Syllabus for POLI 891: Advanced Topics in Causal Inference

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Course description

This graduate-level seminar aims to equip participants with a modern perspective on the progress in causal inference and the skill to apply these frontier methods to social science studies. The course consists of two separate yet interdependent parts. The first part includes four lectures on several topics in causal inference. We start from reviewing basic concepts such as the Neyman-Rubin model and counterfactual. Then, we discuss power analysis, directed acyclic graphs (DAGs), and mediation analysis. We conclude this part with a review of methods in panel data analysis, focusing on how to estimate carryover effects.

In the second part, students will give presentations on four selected topics in political methodology: complex experiments (1 week), basic algorithms in machine learning (2 weeks), the application of machine learning in causal inference (4 weeks) and causal inference under interference (3 weeks). Students are expected to present their own research design in the last week.

Time and location

Classes: 12:20pm-3:10pm on Wednesdays, Room 0115 in Murphey Hall.
There will no class on Oct. 15 or Nov. 26 (Thanksgiving).
Office hours: 1:00pm-4:00pm on Tuesdays, Room 322 in Hamilton Hall (by appointment).

Texts and software

The course will draw a lot from the following textbooks:

1. Imbens and Rubin (2015)
2. Hernán and Robins (2010)
3. Gareth et al. (2013)

We may also refer to other textbooks and research papers for certain topics. More details can be found in the section on course outline. It is expected that students try to read materials listed as references before class.

We will working with R in this course, which is an open-source computing language that is very widely used in statistics. You can download it for free from www.r-project.org. You are also encouraged to use Rmarkdown for your homework.

Requirements

Students enrolling in this course are expected to have a solid understanding of probability theory, matrix algebra, and calculus, along with practical experience in scripting with R. It is highly recommended that participants have completed POLI-783 and POLI-784 offered by the Department of Political Science or a comparable course.

Grading of the course is based on class participation (20%), presentation (40%), and the final proposal (40%). In the second part of the course, you are expected to read the assigned papers or book chapters carefully prior to class and participate actively in the discussion of these papers. Each student needs to give two to three presentations during the seminar. The presentation should cover the basic ideas of the method, assumptions and contexts for it to work, how to implement it in R, and its potential applications in political science.

You are required to submit a two-page description of a research proposal in the middle of the semester (before October 23) and a complete draft of the proposal before December 5. There is no restriction on the research question in the proposal. But it must include a section in which you justify your research design from the design-based perspective, such as what assumptions you have imposed for causal identification, why they are convincing in your context and what methods are proper in this case. In the last week of the course, each student will give a 10-minute presentation on the proposal that is going to be submitted.

Class Policies

Attendance

Attendance is here understood to mean in-person. UNC's policy gives no right or privilege that allows a student to be absent from any class meetings, except for University Approved Absences. If you are not feeling in good health, please refrain from coming to class, and submit paperwork when appropriate.

Technology in the classroom

Use your computers only for class-related purposes. Please put your phone away before class starts and don't bring it out. This class fully adheres to UNC's guidelines on the use of generative A.I., which you can review here. Failure to adhere to these guidelines may be a reportable violation to the UNC Honor Court.

Counseling and mental health services

Graduate school can be overwhelming. Counseling and Psychological Services (CAPS) at UNC is strongly committed to addressing the mental health needs of a diverse student body through timely access to consultation and connection to clinically appropriate services, whether for short or long-term needs. Go to their website: https://caps.unc.edu/ or visit their facilities on the third floor of the Campus Health Services building for a walk-in evaluation to learn more.

Harassment and discrimination – Title IX

Any student who is impacted by discrimination, harassment, interpersonal (relationship) violence, sexual violence, sexual exploitation, or stalking is encouraged to seek resources on campus or in the community. Reports can be made online to the EOC. Please contact the University's Title IX Coordinator (titleixcoordinator@unc.edu), Report and Response Coordinators in the Compliance Office (reportandresponse@unc.edu), Counseling and Psychological Services (confidential), or the Gender Violence Services

Coordinators (gvsc@unc.edu; confidential) to discuss your specific needs. Additional resources are available at safe.unc.edu.

Students with disabilities

The University of North Carolina at Chapel Hill facilitates the implementation of reasonable accommodations, including resources and services, for students with disabilities, chronic medical conditions, a temporary disability or pregnancy complications resulting in barriers to fully accessing University courses, programs and activities.

Accommodations are determined through the Office of Accessibility Resources and Service (ARS) for individuals with documented qualifying disabilities in accordance with applicable state and federal laws. See the ARS Website for contact information or email ars@unc.edu.

Religious observances

If you have a religious observance that conflicts with your participation in the course, please complete the Request Form and send it to religiousaccommodations@unc.edu for consideration. Once you receive a response, please forward it to the instructor. You are expected to complete this process before the end of the second week of the semester.

Course outline

Week 1: Basic Concepts in Causal Inference (August 20, lecture)

Review.
Method of moments.
Finite population vs. super population.

Week 2: Topics in Causal Inference I (August 27, lecture)

Power analysis.
DAG.
Mediation analysis.

References: Blair et al. (2019), Imai, Keele, and Yamamoto (2010)

Week 3, Topics in Causal Inference II (September 3, lecture)

Review methods in panel data analysis.

References: L. Liu, Wang, and Xu (2024), Imai and Kim (2019)

Week 4, Topics in Causal Inference III (September 10, lecture)

Carryover effects in panel data analysis.

