Introduction to Debiased Machine Learning

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These lectures are about using machine learning (ML) to estimate economic and causal parameters of interest that depend on unknown high dimensional and/or nonparametric functions. The models and methods encompassed here are collectively referred to as debiased machine learning (DML). The lectures explain how to apply these methods, including some examples, and give theory to explain how they can be applied in settings other than those explicitly considered here. Many other examples are given in the literature referred to here.

One good introductory reference is the book

*Chernozhukov, V., C. Hansen, N. Kallus, M; Spindler, V. Syrgkanis (2024): *Applied Causal Inference Powered by ML and AI*, https://arxiv.org/abs/2403.02467

Chapter 1, 3, and 4 are useful introductions to machine learning methods. In what follows an asterik * highlights an especially useful reference for the purpose of these lectures.

A common reference that provides a good overview is

*Chernozhukov, V., D. Chetverikov, M. Demirer, E. Duflo, C. Hansen, W. Newey, J. Robins (2018): "Double/Debiased Machine Learning for Treatment and Structural Parameters," *Econometrics Journal.*

Here are subjects and references for each of the lectures

Lecture 1: Double Lasso and an introduction to Neyman orthogonality and cross-fitting.

*Chapter 1 of *Applied Causal Inference*

Lecture 2: Automatic DML for parameters that depend linearly on a regression.

*Sections 1-5 of Chernozhukov, V., V. Quintas-Martinez, W.K. Newey, V. Syrgkanis, (2021): "Automatic Debiased Machine Learning via Reisz Regressions," \
https://arxiv.org/pdf/2104.14737.

Lecture 3: Neyman orthogonality via "profiling" and influence functions; large sample theory.

*Newey, W.K. (1994): "The Asymptotic Variance of Semiparametric Estimators," *Econometrica* 62, 1349-1382.

*Sections 2, 4 of Chernozhukov, V., J.-C. Escanciano, H. Ichimura, W.K. Newey, J.M. Robins (2022): "Locally Robust Semiparametric Estimation," *Econometrica* 90, 1501-1535.

Lecture 4: Double robustness, DML for nonparametric objects.

*Section 5 of Chernozhukov, V., J.-C. Escanciano, H. Ichimura, W.K. Newey, J.M. Robins (2022): "Locally Robust Semiparametric Estimation," *Econometrica* 90, 1501-1535.

*Chernozhukov, V., W.K. Newey, V. Syrgkanis (2024): "Conditional Influence Functions," https://arxiv.org/pdf/2412.18080.

Here are more extensive references organized by timing and topics.

Early works:

*Newey, W.K. (1994): "The Asymptotic Variance of Semiparametric Estimators," *Econometrica* 62, 1349-1382.

Robins, J.M. and A. Rotnitzky (1995): "Semiparametric Efficiency in Multivariate Regression Models with Missing Data," *Journal of the American Statistical Association* 90:122–129.

Belloni, A., D. Chen, and V. Chernozhukov, and C. Hansen (2012): "Sparse Models and Methods for Optimal Instruments with an Application to Eminent Domain," *Econometrica* 80, 2369–429.

Belloni, A., V. Chernozhukov, and C. Hansen (2014): "Inference on Treatment Effects after Selection among High-Dimensional Controls," *Review of Economic Studies* 81, 608–650.

Farrell, M. (2015): "Robust Inference on Average Treatment Effects with Possibly More Covariates than Observations," *Journal of Econometrics* 189, 1–23.

Athey, S., G. Imbens, and S. Wager (2018): "Approximate residual balancing: debiased inference of average treatment effects in high dimensions," *Journal of the Royal Statistical Society, Series B,* 80, 597-623.

Influence Functions:

Ichimura, H. and W.K. Newey (2022) "The Influence Function of Semiparametric Estimators," *Quantitative Economics* 13, 29–61.

Andrews, I., M. Gentzkow, J.M. Shapiro (2017): "Measuring the Sensitivity of Parameter Estimates to Estimation Moments," *The Quarterly Journal of Economics* 132, 1553-1592.

