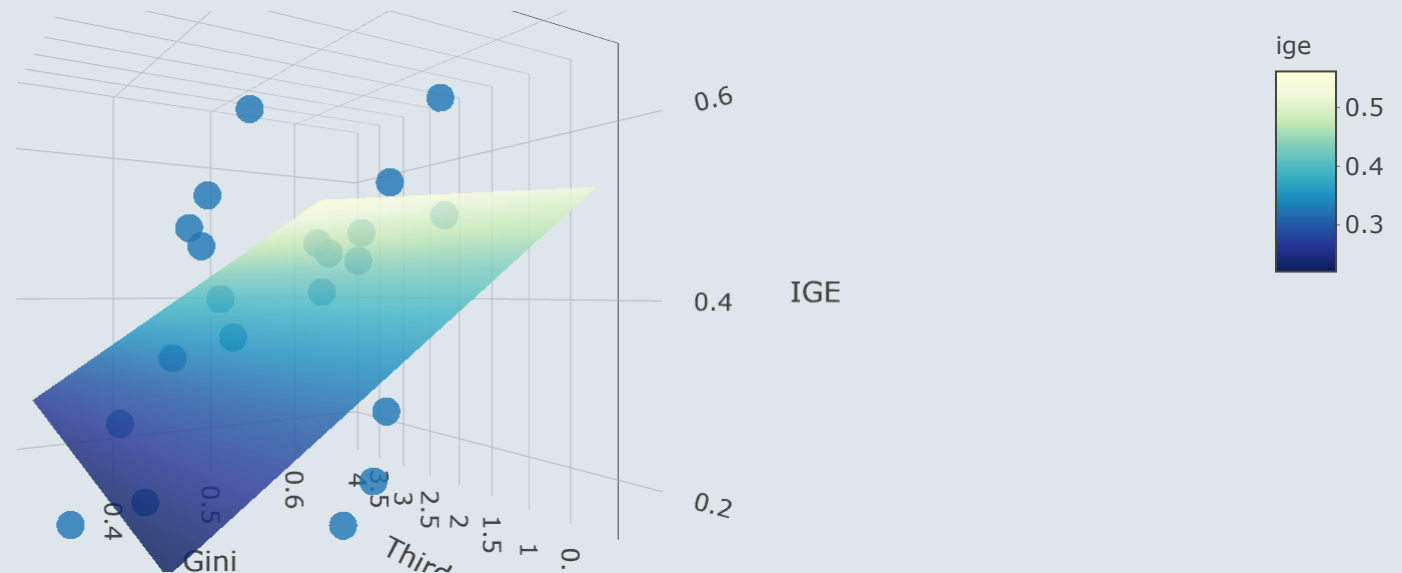




2. Control variables

2.3. Continuous

- The **same** idea apply when we control for **continuous** variables
 - Including it in the regression allows to **account for another dimension**
 - Such that when x moves this variable **remains constant**
 - This **nets out** the relationship of x and y from the potential **confounding effect** of this variable
 - This is why we call it **controlling for something**



Practice

05:00

1) Using the `asec` data, regress (yearly) earnings on (weekly) hours worked

2) Regress earnings on hours worked controlling for sex

3) Interpret the difference between the results from 1) and 2)

You've got 5 minutes!

Solution

1) Using the `asec` data, regress (yearly) earnings on (weekly) hours worked

```
lm(Earnings ~ Hours, asec)$coefficients
```

```
## (Intercept)      Hours  
##   -20038.85    2077.79
```

2) Regress earnings on hours worked controlling for sex

```
lm(Earnings ~ Hours + Sex, asec)$coefficients
```

```
## (Intercept)      Hours    SexMale  
##   -22296.150    1953.829    13794.385
```

Solution

3) Interpret the difference between the results from 1) and 2)

- The **slope** is still positive **less steep**
 - In the **first regression** as the number of **hours increases** the probability to be a **male does increase** as well
 - Because **males** tend to **earn more** this **contributes** to the positive **relationship** between Hours and Earnings
 - In the **second regression, controlling** for sex allows to maintain the probability to be a **male constant** along the hour axis to **remove this effect**



