Package 'ddml'

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Title Double/Debiased Machine Learning

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Description Estimate common causal parameters using double/debiased machine learning as proposed by Chernozhukov et al. (2018) <doi:10.1111/ectj.12097>. 'ddml' simplifies estimation based on (short-)stacking as discussed in Ahrens et al. (2024) <doi:10.1002/jae.3103>, which leverages multiple base learners to increase robustness to the underlying data generating process.

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URL `https://github.com/thomaswiemann/ddml`, `https://thomaswiemann.com/ddml/`

BugReports `https://github.com/thomaswiemann/ddml/issues`

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LazyData true

RoxygenNote 7.3.3

Depends R (>= 4.3)

Imports methods, stats, AER, MASS, Matrix, nnls, quadprog, glmnet, ranger, xgboost

Suggests sandwich, covr, testthat (>= 3.0.0), knitr, rmarkdown

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Contents

`AE98` *Random subsample from the data of Angrist & Evans (1991).*

Description

Random subsample from the data of Angrist & Evans (1991).

Usage

```
AE98
```

Format

A data frame with 5,000 rows and 13 variables.

worked Indicator equal to 1 if the mother is employed.

weeksw Number of weeks of employment.

hoursw Hours worked per week.

morekids Indicator equal to 1 if the mother has more than 2 kids.

samesex Indicator equal to 1 if the first two children are of the same sex.

age Age in years.

agefst Age in years at birth of the first child.

black Indicator equal to 1 if the mother is black.

hisp Indicator equal to 1 if the mother is Hispanic.

othrace Indicator equal to 1 if the mother is neither black nor Hispanic.

educ Years of education.

boy1st Indicator equal to 1 if the first child is male.

boy2nd Indicator equal to 1 if the second child is male.

Source

doi:10.7910/DVN/4W9GW2

References

Angrist J, Evans W (1998). "Children and Their Parents' Labor Supply: Evidence from Exogenous Variation in Family Size." American Economic Review, 88(3), 450-477.

`crosspred` *Cross-Predictions using Stacking.*

Description

Cross-predictions using stacking.

Usage

```
crosspred(
  y,
  X,
  Z = NULL,
  learners,
  sample_folds = 2,
  ensemble_type = "average",
  cv_folds = 5,
  custom_ensemble_weights = NULL,
  compute_insample_predictions = FALSE,
  compute_predictions_bylearner = FALSE,
  subsamples = NULL,
  cv_subsamples_list = NULL,
  silent = FALSE,
  progress = NULL,
  auxiliary_X = NULL
)
```

Arguments

`y` The outcome variable.

`X` A (sparse) matrix of predictive variables.

`Z` Optional additional (sparse) matrix of predictive variables.

`learners` May take one of two forms, depending on whether a single learner or stacking with multiple learners is used for estimation of the predictor. If a single learner is used, `learners` is a list with two named elements:

- `what` The base learner function. The function must be such that it predicts a named input `y` using a named input `X`.
- `args` Optional arguments to be passed to `what`.

If stacking with multiple learners is used, `learners` is a list of lists, each containing four named elements:

- `fun` The base learner function. The function must be such that it predicts a named input `y` using a named input `X`.
- `args` Optional arguments to be passed to `fun`.
- `assign_X` An optional vector of column indices corresponding to predictive variables in `X` that are passed to the base learner.
- `assign_Z` An optional vector of column indices corresponding to predictive in `Z` that are passed to the base learner.

Omission of the `args` element results in default arguments being used in `fun`. Omission of `assign_X` (and/or `assign_Z`) results in inclusion of all variables in `X` (and/or `Z`).

`sample_folds` Number of cross-fitting folds.

`ensemble_type` Ensemble method to combine base learners into final estimate of the conditional expectation functions. Possible values are:

- `"nnls"` Non-negative least squares.
- `"nnls1"` Non-negative least squares with the constraint that all weights sum to one.
- `"singlebest"` Select base learner with minimum MSPE.
- `"ols"` Ordinary least squares.
- `"average"` Simple average over base learners.

Multiple ensemble types may be passed as a vector of strings.

`cv_folds` Number of folds used for cross-validation in ensemble construction.

`custom_ensemble_weights` A numerical matrix with user-specified ensemble weights. Each column corresponds to a custom ensemble specification, each row corresponds to a base learner in `learners` (in chronological order). Optional column names are used to name the estimation results corresponding the custom ensemble specification.

`compute_insample_predictions` Indicator equal to 1 if in-sample predictions should also be computed.

