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So many choices in Double Machine Learning!? Practical insights from a simulations study

2022 Causal Data Science Meeting

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What is Double Machine Learning?

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- **Double/debiased machine learning (DML)** introduced by Chernozhukov et al. (2018)
- General framework based on machine learning tools for causal inference and estimation of treatment effects
- Combines the strength of **machine learning** and **econometrics**
- Resulting estimator has good properties ($\sqrt{N}$-consistency, approx. Gaussian)
- Our object-oriented implementation **DoubleML** provides a general interface for models and methods for DML (in `R` and in `Python`)

The Key Ingredients of DML

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1. Neyman Orthogonality

   Inference is based on a method-of-moments estimator that obeys the **Neyman orthogonality condition**

2. High-Quality Machine Learning Estimators

   The nuisance parameters are estimated with high-quality (fast-enough converging) machine learning methods

3. Sample Splitting

   To avoid the biases arising from overfitting, a form of **sample splitting** is used at the stage of producing the estimator of the main parameter θ_0

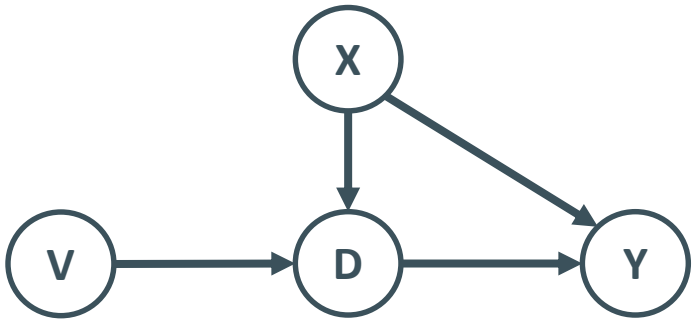
Example: Partially Linear Regression Model

Partially linear regression (**PLR**) model

$$
\begin{aligned}
Y &= D\theta_0 + g_0(X) + \zeta, & \mathbb{E}[\zeta|D, X] &= 0, \\
D &= m_0(X) + V, & \mathbb{E}[V|X] &= 0,
\end{aligned}
$$

with

- outcome variable Y
- Policy or Treatment variable of interest D
- High-dimensional vector of confounding covariates $X = (X_1, \ldots, X_p)$
- Stochastic errors ζ and V



Tuning in Double Machine Learning

- PLR example: To estimate θ_0, the following **Neyman orthogonal score** is used

$$\psi(W;\theta,\eta) = \Big(Y - g(X) - \theta\big(D - m(X)\big)\Big)\big(D - m(X)\big)$$

- The nuisance $\eta = (g(X) = \mathbb{E}[\,Y \mid X\,], m(X) = \mathbb{E}[D \mid X])$ is estimated by ML learners
- Double Machine Learning is inherently **robust against small biases** from regularization or overfitting
- **Tuning** DML nuisance predictors is an open question

Tuning in Double Machine Learning

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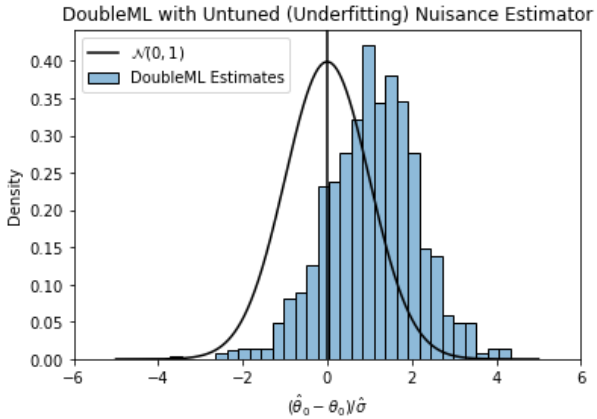
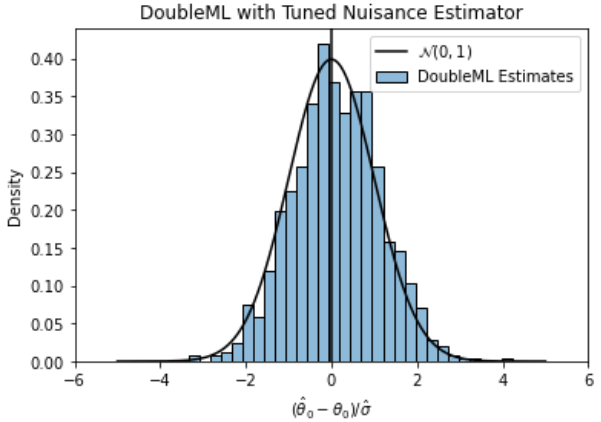
- Using **untuned** ML estimators for nuisance prediction however can lead to a severely biased estimation in the causal parameter of interest





- How do we get to the right estimator?

