

September 2019

Potsdam

## Causal Inference and Machine Learning

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### Course Description

The course will cover topics on the intersection of causal inference and machine learning. There will be particular emphasis on the use of machine learning methods for estimating causal effects. In addition there will be some discussion of basic machine learning methods that we view as useful tools for empirical economists.

### Lectures

There will be six lectures.

### Background Reading

We strongly recommend that participants read these articles in preparation for the course.

- Athey, Susan, and Guido W. Imbens. "The state of applied econometrics: Causality and policy evaluation." *Journal of Economic Perspectives* 31.2 (2017): 3-32.

### Course Outline

#### 1. Introduction to Causal Inference

- (a) Holland, Paul W. "Statistics and causal inference." *Journal of the American statistical Association* 81.396 (1986): 945-960.
- (b) Imbens, Guido W., and Donald B. Rubin. *Causal inference in statistics, social, and biomedical sciences*. Cambridge University Press, 2015.
- (c) Imbens, Guido W., and Jeffrey M. Wooldridge. "Recent developments in the econometrics of program evaluation." *Journal of economic literature* 47.1 (2009): 5-86.

#### 2. Introduction to Machine Learning Concepts

- (a) S. Athey (2018, January) "The Impact of Machine Learning on Economics," *Sections 1-2*. <http://bit.ly/2EENTvy>
- (b) H. R. Varian (2014) "Big data: New tricks for econometrics." *The Journal of Economic Perspectives*, 28 (2):3-27. <http://pubs.aeaweb.org/doi/pdfplus/10.1257/jep.28.2.3>
- (c) S. Mullainathan and J. Spiess (2017) "Machine learning: an applied econometric approach" *Journal of Economic Perspectives*, 31(2):87-106 <http://pubs.aeaweb.org/doi/pdfplus/10.1257/jep.31.2.87>

- (d) L. Breiman, J. Friedman, C. J. Stone R. A. Olshen (1984) “Classification and regression trees,” CRC press.
  - (e) Friedman, Jerome, Trevor Hastie, and Robert Tibshirani. The elements of statistical learning. Vol. 1. No. 10. New York, NY, USA.: Springer series in statistics, 2001.
  - (f) I. Goodfellow, Y. Bengio, and A. Courville (2016) “Deep Learning.” MIT Press.
3. Causal Inference: Average Treatment Effects with Many Covariates
- (a) A. Belloni, V. Chernozhukov, and C. Hansen (2014) “High-dimensional methods and inference on structural and treatment effects.” *The Journal of Economic Perspectives*, 28(2):29-50. <http://pubs.aeaweb.org/doi/pdfplus/10.1257/jep.28.2.29>
  - (b) V. Chernozhukov, D. Chetverikov, M. Demirer, E. Duflo, C. Hansen, W. Newey, and J. Robins (2017, December) “Double/Debiased Machine Learning for Treatment and Causal Parameters.” <https://arxiv.org/abs/1608.00060>.
  - (c) Athey, Susan, Guido W. Imbens, and Stefan Wager. ”Approximate residual balancing: debiased inference of average treatment effects in high dimensions.” *Journal of the Royal Statistical Society: Series B (Statistical Methodology)* 80.4 (2018): 597-623.
  - (d) S. Athey, G. Imbens, and S. Wager (2016) “Estimating Average Treatment Effects: Supplementary Analyses and Remaining Challenges.” <http://arXiv/abs/1702.01250>. Forthcoming, *Journal of the Royal Statistical Society-Series B*.
4. ~~Monday 2.30-4.00pm~~: Causal Inference: Heterogeneous Treatment Effects
- (a) S. Wager and S. Athey (2017) “Estimation and inference of heterogeneous treatment effects using random forests.” *Journal of the American Statistical Association* <http://arxiv.org/abs/1510.04342>
  - (b) S. Athey, Tibshirani, J., and S. Wager (2017, July) “Generalized Random Forests” <http://arxiv.org/abs/1610.01271>
5. Causal Inference: Experimental Design and Multi-armed Bandits
- (a) S. Athey and S. Wager (2017) “Efficient Policy Learning.” <http://arXiv.org/abs/1702.02896>.
  - (b) M. Dudik, D. Erhan, J. Langford, and L. Li, (2014) “Doubly Robust Policy Evaluation and Optimization” *Statistical Science*, Vol 29(4):485-511.
  - (c) S. Scott (2010), “A modern Bayesian look at the multi-armed bandit,” *Applied Stochastic Models in Business and Industry*, vol 26(6):639–658.
  - (d) M. Dimakopoulou, S. Athey, and G. Imbens (2017). “Estimation Considerations in Contextual Bandits.” <http://arXiv.org/abs/1711.07077>.
6. Synthetic Control Methods and Matrix Completion

- (a) S. Athey, M. Bayati, N. Doudchenko, G. Imbens, and K. Khosravi (2017) “Matrix Completion Methods for Causal Panel Data Models.” <http://arXiv.org/abs/1710.10251>.
- (b) J. Bai (2009), “Panel data models with interactive fixed effects.” *Econometrica*, 77(4): 1229–1279.
- (c) E. Candès and B. Recht (2009) “Exact matrix completion via convex optimization.” *Foundations of Computational mathematics*, 9(6):717-730.