`compute_predictions_bylearner` Indicator equal to 1 if in-sample predictions should also be computed for each learner (rather than the entire ensemble).

subsamples — List of vectors with sample indices for cross-fitting.

cv_subsamples_list — List of lists, each corresponding to a subsample containing vectors with subsample indices for cross-validation.

silent — Boolean to silence estimation updates.

progress — String to print before learner and cv fold progress.

auxiliary_X — An optional list of matrices of length sample_folds, each containing additional observations to calculate predictions for.

Value

crosspred returns a list containing the following components:

- oos_fitted A matrix of out-of-sample predictions, each column corresponding to an ensemble type (in chronological order).
- weights An array, providing the weight assigned to each base learner (in chronological order) by the ensemble procedures.
- is_fitted When compute_insample_predictions = T. a list of matrices with in-sample predictions by sample fold.
- auxiliary_fitted When auxiliary_X is not NULL, a list of matrices with additional predictions.
- oos_fitted_bylearner When compute_predictions_bylearner = T, a matrix of out-of-sample predictions, each column corresponding to a base learner (in chronological order).
- is_fitted_bylearner When compute_insample_predictions = T and compute_predictions_bylearner = T, a list of matrices with in-sample predictions by sample fold.
- auxiliary_fitted_bylearner When auxiliary_X is not NULL and compute_predictions_bylearner = T, a list of matrices with additional predictions for each learner.

References

Ahrens A, Hansen C B, Schaffer M E, Wiemann T (2024). "Model Averaging and Double Machine Learning." Journal of Applied Econometrics, 40(3): 249-269.

Wolpert D H (1992). "Stacked generalization." Neural Networks, 5(2), 241-259.

See Also

Other utilities: crossval(), shortstacking()

Examples

```
# Construct variables from the included Angrist & Evans (1998) data
y = AE98[, "worked"]
X = AE98[, c("morekids", "age","agefst","black","hisp","othrace","educ")]

# Compute cross-predictions using stacking with base learners ols and lasso.
#     Two stacking approaches are simultaneously computed: Equally
#     weighted (ensemble_type = "average") and MSPE-minimizing with weights
#     in the unit simplex (ensemble_type = "nnls1"). Predictions for each
```

```
#     learner are also calculated.
crosspred_res <- crosspred(y, X,
                           learners = list(list(fun = ols),
                                           list(fun = mdl_glmnet)),
                           ensemble_type = c("average",
                                             "nnls1",
                                             "singlebest"),
                           compute_predictions_bylearner = TRUE,
                           sample_folds = 2,
                           cv_folds = 2,
                           silent = TRUE)
dim(crosspred_res$oos_fitted) # = length(y) by length(ensemble_type)
dim(crosspred_res$oos_fitted_bylearner) # = length(y) by length(learners)
```

`crossval` *Estimator of the Mean Squared Prediction Error using Cross-Validation.*

Description

Estimator of the mean squared prediction error of different learners using cross-validation.

Usage

```
crossval(
  y,
  X,
  Z = NULL,
  learners,
  cv_folds = 5,
  cv_subsamples = NULL,
  silent = FALSE,
  progress = NULL
)
```

Arguments

`y` The outcome variable.

`X` A (sparse) matrix of predictive variables.

`Z` Optional additional (sparse) matrix of predictive variables.

`learners` `learners` is a list of lists, each containing four named elements:

- `fun` The base learner function. The function must be such that it predicts a named input `y` using a named input `X`.
- `args` Optional arguments to be passed to `fun`.
- `assign_X` An optional vector of column indices corresponding to variables in `X` that are passed to the base learner.

- assign_Z An optional vector of column indices corresponding to variables in Z that are passed to the base learner.

Omission of the args element results in default arguments being used in fun. Omission of assign_X (and/or assign_Z) results in inclusion of all predictive variables in X (and/or Z).

cv_folds Number of folds used for cross-validation.

cv_subsamples List of vectors with sample indices for cross-validation.

silent Boolean to silence estimation updates.

progress String to print before learner and cv fold progress.

Value

crossval returns a list containing the following components:

mspe A vector of MSPE estimates, each corresponding to a base learners (in chronological order).

oos_resid A matrix of out-of-sample prediction errors, each column corresponding to a base learners (in chronological order).

cv_subsamples Pass-through of cv_subsamples. See above.