Our Project

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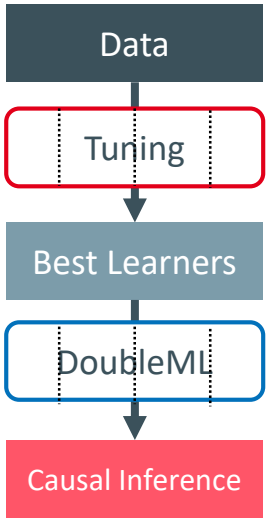
- Carry out large scale simulation study to answer important questions double machine learning users face
  - Which Machine Learning Methods to use?
  - Role of sample splitting in tuning?
  - How to assess the quality of fit?

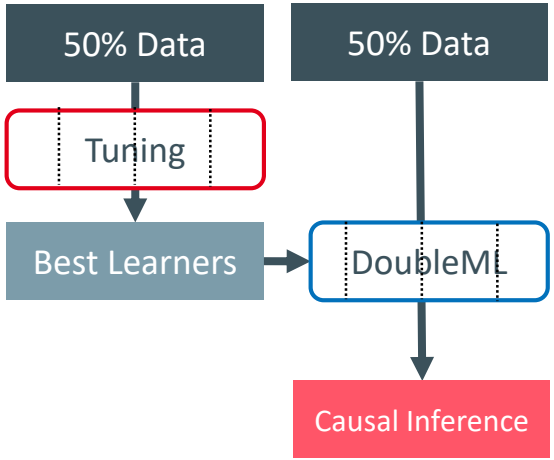
Our Simulation Study

- We use plug-in Automated Machine Learning Estimators from the library `flaml`.
- Three different tuning approaches are tested high-dimensional datasets from the ACIC 2019