Overview

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3. Interactions

3.1. Motivation

- Now we know how to **remove** the **confounding effect** of a third variable by **controlling** for it
 - But what if the main **relationship varies** depending on the value of the **third variable**?
- Let's get back to the previous example

$$\text{Pollution}_i = \hat{\alpha} + \hat{\beta}_1 \text{Income}_i + \hat{\beta}_2 \text{Distance}_i + \hat{\epsilon}_i$$

- The **equation imposes** that the **effect** of income on pollution is **constant**: $\hat{\beta}_2$
 - But what if the relationship was actually not the same close to Paris than further away?
 - Maybe that the closer from Paris the larger the effect (higher segregation, ...)
- But how to **capture how the relationship** between income and pollution varies with distance?
 - We should allow for it in the equation!
 - By **adding a term** that depends both on income and distance
 - What we use is their **product**, and we call that an **interaction**

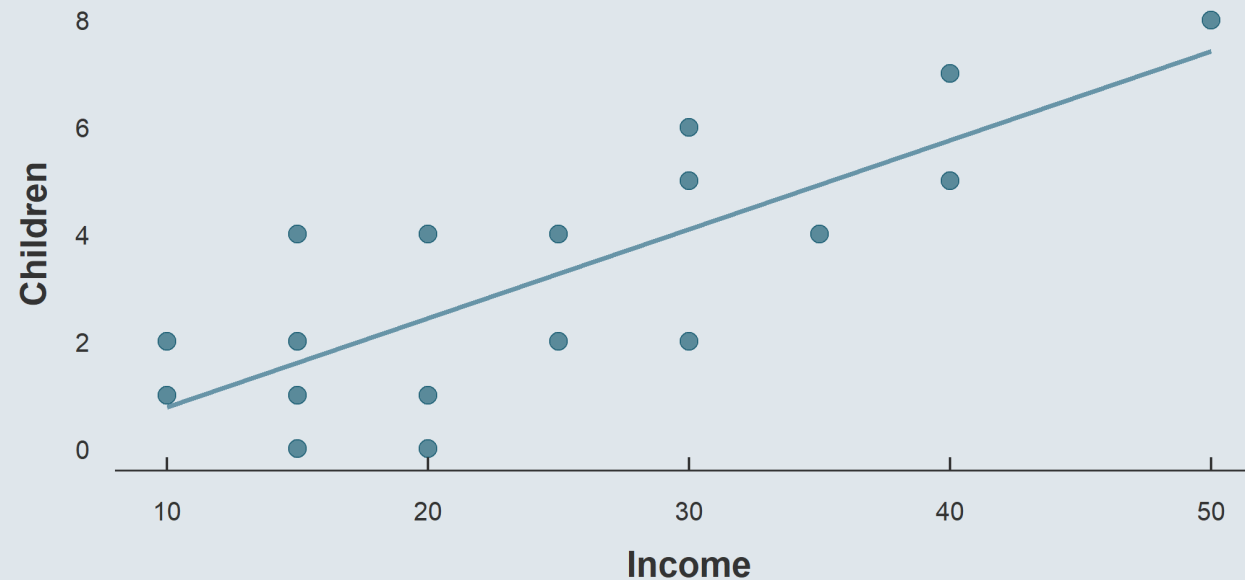
$$\text{Pollution}_i = \hat{\alpha}_2 + \hat{\beta}_3 \text{Income}_i + \hat{\beta}_4 \text{Distance}_i + \hat{\beta}_5 (\text{Distance}_i \times \text{Income}_i) + \hat{\epsilon}_i$$



3. Interactions

3.2. Discrete

- Take for instance the following **relationship** between **household income** and the **number of children**