Kennedy, E. Recent Lecture notes.

Neyman Orthogonality

*Section 2 and 4 of Chernozhukov, V., J.-C. Escanciano, H. Ichimura, W.K. Newey, J.M. Robins (2022): "Locally Robust Semiparametric Estimation," *Econometrica* 90, 1501-1535 (LR henceforth).

*Sections 3, 4, 5 of Chernozhukov, V., V. Quintas-Martinez, W.K. Newey, V. Syrgkanis, (2021): "Automatic Debiased Machine Learning via Reisz Regressions,"

https://arxiv.org/pdf/2104.14737.

Chernozhukov, V., W.K. Newey, and R. Singh (2022): "Automatic Debiased Machine Learning of Structural and Causal Effects," with V. Chernozhukov and R. Singh, *Econometrica* 90, 967-1027.

Chernozhukov, V., V. Quintas-Martinez, W.K. Newey, V. Syrgkanis, (2022): "RieszNet and ForestRiesz: Automatic Debiased Machine Learning with Neural Nets and Random Forests," *Proceedings of the 39th International Conference on Machine Learning* 162, 2022, https://arxiv.org/abs/2110.03031.

Cross-fitting:

Newey, W.K. and J.Robins (2018): "Cross-fitting and Fast Remainder Rates for Semiparametric Estimation," https://arxiv.org/pdf/1801.09138.

Velez, A. (2024): "On the Asymptotic Properties of Debiased Machine Learning Estimators," https://www.amilcarvelez.com/JMP/DML/JMP_AV.pdf

Double Robustness:

*Section 5 of Chernozhukov, V., J.-C. Escanciano, H. Ichimura, W.K. Newey, J.M. Robins (2022): "Locally Robust Semiparametric Estimation," *Econometrica* 90, 1501-1535.

Rotnitzky, A., E. Smucler, and J.M. Robins (2021): "Characterization of Parameters with a Mixed Bias Property," *Biometrika* 108, 231-238.

Bang, and Robins (2005): "Doubly Robust Estimation in Missing Data and Causal Inference Models," *Biometrics* 61, 962–972.

Zhu, Y. and J. Bradic (2017a): "Linear Hypothesis Testing in Dense High-Dimensional Linear Models," *Journal of the American Statistical Association* 112.

More Examples:

Section 3 of LR.

Chernozhukov, V., M.K. Newey, W.K. Newey, R. Singh, V. Srygkanis (2024): "Automatic Debiased Machine Learning for Covariate Shifts," https://arxiv.org/pdf/2307.04527.

Chernozhukov, V., W.K. Newey, and V. Semenova (2024): "Welfare Analysis in Dynamic Models," https://arxiv.org/pdf/1908.09173.

Bennett, A., N. Kallus, X. Mao, W.K. Newey, V. Syrgkanis, M. Uehara (2023): "Inference on Strongly Identified Functionals of Weakly Identified Functions,"

https://arxiv.org/pdf/2208.08291.

van der Laan, L., A. Bibaut, N. Kallus, A. Luedtke (2024): "Automatic Debiased Machine Learning for Smooth Functionals of Nonparametric M-Estimands,"

https://arxiv.org/pdf/2501.11868

Debiased Machine Learning for Nonparametric Objects

*Chernozhukov, V., W.K. Newey, V. Syrgkanis (2024): "Conditional Influence Functions," https://arxiv.org/pdf/2412.18080.

Semenova, V. and V. Chernozhukov (2021): "Debiased Machine Learning of Conditional Average Treatment Effects and Other Causal Functions" *Econometrics Journal* 24, 264-289.

Chernozhukov, V., W.K. Newey, and R. Singh (2022): "De-Biased Machine Learning of Global and Local Parameters Using Regularized Riesz Representers," *Econometrics Journal* 25, 576–601.

Foster, D.F. and V. Syrgkanis (2023): "Orthogonal Statistical Learning," *Annals of Statistics* 51, 879 - 908.