References: Arkhangelsky et al. (2019), Hazlett and Xu (2018)

Week 5, Complex Experiments (September 17, presentation)

References: Hainmueller, Hopkins, and Yamamoto (2014), Abramson, Koçak, and Magazinnik (2022), Knox et al. (2019)

Week 6, Linear Methods in Machine Learning (September 24, lecture and presentation)

References: Ch6 of Gareth et al. (2013)

Week 7, Tree-Based Methods in Machine Learning (October 1, presentation)

References: Ch8 of Gareth et al. (2013), Montgomery and Olivella (2018)

Week 8, Estimating Heterogeneous Treatment Effects (October 8, lecture and presentation)

References: J. Liu, Liu, and Xu (2025)

Week 9, Policy Learning and External Validity (October 22, lecture and presentation)

References: Kitagawa and Tetenov (2018), Dehejia, Pop-Eleches, and Samii (2019), Egami and Hartman (2023)

Week 10, Large Language Models (October 29, presentation and guest lecture)

Guest lecturer: Patrick Chester

References: Egami et al. (2023), Imai and Nakamura (2024), Ludwig, Mullainathan, and Rambachan (2025)

Week 11, Partial Interference and Exposure Mapping (November 5, lecture and presentation)

References: Hudgens and Halloran (2008), Todd et al. (2021), Aronow and Samii (2017)

Week 12, Interference in Space and Social Networks (November 12, lecture and presentation)

References: Wang et al. (2020), Wang (2022)

Week 13, Shift-Share Designs (November 19, lecture and presentation)

References: Adao, Kolesár, and Morales (2019), Autor, Dorn, and Hanson (2013)

Week 14, Final presentation (December 3)

References:

Abramson, Scott F, Korhan Koçak, and Asya Magazinnik. 2022. "What Do We Learn about Voter Preferences from Conjoint Experiments?" *American Journal of Political Science* 66 (4): 1008–20.

Adao, Rodrigo, Michal Kolesár, and Eduardo Morales. 2019. "Shift-Share Designs: Theory and Inference." *The Quarterly Journal of Economics* 134 (4): 1949–2010.

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

Autor, David H, David Dorn, and Gordon H Hanson. 2013. "The China Syndrome: Local Labor Market Effects of Import Competition in the United States." *The American Economic Review*, 2121–68.

Blair, Graeme, Jasper Cooper, Alexander Coppock, and Macartan Humphreys. 2019. "Declaring and Diagnosing Research Designs." *American Political Science Review* 113 (3): 838–59.

Dehejia, Rajeev, Cristian Pop-Eleches, and Cyrus Samii. 2019. "From Local to Global: External Validity in a Fertility Natural Experiment." *Journal of Business & Economic Statistics*, 1–27.

Egami, Naoki, and Erin Hartman. 2023. "Elements of External Validity: Framework, Design, and Analysis." *American Political Science Review* 117 (3): 1070–88.

Egami, Naoki, Musashi Hinck, Brandon Stewart, and Hanying Wei. 2023. "Using Imperfect Surrogates for Downstream Inference: Design-Based Supervised Learning for Social Science Applications of Large Language Models." *Advances in Neural Information Processing Systems* 36: 68589–601.

Gareth, James, Witten Daniela, Hastie Trevor, and Tibshirani Robert. 2013. *An Introduction to Statistical Learning: With Applications in r*. Spinger.

Hainmueller, Jens, Daniel J Hopkins, and Teppei Yamamoto. 2014. "Causal Inference in Conjoint Analysis: Understanding Multidimensional Choices via Stated Preference Experiments." *Political Analysis* 22 (1): 1–30.

Hazlett, Chad, and Yiqing Xu. 2018. "Trajectory Balancing: A General Reweighting Approach to Causal Inference with Time-Series Cross-Sectional Data." *Available at SSRN 3214231*.

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Imai, Kosuke, and In Song Kim. 2019. "When Should We Use Unit Fixed Effects Regression Models for Causal Inference with Longitudinal Data?" *American Journal of Political Science* 63 (2): 467–90.

Imai, Kosuke, and Kentaro Nakamura. 2024. "Causal Representation Learning with Generative Artificial Intelligence: Application to Texts as Treatments." *arXiv Preprint arXiv:2410.00903*.

Imbens, Guido W, and Donald B Rubin. 2015. *Causal Inference in Statistics, Social, and Biomedical Sciences*. Cambridge University Press.

Kitagawa, Toru, and Aleksey Tetenov. 2018. "Who Should Be Treated? Empirical Welfare Maximization Methods for Treatment Choice." *Econometrica* 86 (2): 591–616.

Knox, Dean, Teppei Yamamoto, Matthew A Baum, and Adam J Berinsky. 2019. "Design, Identification, and Sensitivity Analysis for Patient Preference Trials." *Journal of the American Statistical Association* 114 (528): 1532–46.

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Montgomery, Jacob M, and Santiago Olivella. 2018. "Tree-Based Models for Political Science Data." *American Journal of Political Science* 62 (3): 729–44.

Todd, Jason Douglas, Edmund J Malesky, Anh Tran, and Quoc Anh Le. 2021. "Testing Legislator Responsiveness to Citizens and Firms in Single-Party Regimes: A Field Experiment in the Vietnamese

National Assembly." *The Journal of Politics* 83 (4): 1573–88.
Wang, Ye. 2022. "Causal Inference Under Temporal and Spatial Interference."
Wang, Ye, Cyrus Samii, Haoge Chang, and Peter M Aronow. 2020. "Design-Based Inference for Spatial Experiments with Interference." *arXiv Preprint arXiv:2010.13599*.