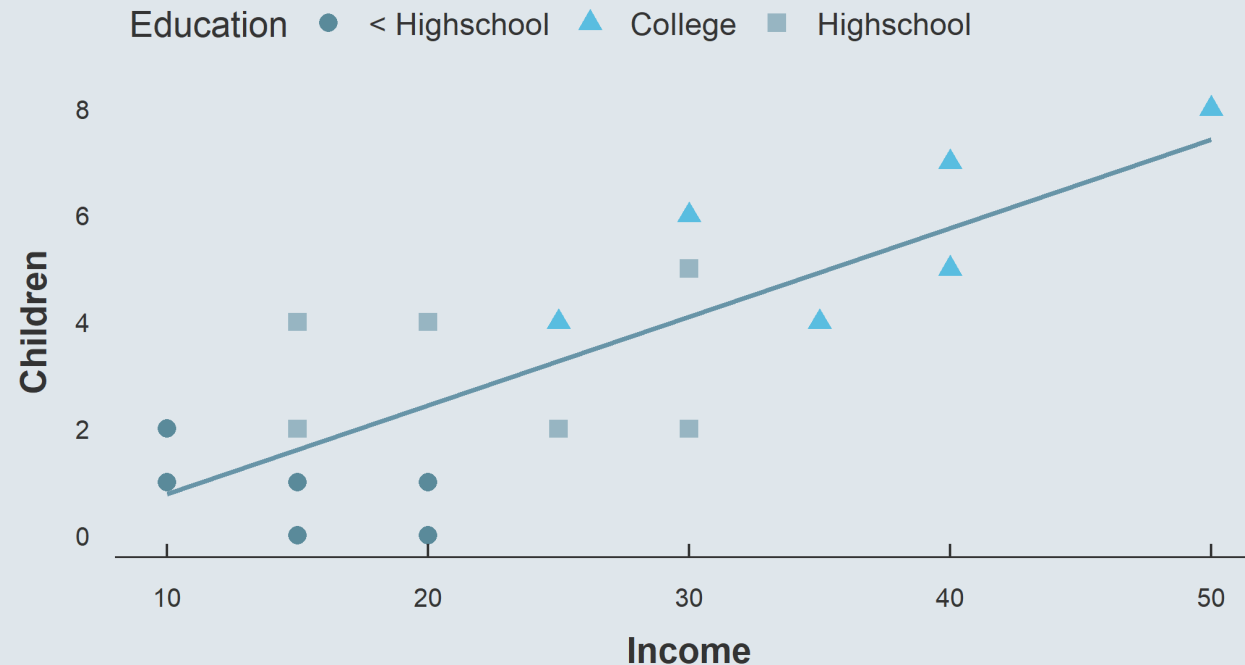




3. Interactions

3.2. Discrete

- Take for instance the following **relationship** between **household income** and the **number of children**
 - The level of **education** seems to **play a role** in the relationship

