Causal inference and experimental design

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1 Class resources

- All resources: https://macartan.github.io/ci
- This syllabus: https://macartan.github.io/ci/syllabus.pdf
- Slides (in progress): https://macartan.github.io/ci/ci_2024.html
- Puzzles (in progress): https://macartan.github.io/ci/exercises.html
- Student survey
- Git repo https://github.com/macartan/ci

2 Times and locations

Raum: K12B

- Jan 12: 12-14 (short introductory lecture)
- Jan 19: 12-18
- Jan 26: 12-18
- Feb 2: 12-18
- Feb 9: 12-18

The longer sessions will be structured roughly as follows.

- 12:00 - 13:50: lecture
- 13:50 - 14:30: team presentations and discussions
- 14:30 - 15:15: late lunch break
- 15:15 - 17:00: lecture
- 17:00 - 17:10: break
- 17:10 - 18:00: team presentations and discussions

3 Abstract

The course addresses advanced topics in causal inference and experimental design. It is a hands on course in which theoretical results are introduced through lecture, demonstrated in practice, and worked on in groups. Topics likely include sampling and randomization schemes, including multilevel trials, restricted randomization, and patient preference trials; Bayesian approaches to causal inference, exact inference: sharp nulls for complex hypotheses, inverting hypothesis tests, Mediation analysis, Multiple comparisons, Open science workflows.

4 Readings

The course is primarily lecture and exercise based. We will not discuss readings in class, though some are relevant for different exercises. I do recommend the readings both for giving background to the lectures and for going beyond the lectures.

All readings are linked from this document.

I will draw material especially from two recent books I worked on, both open access:

- Research Design in the Social Sciences
- Integrated Inferences

I point a number of times to bits from this excellent draft text, also open access:

- Hernán and Robins (forthcoming)
- Cunningham's "mixed tape" is a great accompanying read to fundamentals and topics:

Recommended non open access readings include:

- Gerber and Green (2012) with supplementary material available here: https://isps.yale.edu/FEDAI

5 Prerequisites

You should already have background in statistics up to the point with feeling comfortable with regression.

In addition you should know some `R`. Really, the more you can invest on getting on top of `R` before the class the better.

- Resources for learning `R`: http://www.r-bloggers.com/how-to-learn-r-2/

Please make sure your `R` is up-to-date and that you are working in `R studio`. Then make sure you have the following packages installed.

```
pacman::p_load(
  rstan,
  dagitty,
  DeclareDesign,
  CausalQueries,
  ri2,
  tidyverse,
  knitr
  )
```

5.1 File Sharing via Git

I encourage you to set up and send me your `git` user names and we can access all materials on github. The git contains slides and exercises but will also have a folder structure where group presentations can be stored.

5.2 Writing with `Rmd` or `qmd`

Please plan to do drafting in `Quarto`. This is a simple markup language that lets you integrate writing and coding. This document is written in `quarto` and the slides will be also.

The key thing is that you can insert code chunks like this.

```
# Define a random number
x <- rnorm(1)
```

Code like this is run as the document compiles, and results can be accessed as needed, like this: we just sampled the random number x = -0.7849183.

I recommend using `Rstudio` as an editor. More information here: https://quarto.org/docs/get-started/hello/rstudio.html

6 Modules and Readings

6.1 Day 1: Intro

6.1.1 Course outline, tools,

- Keele (2015) gives a good high level overview of many key ideas in this course
- See Wickham, Çetinkaya-Rundel, and Grolemund (2023) on Workflow and Quarto

6.1.2 Introduction to Declare design

- DD, Ch 2 introduces ideas at a high level
- DD, Ch 13 gives more practical guidance on getting started

6.2 Day 2: Causality

6.2.1 Fundamental problems and basic solutions

- II Ch 2, goes over both potential outcomes and DAGs
- Holland is a beautiful classic reading on the fundamental problem of causal inference
- Imai, King, and Stuart (2008)
- Hernán and Robins (forthcoming) Ch 6

6.2.2 2.2 General inquiries and causal identification

- II Ch 4
- DD, Ch 7
- See also: Hernán and Robins (forthcoming) (Section 3.1, 7.2, 8.4, 10.1)
- Lundberg, Johnson, and Stewart (2021)

