

Causal Inference and Statistical Designs (M16)

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Scientific research involves iterating between hypothesis formulation, study design, experiment/data collection, and data analysis. This course will introduce some modern perspectives on this process, with a focus on what assumptions and methods enable causal inference from experimental and non-experimental data. Provisional schedule below.

1. Motivating scientific examples in biological and social sciences. [1]
2. Randomization inference: randomization and blocking, Neyman-Rubin causal model, randomization tests, regression adjustment. [2]
3. Linear structural equation model: Wright's path analysis, graph marginalization, m-separation, estimation. [2]
4. Causal graphical models: factorization and Markov properties, causal Markov model, single-world intervention graphs, do/po-calculus, backdoor and frontdoor criteria, ID algorithm. [4]
5. Confounder adjustment: statistical inference of the average treatment effect, sensitivity analysis. [2]
6. Instrumental variables: core assumptions, generalized method of moments, monotonicity and principal stratification. [2]
7. Regression discontinuity design: sharp and fuzzy RDD, identification, estimation. [1]
8. Proximal causal inference: identification via bridge function/inverse problems. [1]
9. Mediation analysis: path-specific effects in linear SEMs, natural direct/indirect effects and interventionist interpretation. [1]

Pre-requisites

This course assumes a good understanding of undergraduate-level probability and statistics. Familiarity with asymptotic statistics and applied statistics may be useful.

Literature

1. Hernán M. A. and Robins, J. M. (2020) *Causal Inference: What If*. Chapman & Hall. Available at
<https://miguelhernan.org/whatifbook>.
2. Imbens, G. W. and Rubin, D. B. (2015) *Causal Inference in Statistics, Social, and Biomedical Sciences*. Cambridge University Press.
3. Lauritzen, S. L. (2026). *Graphical Models*. 2nd Edition. Oxford University Press.
4. Angrist, J. D. and Pischke, J. S. (2008) *Mostly Harmless Econometrics: An Empiricist's Companion*. Princeton University Press.

Additional support

Lecture notes will be provided. Three examples sheets will be provided and three associated examples classes will be given. There will also be a revision class in the Easter Term.