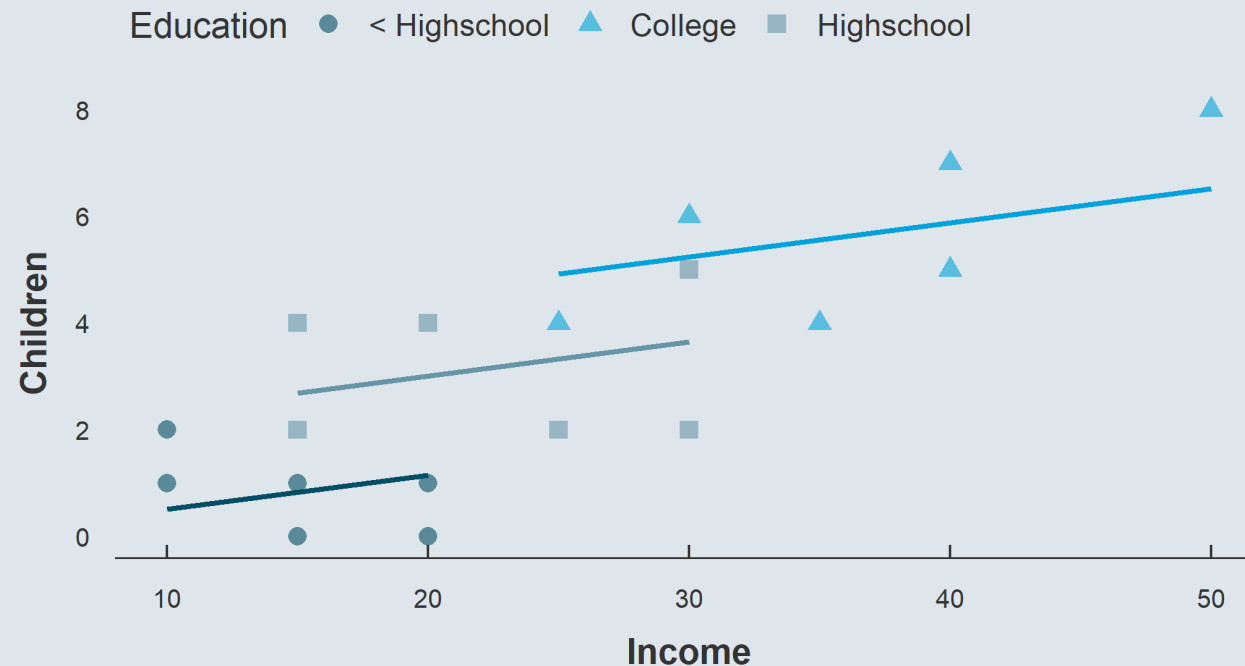




3. Interactions

3.2. Discrete

- Take for instance the following **relationship** between **household income** and the **number of children**
 - The level of **education** seems to **play a role** in the relationship
 - But simply **controlling** for education does **not** seem **sufficient**

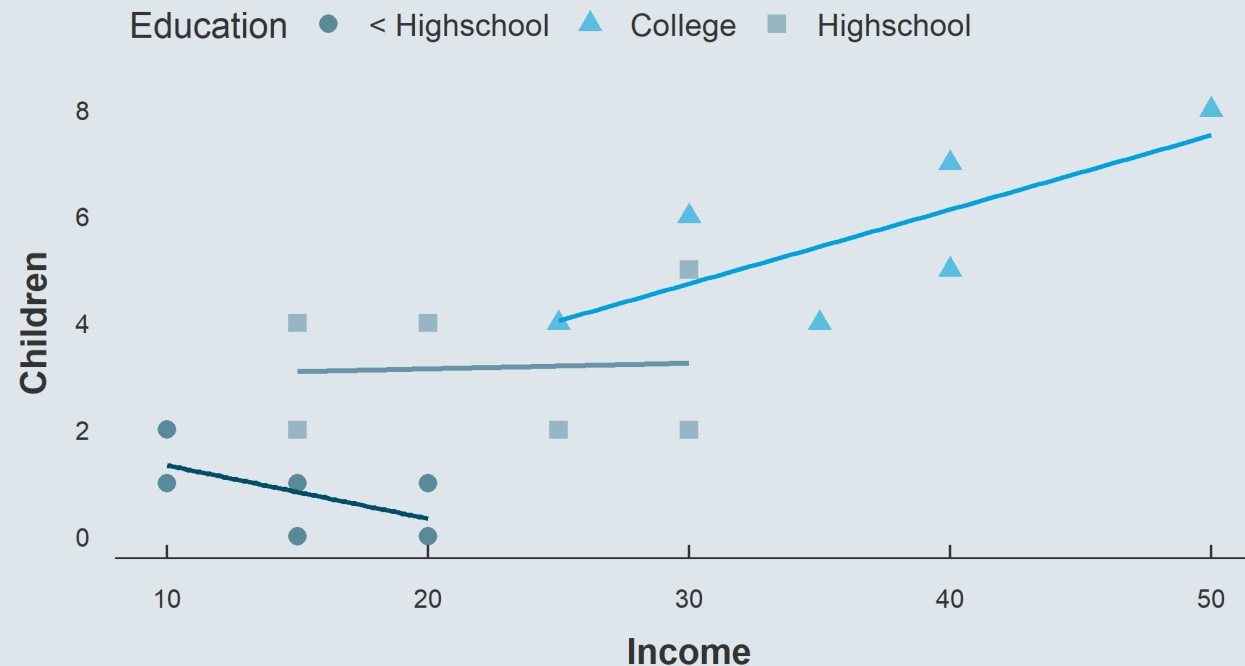




3. Interactions

3.2. Discrete

- This is because the **relationship** between income and children **varies with education**
 - **Interacting** income with education allows to **account for that**
 - Like **controlling** allows for **different intercepts**, **interacting** allows for **different slopes**





3. Interactions

3.2. Discrete

→ It is clearly **equivalent to regressing** children on income separately **per education group**

$$\begin{aligned} \text{Income}_i = & \hat{\alpha} + \hat{\beta}_1 \text{Children}_i + && \text{Baseline equation} \\ & \hat{\beta}_2 (<\text{Highschool})_i + \hat{\beta}_3 \text{Highschool}_i + \hat{\beta}_4 \text{College}_i + && \text{Allow for } \neq \text{ slopes} \\ & \text{Children}_i \times \left[\hat{\beta}_5 (<\text{Highschool})_i + \hat{\beta}_6 \text{Highschool}_i + \hat{\beta}_7 \text{College}_i \right] + \hat{\varepsilon}_i && \text{Allow for } \neq \text{ intercepts} \end{aligned}$$



