Causal Inference (L16)

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From its onset, modern statistics engages in the problem of inferring causality from data. A common belief is that causal inference is only possible using randomized experiments, but recent developments in statistics and related fields have shown that this view is too simplistic. We now have a much better understanding of the assumptions and methodologies that enable causal inference from observational data. This course aims to cover the most fundamental ideas in causal inference, a vibrant research area where statistical theory meets scientific practice.

1. **Motivation and basic methods:**
    - Principles of causal inference: motivations; historical perspectives; basic concepts.
    - Randomized experiments: randomization tests, regression adjustment and its asymptotic inference.
    - Path analysis and linear structural equation models (SEMs).
2. **Causal graphical models and identification:**
    - Directed acyclic graphical (DAG) models and extensions: Markov properties, d-separation, structure discovery.
    - Counterfactual causal models: nonparametric SEMs; single-world intervention graphs; g-computation formula.
    - Causal identification: back-door criterion, front-door criterion; fixing operator and potential outcomes calculus; examples.
3. **Design and statistical methods:**
    - Observed confounders: matching, randomization inference, influence functions and semiparametric inference.
    - Instrumental variables (IV): core IV assumptions; generalised method of moments; principal stratification.
    - Additional selected topics (time permitting): mediation analysis; regression discontinuity design; difference in differences and negative control methods; longitudinal data and time-varying treatments; meta-analysis and evidence synthesis.

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.
2. Imbens, G. W. and Rubin, D. B. (2015) *Causal Inference in Statistics, Social, and Biomedical Sciences.* Cambridge University Press.
3. Lauritzen, S. L. (1996). *Graphical Models.* Clarendon 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.