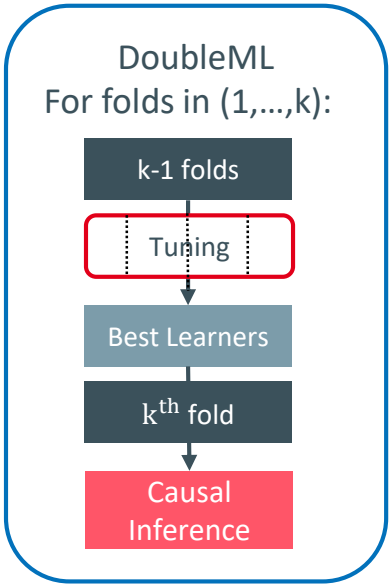
Tune on full sample



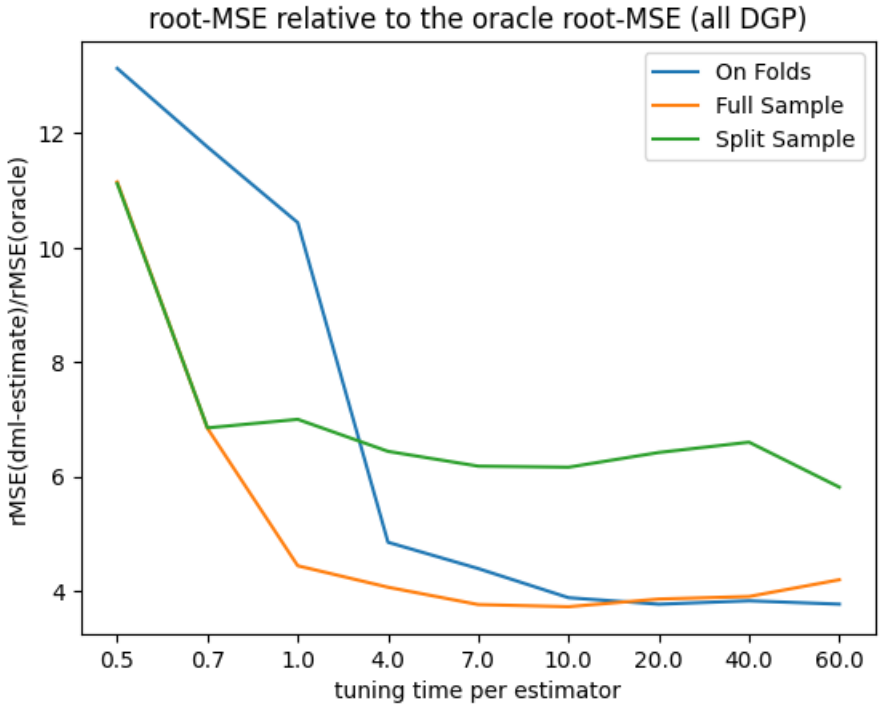
Tune on hold-out sample



Tune on the folds

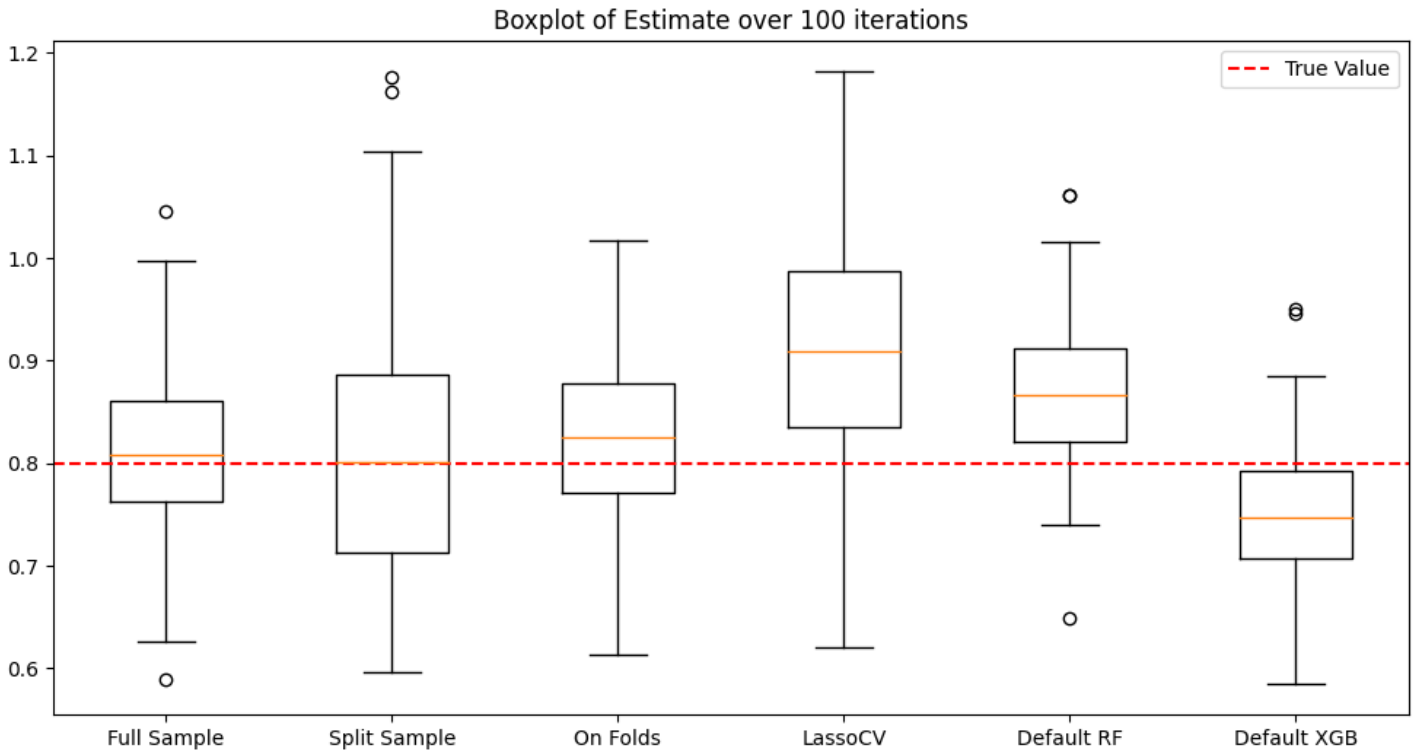


Results



$n = 1000, p = 200$

Results


Boxplot of Estimate over 100 iterations
True Value
1.2
1.1
1.0
0.9
0.8
0.7
0.6
Full Sample
Split Sample
On Folds
LassoCV
Default RF
Default XGB