3. Interactions

3.2. Discrete

→ It is clearly **equivalent to regressing** children on income separately **per education group**

$$\begin{aligned} \text{Income}_i = & \hat{\alpha} + \hat{\beta}_1 \text{Children}_i + \underbrace{\hat{\beta}_2 (<\text{Highschool})_i}_1 + \underbrace{\hat{\beta}_3 \text{Highschool}_i}_0 + \underbrace{\hat{\beta}_4 \text{College}_i}_0 \\ & \text{Children}_i \times \left[\underbrace{\hat{\beta}_5 (<\text{Highschool})_i}_1 + \underbrace{\hat{\beta}_6 \text{Highschool}_i}_0 + \underbrace{\hat{\beta}_7 \text{College}_i}_0 \right] + \hat{\varepsilon}_i \end{aligned}$$

Baseline equation
Allow for \neq slopes

Allow for \neq intercepts

< **Highschool**: $\text{Income}_i = (\hat{\alpha} + \hat{\beta}_2) + (\hat{\beta}_1 + \hat{\beta}_5) \text{Children}_i + \hat{\varepsilon}_i$



3. Interactions

3.2. Discrete

→ It is clearly **equivalent to regressing** children on income separately **per education group**

$$\begin{aligned} \text{Income}_i = & \hat{\alpha} + \hat{\beta}_1 \text{Children}_i + \underbrace{\hat{\beta}_2 (<\text{Highschool})_i}_0 + \underbrace{\hat{\beta}_3 \text{Highschool}_i}_1 + \underbrace{\hat{\beta}_4 \text{College}_i}_0 \\ & + \text{Children}_i \times \left[\underbrace{\hat{\beta}_5 (<\text{Highschool})_i}_0 + \underbrace{\hat{\beta}_6 \text{Highschool}_i}_1 + \underbrace{\hat{\beta}_7 \text{College}_i}_0 \right] + \hat{\varepsilon}_i \end{aligned}$$

Baseline equation
Allow for \neq slopes

Allow for \neq intercepts

Highschool: $\text{Income}_i = (\hat{\alpha} + \hat{\beta}_3) + (\hat{\beta}_1 + \hat{\beta}_6) \text{Children}_i + \hat{\varepsilon}_i$



3. Interactions

3.2. Discrete

→ It is clearly **equivalent to regressing** children on income separately **per education group**

$$\begin{aligned} \text{Income}_i = & \hat{\alpha} + \hat{\beta}_1 \text{Children}_i + \underbrace{\hat{\beta}_2 (<\text{Highschool})_i}_0 + \underbrace{\hat{\beta}_3 \text{Highschool}_i}_0 + \underbrace{\hat{\beta}_4 \text{College}_i}_1 \\ & \text{Children}_i \times \left[\underbrace{\hat{\beta}_5 (<\text{Highschool})_i}_0 + \underbrace{\hat{\beta}_6 \text{Highschool}_i}_0 + \underbrace{\hat{\beta}_7 \text{College}_i}_1 \right] + \hat{\varepsilon}_i \end{aligned}$$

Baseline equation
Allow for \neq slopes

Allow for \neq intercepts

College: $\text{Income}_i = (\hat{\alpha} + \hat{\beta}_4) + (\hat{\beta}_1 + \hat{\beta}_7) \text{Children}_i + \hat{\varepsilon}_i$



3. Interactions

3.2. Discrete

→ It is clearly **equivalent to regressing** children on income separately **per education group**

$$\begin{aligned} \text{Income}_i &= \hat{\alpha} + \hat{\beta}_1 \text{Children}_i + && \text{Baseline equation} \\ &\hat{\beta}_2 (<\text{Highschool})_i + \hat{\beta}_3 \text{Highschool}_i + \hat{\beta}_4 \text{College}_i + && \text{Allow for } \neq \text{ slopes} \\ &\text{Children}_i \times \left[\hat{\beta}_5 (<\text{Highschool})_i + \hat{\beta}_6 \text{Highschool}_i + \hat{\beta}_7 \text{College}_i \right] + \hat{\varepsilon}_i && \text{Allow for } \neq \text{ intercepts} \end{aligned}$$

