Conditional Exchangeability in Observational Studies

INFO/STSCI/ILRST 3900: Causal Inference

17 Sep 2024

Logistics

- Peer reviews for pset 1 due today by 5pm
- Pset 2 $\longrightarrow$ Due Tue (9/24) @ 5pm
- Post questions on Ed Discussion or come to office hours!
- After class, read 3.4 and 3.5 of Hernán & Robins

Learning goals for today

At the end of class, you will be able to:

1. Explain the challenge of satisfying conditional exchangeability in observational data
2. Explain part one the consistency assumption
   - Well-defined, precise treatments

What could go wrong?

- What does $Y_i^{a=1}, Y_i^{a=0} \perp\!\!\!\perp A_i$ (exchangeability) mean?
- Effect of college degree (A) on income level (Y) at age 30
  - $A_i = 1$ if college degree, $A_i = 0$ if no college degree
- Suppose we have information on parental income (L)
  - $L_i = 1$: parents have high income
  - $L_i = 0$: parents have low income
- L associated with the outcome $L \not\!\perp\!\!\!\perp Y_i^{a=1}, Y_i^{a=0}$

Check Your Understanding: Exchangeability

Discuss in groups, then submit your response individually to PollEverywhere. Your response won't be graded.

Recall the of definition (marginal) exchangeability:

$$Y_i^{a=1}, Y_i^{a=0} \perp\!\!\!\perp A_i$$

If exchangeability holds, which of the following are true?

https://pollev.com/causal3900

PollEverywhere: Possible Answers

Recall the of definition (marginal) exchangeability:

$$Y_i^{a=1}, Y_i^{a=0} \perp\!\!\!\perp A_i$$

If exchangeability holds, which of the following must be true?

(A) Your potential outcome under treatment would be the same regardless of the treatment observed

- $E(Y_{\text{You}}^{\text{a=1}} \mid A_{\text{You}} = 1) = E(Y_{\text{You}}^{\text{a=1}} \mid A_{\text{You}} = 0)$

(B) Your potential outcome depends on what treatment is observed

(C) Your potential outcome under no treatment would be the same regardless of the treatment observed

- $E(Y_{\text{You}}^{\text{a=0}} \mid A_{\text{You}} = 1) = E(Y_{\text{You}}^{\text{a=0}} \mid A_{\text{You}} = 0)$

(D) Your observed outcome depends on what treatment is observed

Conditional Exchangeability in Observational Studies

- Conditional exchangeability lets us estimate causal effects
- Stratification: conditional average treatment effects
- Standardization or inverse probability weighting: population average treatment effect
- By design, conditional exchangeability holds in conditionally randomized experiments
- Conditional exchangeability more reasonable in observational data than marginal exchangeability

What could go wrong?

- Effect of college degree (A) on income level (Y) at age 30
  - $A_i = 1$ if college degree, $A_i = 0$ if no college degree
- Suppose we have information on parental income (L)
  - $L = 1$: parents have high income
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- L associated with the outcome $L \not\perp\!\!\!\perp Y_i^{a=1}, Y_i^{a=0}$
- Are your own education level and your parents' income the only two factors that influence your income level?
- What additional information would you gather to make conditional exchangebaility plausible?

$$Y_i^{a=1}, Y_i^{a=0} \perp\!\!\!\perp A_i \mid L_1, L_2, \cdots, L_k$$

Conditional exchangeability in observational data

- Even if gathering data was possible for every covariate we want, when do we stop?
- Never 100% sure that conditional exchangeability holds
- Is it reasonable?
- Causal inference with observational data requires expert knowledge!

Indentification Assumptions

- Exchangeability is an *identification assumption*
- Identification assumptions take us from observable quantities to causal effects (which deal with unobservable potential outcomes)
- In randomized experiments, often take identification assumptions for granted
- The rest of the class will mostly deal with observational settings!
- This means we have to think more critically about the implicit assumptions we often make

Activity

- Looking at data to analyze the effectiveness of a medication on relieving headaches
- *"What is the effect of taking HeadacheRelief™ on a person's headache within one hour of taking it?"*
- Info collected for each study participant:
  - whether or not they took HeadacheRelief™ ($A_i = 1$ or $A_i = 0$)
  - whether or not their headache was relieved within one hour of taking the medication ($Y_i = 1$ or $Y_i = 0$)
- With the people around you, discuss the following:
  - Thinking about how treatment is defined here, could there be any potential issues in this study?
  - How do you interpret "take headache medication"?

The consistency assumption

- holds for precise treatments (today)
- holds with clarity about interference among units (next lecture)

$$\boxed{\text{If } A_i = a, \text{ then } Y_i^a = Y_i}$$

$Y_i^{\text{Treatment}}$

Y_i^{Control}

Potential Outcomes

Y_i

Factual Outcomes

Precise treatments

Imagine you are a high school counselor.

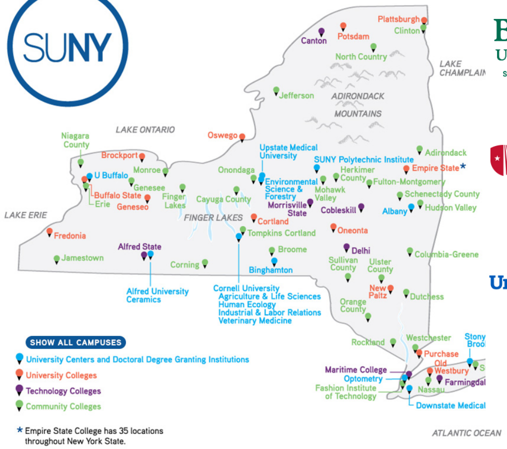
A statistician tells you

The probability of receiving a BA in 6 years would be higher if a student initially enrolled in the State University of New York instead of a community college

$$\text{P}\left(\text{BA}^{\text{Enroll in SUNY}}\right) > \text{P}\left(\text{BA}^{\text{Enroll in Community College}}\right)$$

How would you advise students?

Precise treatments



	6-year graduation rate
Binghamton University, State University of New York	83%
Stony Brook University	78%
University at Buffalo, The State University of New York	74%
University at Albany, State University of New York	66%

Precise treatments

The treatment value
`Enroll in SUNY`
is not sufficiently precise

$$
\begin{aligned}
\text{BA}^{\text{Binghamton}} &\neq \text{BA}^{\text{Stony Brook}} \\
&\neq \text{BA}^{\text{Buffalo}} \\
&\neq \text{BA}^{\text{Albany}}
\end{aligned}
$$

To advise the student,
a precise treatment
is more helpful

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University at Albany, State University of New York	66%

Precise treatments

Consistency assumption: $Y = Y^A$

More credible when A is very precise

- it is clear how to run a hypothetical experiment
- it is clear how to inform policy

Example:

- if $a =$ SUNY, then Y^a is vague.
  To which SUNY should you send the student?
- if $a =$ Binghamton, then Y^a is clearer

A good read:
Hernán, M. 2016.
"Does water kill? A call for less casual causal inferences."
Annals of Epidemiology 26(10):674–680.

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