Results

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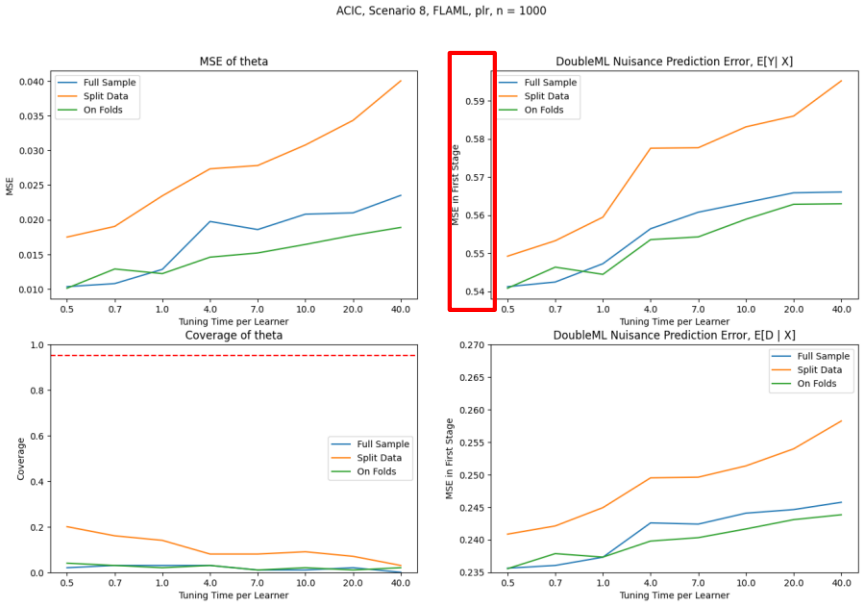
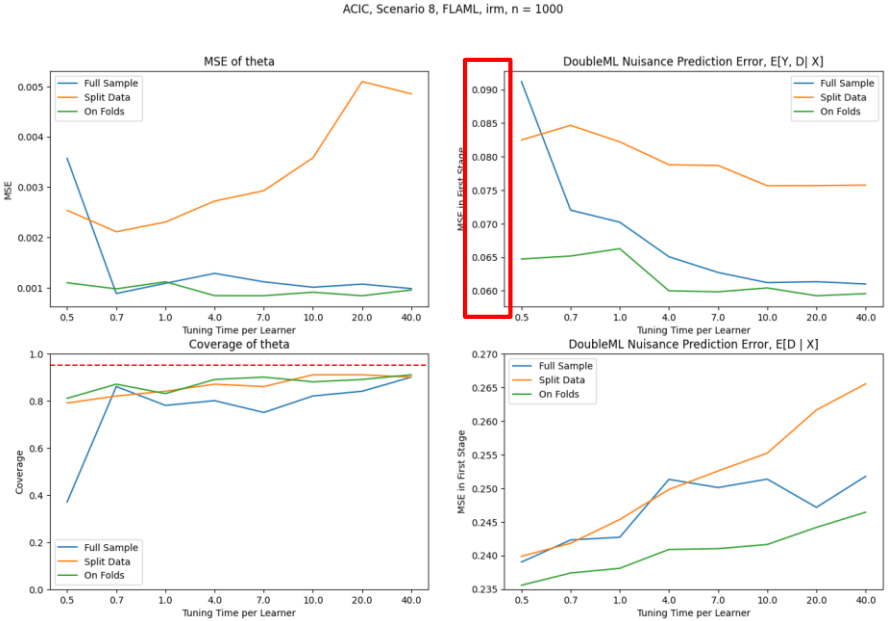
Misspecified Model

(linear, additive effect)



Correct Model

(heterogenous effect)



Key Take-Aways and Outlook

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- Tuning the nuisance estimators has influence on inference accuracy in double machine learning
- Plug-in AutoML estimators work well here
- Tuning on hold-out data is in investigated cases not efficient
- We recommend monitoring the nuisance prediction error for assessment of causal inference quality
- Full results for all DGPs to be published / further studies on influence of cross-fitting
- Extension to further AutoML frameworks
- **Extension module** for DoubleML

Thank you for your attention!

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Comments, ideas? **Feel free to reach out!**

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More about **DoubleML**:

https://docs.doubleml.org

https://github.com/DoubleML/doubleml-for-py

https://github.com/DoubleML/doubleml-for-r