< Highschool: $\text{Income}_i = (\hat{\alpha} + \hat{\beta}_2) + (\hat{\beta}_1 + \hat{\beta}_5) \text{Children}_i + \hat{\varepsilon}_i$

Highschool: $\text{Income}_i = (\hat{\alpha} + \hat{\beta}_3) + (\hat{\beta}_1 + \hat{\beta}_6) \text{Children}_i + \hat{\varepsilon}_i$

College: $\text{Income}_i = (\hat{\alpha} + \hat{\beta}_4) + (\hat{\beta}_1 + \hat{\beta}_7) \text{Children}_i + \hat{\varepsilon}_i$

3. Interactions

3.3. Continuous

- The **same principle** applies to **continuous variables**:

$$\text{Pollution}_i = \hat{\alpha} + \hat{\beta}_1 \text{Income}_i + \hat{\beta}_2 \text{Distance}_i + \hat{\beta}_3 (\text{Distance}_i \times \text{Income}_i) + \hat{\epsilon}_i$$

- What is the **effect of** 1-unit increase in **income here?**

$$\hat{\beta}_1 + \hat{\beta}_3 \text{Distance}_i$$

- The **coefficient** associated with the **interaction**, $\hat{\beta}_3$, indicates:
 - By how the **effect** of a one unit increase in **income** on pollution **varies with distance**
 - When **distance = 0** the effect of income is $\hat{\beta}_1$
 - For every **additional unit** of distance, the effect of income on pollution **increases by** $\hat{\beta}_3$

