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: https://macartan.github.io/ci/ci_2025.html
- Puzzles: https://macartan.github.io/ci/exercises.html
- Student survey
- Git repo https://github.com/macartan/ci

2 Times and locations

Meetings will be held at the WZB

Date	Time	Location	Topic
10 Jan 2025	10 - 12	WZB B002/003	Intro
17 Jan 2025	9 - 1	WZB B002/003	Causality and causal inquiries
24 Jan 2025	9 - 1	WZB B002/003	Frequentist answer strategies
31 Jan 2025	9 - 1	WZB B002/003	Bayesian answer strategies
14 Feb 2025	9 - 1	WZB B002/003	Design and evaluation
21 Feb 2025	9 - 1	WZB B002/003	Topics 1
28 Feb 2025	9 - 1	WZB B002/003	Topics 2

The longer sessions will be structured roughly as follows.

- 9:00 - 11:00: lecture
- 11:00 - 11:15: break
- 11:15 - 13:00: discussions, team presentations and in-class exercises

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 Expectations

- (Required) Work in four "exercise teams": 1 team (and typically 2 exercises) for 4 of 6 substantive sessions
- (Optional) Prepare a research design or short paper, perhaps building on existing work. Typically this contains:

  - a problem statement
  - a description of a method to address the problem
  - analytic or simulation based results describing properties of the solution
  - a discussion of implications for practice.
  - A passing paper will illustrate subtle features of a method; a good paper will identify unknown properties of a method; en excellent paper will develop a new method.
- Plus general reading and participation.

5 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 strongly 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 (2024) (Open access)

See also the very useful:

- Cunningham's "mixed tape" is a great accompanying read to fundamentals and topics:
- Pearl's primer

Recommended non open access readings include:

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

6 Prerequisites and tools

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/

*Hadley Wickham's R for Data Science

Before the first class 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,
  tidyverse,
  knitr
  )
```

6.1 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.

6.2 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 $x = 0.3171623$.

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

6.3 More resources for getting set up

https://github.com/uo-ec607/lectures

6.4 AI

AI can be a great aid to help understand this material and also to develop code. However it should only be used as an aid: it makes many many mistakes; you remain responsible for your code and more importantly for your comprehension.

7 Modules and Readings

We will have an introductioory meeting and six substantive sessions.

7.1 Intro

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

Introduction to Declare design

Please read:

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

7.2 Causality

- **Causal effects, potential outcomes, causal models**
- **General inquiries and causal identification**

Please read:

- Holland is a beautiful classic reading on the fundamental problem of causal inference
- II Ch 2, goes over both potential outcomes and DAGs
- DD, Ch 7

Optional:

- Imai, King, and Stuart (2008)
- Hernán and Robins (2024) (Section 3.1, 7.2, 8.4, 10.1)
- Hernán and Robins (2024) Ch 6
- II Ch 4
- Lundberg, Johnson, and Stewart (2021)

7.3 Estimation and Inference: Frequentist

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

Optional:

- Bind and Rubin (2020) on RI
- Chang, Middleton, and Aronow (2024) follows up on Lin (2012).

7.4 Estimation and Inference: Bayesian

Please read:

- *Bayesian Data Analysis* Chapters 1-3. The 3rd edition is open access.

Additional:

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

7.5 Experimental Design and Evaluation

Please read:

- DD, Ch 8 on data strategies
- DD, Ch 9 on answer strategies
- DD, Ch 7

7.6 Likely topics: Diff in Diff, IV, RDD, Mediation

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

- Imai and Kim (2021)
- De Chaisemartin and d'Haultfoeuille (2020) on diff in diff

7.7 Likely topics: Spillovers, Survey experiments, Workflows

- Imai, Keele, and Tingley (2010) on mediation
- Aronow and Samii (2017) on spillovers
- 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

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Aronow, P M, and Cyrus Samii. 2017. "Estimating Average Causal Effects Under General Interference, with Application to a Social Network Experiment." *Annals of Applied Statistics* 11 (4): 1912–47.

Bind, M-AC, and DB Rubin. 2020. "When Possible, Report a Fisher-Exact p Value and Display Its Underlying Null Randomization Distribution." *Proceedings of the National Academy of Sciences* 117 (32): 19151–58.

Chang, Haoge, Joel A Middleton, and PM Aronow. 2024. "Exact Bias Correction for Linear Adjustment of Randomized Controlled Trials." *Econometrica* 92 (5): 1503–19.

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Hernán, Miguel A, and James M Robins. 2024. *What If?* Boca Raton: Chapman & Hall/CRC.

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