6.3 Day 3: Estimation and Inference

6.3.1 Frequentist

- Freedman (2008) helps make connections between design based inference and regression
- Lin (2012) relieves some worries you might have after reading Freedman (2008)

6.3.2 Bayesian

- II ch 5 gives an introduction to Bayesian ideas
- `rstan`'s Getting started gets you going on `Stan`; try running the 8 schools model

6.4 Day 4:

6.4.1 Experimental Design

- DD, Ch 8 on data strategies
- DD, Ch 9 on answer strategies

6.4.2 Design evaluation

- DD, Ch 7

6.5 Day 5:

6.5.1 Topics and techniques

Readings here depend in part on our final topic selection but likely readings include:

- Imai and Kim (2021) and De Chaisemartin and d'Haultfoeuille (2020) on diff in diff
- Imai, Keele, and Tingley (2010) on mediation
- Knox, Lowe, and Mummolo (2020) on patient preference trials

6.5.2 Open science

- DD sections: Ethics, PAPs, Populated PAPs, Reconciliation
- Alvarez, Key, and Núñez (2018)
- Humphreys, De la Sierra, and Van der Windt (2013) on fishing and registration
- Humphreys (2015) on ethics in experiments

References

Alvarez, R Michael, Ellen M Key, and Lucas Núñez. 2018. "Research Replication: Practical Considerations." *PS: Political Science & Politics* 51 (2): 422–26.

De Chaisemartin, Clément, and Xavier d'Haultfoeuille. 2020. "Two-Way Fixed Effects Estimators with Heterogeneous Treatment Effects." *American Economic Review* 110 (9): 2964–96.

Freedman, David A. 2008. "On Regression Adjustments to Experimental Data." *Advances in Applied Mathematics* 40 (2): 180–93.

Gerber, Alan S, and Donald P Green. 2012. *Field Experiments: Design, Analysis, and Interpretation*. Norton.

Hernán, Miguel A, and James M Robins. forthcoming. *What If?* Boca Raton: Chapman & Hall/CRC. https://www.hsph.harvard.edu/miguel-hernan/wp-content/uploads/sites/1268/2024/01/hernanrobins_WhatIf_2jan24.pdf.

Humphreys, Macartan. 2015. "Reflections on the Ethics of Social Experimentation." *Journal of Globalization and Development* 6 (1): 87–112.

Humphreys, Macartan, Raul Sanchez De la Sierra, and Peter Van der Windt. 2013. "Fishing, Commitment, and Communication: A Proposal for Comprehensive Nonbinding Research Registration." *Political Analysis* 21 (1): 1–20.

Imai, Kosuke, Luke Keele, and Dustin Tingley. 2010. "A General Approach to Causal Mediation Analysis." *Psychological Methods* 15 (4): 309–34.

Imai, Kosuke, and In Song Kim. 2021. "On the Use of Two-Way Fixed Effects Regression Models for Causal Inference with Panel Data." *Political Analysis* 29 (3): 405–15.

Imai, Kosuke, Gary King, and Elizabeth A Stuart. 2008. "Misunderstandings Between Experimentalists and Observationalists about Causal Inference." *Journal of the Royal Statistical Society Series A: Statistics in Society* 171 (2): 481–502.

Keele, Luke. 2015. "The Statistics of Causal Inference: A View from Political Methodology." *Political Analysis* 23 (3): 313–35.

Knox, Dean, Will Lowe, and Jonathan Mummolo. 2020. "Administrative Records Mask Racially Biased Policing." *American Political Science Review* 114 (3): 619–37.

Lin, Winston. 2012. "Agnostic Notes on Regression Adjustments to Experimental Data: Reexamining Freedman's Critique." *arXiv Preprint arXiv:1208.2301*.

Lundberg, Ian, Rebecca Johnson, and Brandon M Stewart. 2021. "What Is Your Estimand? Defining the Target Quantity Connects Statistical Evidence to Theory." *American Sociological Review* 86 (3): 532–65.

Wickham, Hadley, Mine Çetinkaya-Rundel, and Garrett Grolemund. 2023. *R for Data Science*. " O'Reilly Media, Inc.".