→ Don't omit to include your interaction variable as a control in the regression

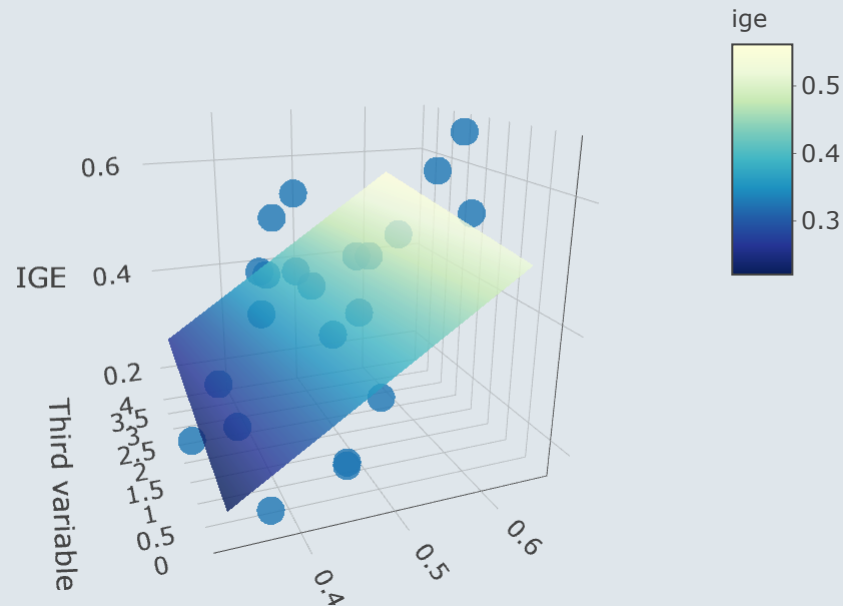


4. Wrap up!

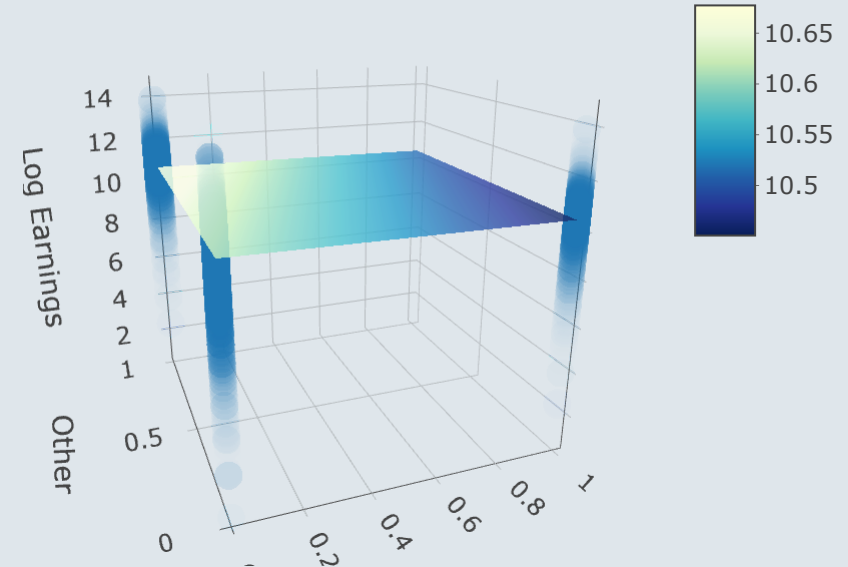
1. Multivariate regressions

- **Adding** a second independent **variable** in the regression amounts to **fitting a plane** instead of a line
 - Adding a third variable would fit an hyperplane of dimension 3 and so on

Adding a continuous variable



Adding a discrete variable



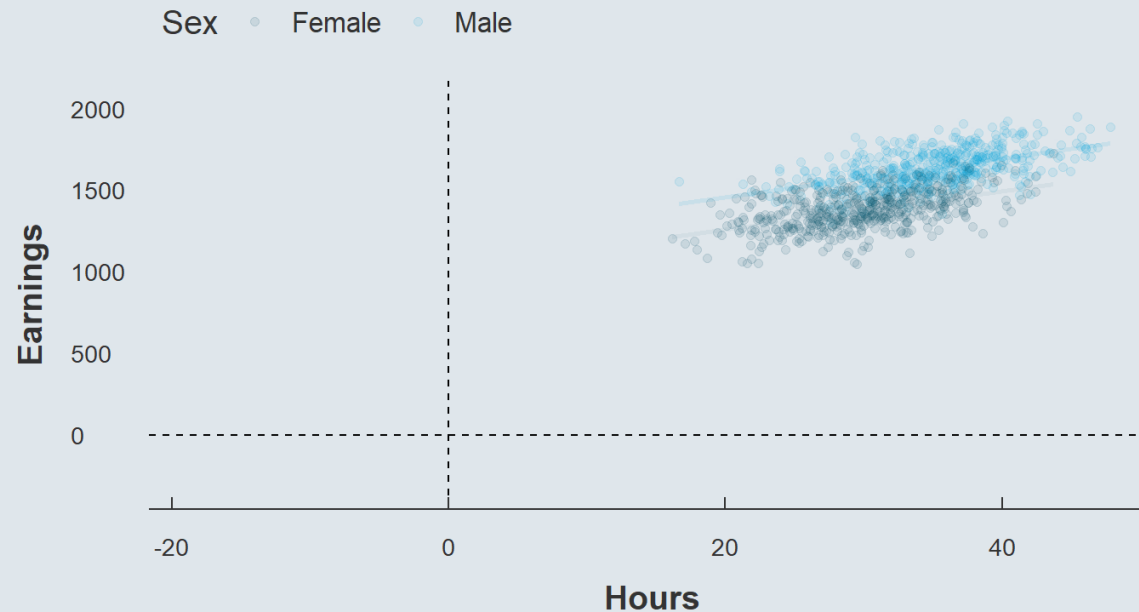


4. Wrap up!

2. Control variables

- Adding a third variable z **removes** its potential **confounding effect** from the relationship between x and y
 - As we move along the x axis, the **third variable remains constant**

$$\hat{y}_i = \hat{\alpha} + \hat{\beta}_1 x + \hat{\beta}_2 z + \hat{\varepsilon}_i$$





4. Wrap up!

3. Interactions

- Adding an **interaction** term with z allows to see **how the effect** of x on y **varies** with z
 - If z is **discrete**, it amounts to **regressing** y on x **separately** for each z group

$$\hat{y}_i = \hat{\alpha} + \hat{\beta}_1 x + \hat{\beta}_2 z + \hat{\beta}_3 (x \times z) + \hat{\varepsilon}_i$$

