Foundations of causality | R

Agenda

- Revisiting lecture
  - Causality
  - Potential Outcomes Framework
  - NATE and biases

- Getting started with R
  - Data-wrangling with `dplyr`

Causal Inference

The *reasoning* process of

- ruling out non-causal explanations of the observed association
- pointing out the assumptions necessary to rule out such sources

plus

- providing evidence to support or refute these assumptions

Potential Outcomes Framework

Key concept: Every individual has a potential outcome (Y_i) both under treatment and under control (no treatment).

The fundamental problem of causal inference: we can only ever observe one of these states.

So, we cannot observe the individual treatment effect (ITE), nor directly observe the average treatment effect (ATE).

POF Notation

$$\text{NATE} = E[y_{1i}|d_i = 1] - E[y_{0i}|d_i = 0]$$

"The expected outcome when treated, for those in the treatment group"

$E[y_{0,i}]$ / $E[y_{0,i}]$ "expected outcomes"

$y_{0,i}$ / $y_{1,i}$ "potential outcomes"

POF Logic

ATE $= E[y_{1i} - y_{0i}] = E[y_{1i}] - E[y_{0i}]$

ATT $= E[y_{1i}|d_i = 1] - E[y_{0i}|d_i = 1]$

ATC $= E[y_{1i}|d_i = 0] - E[y_{0i}|d_i = 0]$

Unattainable: we cannot observe counterfactuals.

NATE $= E[y_{1i}|d_i = 1] - E[y_{0i}|d_i = 0]$

Example

- Contact hypothesis (Allport, 1954)

Inter-group contact (X) $\longrightarrow$ Prejudice (Y)

Each individual *i* in a student sample is exposed (di = 1) to the cause, or not exposed (di = 0) (here: contact with member of different ethnic group).

$y_{0,i}$ = non-exposure $y_{1,i}$ = exposure

ATE, ATT, ATC

If we could observe counterfactuals...

Student (i)	Prejudice			Contact
	y_{0i}	y_{1i}	δ_i	
1	6	5	-1	0
2	4	2	-2	1
3	4	4	0	0
4	6	7	1	0
5	3	1	-2	1
6	2	2	0	1
7	8	7	-1	0
8	4	5	1	0

→

...we could know:

$$ATE = E[\delta_i] = \frac{-1 + (-2) + 0 + 1 + (-2) + 0 + (-1) + 1}{8} = -0.5 \quad (5)$$

$$ATT = \frac{-2 + (-2) + 0}{3} = -1.333$$

$$ATC = \frac{-1 + 0 + 1 + (-1) + 1}{5} = 0$$

NATE

We can only observe half of the potential outcomes we need to get to the ATE...

Student (i)	Prejudice			Contact
	y_{0i}	y_{1i}	δ_i	
1	6			0
2		2		1
3	4			0
4	6			0
5		1		1
6		2		1
7	8			0
8	4			0

Information we *do* have

...so we can only calculate a naïve average treatment effect.

$$
\begin{aligned}
NATE &= E[y_{1i}|d_i = 1] - E[y_{0i}|d_i = 0] \\
&= \frac{2+1+2}{3} - \frac{6+4+6+8+4}{5} \\
&= 1.666 - 5.6 \\
&= -3.933
\end{aligned}
$$

NATE and biases

Student (i)	Prejudice			Contact
	y_{0i}	y_{1i}	δ_i	
1	6			0
2		2		1
3	4			0
4	6			0
5		1		1
6		2		1
7	8			0
8	4			0

Information we *do* have

The treated and untreated groups may differ in more ways than just being treated or not and, therefore, have different potential outcomes.

$$NATE = ATE + \underbrace{E[Y_0|D=1] - E[Y_0|D=0]}_{\text{selection bias}} + \underbrace{(1-p)(ATT - ATU)}_{\text{HTE bias}}$$

baseline bias

heterogeneous / differential treatment effect bias

NATE and biases

$$NATE = ATE + \underbrace{E[Y_0|D=1] - E[Y_0|D=0]}_{\textit{selection bias}} + \underbrace{(1-p)(ATT - ATU)}_{\textit{HTE bias}}$$

Baseline bias: difference in average outcome without treatment for the treatment and control groups.

Differential treatment effect bias: the difference in the average treatment effect between the treatment and control groups, weighted by the proportion of the population in the control group.

Tackling biases

Randomization: randomly assigning subjects to D=0 or D=1.

- The probability of being assigned to treatment is the same for all subjects.
- Being assigned to treatment does not depend of any characteristic of the subjects.
- The treatment and control groups have (on average) the same potential outcomes

- Key point: *when using random assignment* (and the SUTVA holds), then ATE = NATE

$$ATE = E[Y_{1i}] - E[Y_{0i}] \longrightarrow ATE = E[Y_{1i}|D_i = 1] - E[Y_{0i}|D_i = 0]$$

Coding with `dplyr`

We'll often use the pipe operator (`%>%`) to string together commands, and rely on the `dplyr` "verbs". For example:

`select`: subset columns
`filter`: subset rows
`arrange`: reorder rows
`mutate`: add columns to existing data
`summarize`: summarize values in the dataset
`group_by`: defines groups within dataset

Further Ressources

R basics: https://tinyurl.com/vkebh2f

RMarkdown: The definitve guide https://tinyurl.com/y4tyfqmg

Dplyr: https://tinyurl.com/vyrv596

Dplyr video tutorial: https://www.youtube.com/watch?v=jWjqLW-u3hc

Summary of lab materials – Lab homepage

For any coding issues – Stackoverflow

Hertie's Data Science Lab – Research Consulting