Course Code: DATA130059.01
Course Title: Causal Inference & Causal Learning
9:55 - 12:30, Friday, Spring 2024, H3405

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Office Hours: Friday, by appointment
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Provisional and subject to change.

Course Description: Lots of the questions in scientific and policy research are often causal. In this class, we will introduce students to different theoretical frameworks from the perspectives of causal inference and introduce common statistical methods crucial to the practice of causal inference. In terms of theoretical frameworks, we will discuss potential outcomes, causal graphs, randomization, model-based inference, and causal mediation analysis. In terms of statistical tools, we will cover various methodologies including randomized experiments, matching, inverse probability weighting, dynamic causal models, and statistical methods for mediation analysis. We will also analyze the strengths and weaknesses of these methods. The course will draw upon examples from social sciences, public health, and other disciplines. We will illustrate applications of the approaches using R software. Students will be evaluated and will deepen the understanding of the statistical principles underlying the approaches as well as their application in homework assignments, group presentations, a in-class midterm, and a take home final exam.

Prerequisite(s): Competence of coding in some programming language, entry level math, intermediate level in probability and statistics, ability to read book chapters and scientific papers (in English).

Credit Hours: 3

Reference: *Hernán MA, Robins JM (2019). Causal Inference. Boca Raton: Chapman & Hall/CRC, preprint*
Suggested Reference: *Imbens, G. W., & Rubin, D. B. (2015). Causal inference in statistics, social, and biomedical sciences. Cambridge University Press.*

Grade Distribution:

Assignments	30% (10% × 3)
Midterm exam (in-class)	25%
In-class presentation	20%
Final exam (take-home)	25%

Letter Grade Distribution:
A, A- ($\leq 30\%$)
B+, B, B-
C+ and below ($\leq 20\%$)

Course Policies:

- **Assignments**
  - Students are expected to work independently. **Offering** and **accepting** solutions from others is an act of **plagiarism**, which is a serious offense and **all involved parties will be penalized according to the Academic Honesty Policy**. Discussion amongst students is encouraged, but when in doubt, direct your questions to the instructor or teaching assistant.
  - **No late assignments will be accepted under any circumstances**.
- **In-class presentation**
  - Students are divided into n groups.
  - Each group selects one scientific article to present (available in elearning). All scientific articles are high quality publications that use causal inference methods.
  - During the presentation, all group members are encouraged to present.
  - The group will critically analyze the paper and present the paper. Consider structuring the presentation with the following section:
    * Introduction
    * Methods
    * Results
    * Discussion
  - In addition, the group will prepare minimum three questions to engage your classmates in the discussion of the paper.
  - You could ask your TA for clarifications or explanation about the paper during office hours.
  - Evaluation criteria:
    1. Critical analysis of the paper
    2. Clear and concise explanation of methods
    3. Ability to engage the class
    4. Quality of the discussion
    5. Proper use of the presentation time
- **Attendance and Absences**
  - Attendance is expected at each class.
  - Students are responsible for all missed work, regardless of the reason for absence. It is also the absentee's responsibility to get all missing notes or materials.

Topic	Scientific Article
Randomized experiment	• William R. Shadish, M. H. Clark, Peter M. Steiner. Can Nonrandomized Experiments Yield Accurate Answers? A Randomized Experiment Comparing Random and Nonrandom Assignments. Journal of the American Statistical Association, 2008;103:484, 1334-1344. • Hernán MA, Alonso A, Logan R, et al. Observational studies analyzed like randomized experiments: an application to postmenopausal hormone therapy and coronary heart disease. Epidemiology. 2008;19(6):766-779.
Confounding	• Pasquale E Rummo, David K Guilkey, Shu Wen Ng, Katie A Meyer, Barry M Popkin, Jared P Reis, James M Shikany, Penny Gordon-Larsen, Does unmeasured confounding influence associations between the retail food environment and body mass index over time? The Coronary Artery Risk Development in Young Adults (CARDIA) study, International Journal of Epidemiology, Volume 46, Issue 5, October 2017, Pages 1456–1464. • Rolf H H Groenwold, David B Nelson, Kristin L Nichol, Arno W Hoes, Eelko Hak, Sensitivity analyses to estimate the potential impact of unmeasured confounding in causal research, International Journal of Epidemiology, Volume 39, Issue 1, February 2010, Pages 107–117.
Matching	• Chan, G.J., Stuart, E.A., Zaman, M. et al. The effect of intrapartum antibiotics on early-onset neonatal sepsis in Dhaka, Bangladesh: a propensity scores matched analysis. BMC Pediatr 14, 104 (2014). • Deborah A. Costain, Bayesian partitioning for mapping disease risk using a matched case-control approach to confounding, Biostatistics, Volume 14, Issue 1, January 2013, Pages 99–112.
Weighting	• Chung EO, Hagaman A, LeMasters K, et al. The contribution of grandmother involvement to child growth and development: an observational study in rural Pakistan. BMJ Global Health 2020;5:e002181. • Geleris J, Sun Y, Platt J, et al. Observational Study of Hydroxychloroquine in Hospitalized Patients with Covid-19. N Engl J Med. 2020;382(25):2411-2418. • Li, Fan. "PROPENSITY SCORE WEIGHTING FOR CAUSAL INFERENCE WITH MULTIPLE TREATMENTS." The Annals of Applied Statistics 13, no. 4 (2019): 2389–2415. https://www.jstor.org/stable/26866728. 2017;31(7):1009-1016. doi:10.1097/QAD.0000000000001431 • Wu X, Braun D, Schwartz J, Kioumourtzoglou MA, Dominici F. Evaluating the impact of long-term exposure to fine particulate matter on mortality among the elderly. Sci Adv. 2020;6(29): eaba569
Mediation	• Hernández-Díaz S, Schisterman EF, Hernán MA. The birth weight "paradox" uncovered? Am J Epidemiol. 2006;164(11):1115-1120 • Johan Steen, Tom Loeys, Beatrijs Moerkerke, Stijn Vansteelandt, Flexible Mediation Analysis With Multiple Mediators, American Journal of Epidemiology, Volume 186, Issue 2, 15 July 2017, Pages 184–193

Tentative Course Outline: The weekly coverage might change as it depends on the progress of the class. However, it's recommended that you keep up with the reading assignments.

Date	Content
March 1	• Course overview & intro • Reading assignment: none
March 8	• Definition of causal effect & PO • Reading assignment: Chapter 1, p3-10
March 15	• Randomized experiments • Reading assignment: Chapter 2, p13-20
March 22	• Observational studies • Reading assignment: Chapter 3, p27-39
March 29	• Effect modification & interaction • Reading assignment: Chapter 4 & 5, p43-67
April 5	• DAG • Reading assignment: Chapter 6, p71-83
April 12	• Confounding & selection bias & measurement bias • Reading assignment: Chapter 7& 8 & 9, p 85-125
April 19	• Presentation: randomized experiment & confounding • Reading assignment: none
April 26	• IPW & g-formula • Reading assignment: Chapter 12 & 13, p155-173
May 3	• Propensity score based methods • Reading assignment: Chapter 15, p191-197
May 10	• Midterm • No reading assignment
May 17	• Presentation: matching & weighting • Reading assignment: none
May 24	• Instrumental variable method • chapter 16, p201-215
May 31	• Mediation • Reading assignment: chapter 23, p313-319
June 7	• Variable selection for causal learning • Reading assignment: chapter 18, p233-242
June 14	• Presentation: mediation • Reading assignment: none