See Also

Other utilities: crosspred(), shortstacking()

Examples

```
# Construct variables from the included Angrist & Evans (1998) data
y = AE98[, "worked"]
X = AE98[, c("morekids", "age","agefst","black","hisp","othrace","educ")]

# Compare ols, lasso, and ridge using 4-fold cross-validation
cv_res <- crossval(y, X,
                   learners = list(list(fun = ols),
                                   list(fun = mdl_glmnet),
                                   list(fun = mdl_glmnet,
                                        args = list(alpha = 0))),
                   cv_folds = 4,
                   silent = TRUE)
cv_res$mspe
```

---

ddml_ate *Estimators of Average Treatment Effects.*

Description

Estimators of the average treatment effect and the average treatment effect on the treated.

Usage

```
ddml_ate(
  y,
  D,
  X,
  learners,
  learners_DX = learners,
  sample_folds = 10,
  ensemble_type = "nnls",
  shortstack = FALSE,
  cv_folds = 10,
  custom_ensemble_weights = NULL,
  custom_ensemble_weights_DX = custom_ensemble_weights,
  cluster_variable = seq_along(y),
  subsamples_byD = NULL,
  cv_subsamples_byD = NULL,
  trim = 0.01,
  silent = FALSE
)

ddml_att(
  y,
  D,
  X,
  learners,
  learners_DX = learners,
  sample_folds = 10,
  ensemble_type = "nnls",
  shortstack = FALSE,
  cv_folds = 10,
  custom_ensemble_weights = NULL,
  custom_ensemble_weights_DX = custom_ensemble_weights,
  cluster_variable = seq_along(y),
  subsamples_byD = NULL,
  cv_subsamples_byD = NULL,
  trim = 0.01,
  silent = FALSE
)
```

Arguments

`y`	The outcome variable.
`D`	The binary endogenous variable of interest.
`X`	A (sparse) matrix of control variables.
`learners`	May take one of two forms, depending on whether a single learner or stacking with multiple learners is used for estimation of the conditional expectation functions. If a single learner is used, `learners` is a list with two named elements:

- what The base learner function. The function must be such that it predicts a named input y using a named input X.
- args Optional arguments to be passed to what.

If stacking with multiple learners is used, learners is a list of lists, each containing four named elements:

- fun The base learner function. The function must be such that it predicts a named input y using a named input X.
- args Optional arguments to be passed to fun.
- assign_X An optional vector of column indices corresponding to control variables in X that are passed to the base learner.

Omission of the args element results in default arguments being used in fun. Omission of assign_X results in inclusion of all variables in X.

learners_DX
: Optional argument to allow for different estimators of $E[D|X]$. Setup is identical to learners.

sample_folds
: Number of cross-fitting folds.

ensemble_type
: Ensemble method to combine base learners into final estimate of the conditional expectation functions. Possible values are:

- "nnls" Non-negative least squares.
- "nnls1" Non-negative least squares with the constraint that all weights sum to one.
- "singlebest" Select base learner with minimum MSPE.
- "ols" Ordinary least squares.
- "average" Simple average over base learners.

Multiple ensemble types may be passed as a vector of strings.

shortstack
: Boolean to use short-stacking.

cv_folds
: Number of folds used for cross-validation in ensemble construction.

custom_ensemble_weights
: A numerical matrix with user-specified ensemble weights. Each column corresponds to a custom ensemble specification, each row corresponds to a base learner in learners (in chronological order). Optional column names are used to name the estimation results corresponding the custom ensemble specification.

custom_ensemble_weights_DX
: Optional argument to allow for different custom ensemble weights for learners_DX. Setup is identical to custom_ensemble_weights. Note: custom_ensemble_weights and custom_ensemble_weights_DX must have the same number of columns.

cluster_variable
: A vector of cluster indices.

subsamples_byD
: List of two lists corresponding to the two treatment levels. Each list contains vectors with sample indices for cross-fitting.

cv_subsamples_byD
: List of two lists, each corresponding to one of the two treatment levels. Each of the two lists contains lists, each corresponding to a subsample and contains vectors with subsample indices for cross-validation.

`trim`	Number in (0, 1) for trimming the estimated propensity scores at `trim` and `1-trim`.
`silent`	Boolean to silence estimation updates.

Details

`ddml_ate` and `ddml_att` provide double/debiased machine learning estimators for the average treatment effect and the average treatment effect on the treated, respectively, in the interactive model given by

$Y = g_0(D, X) + U,$

where (Y, D, X, U) is a random vector such that $\operatorname{supp} D = \{0, 1\}$, $E[U|D, X] = 0$, and $\Pr(D = 1|X) \in (0, 1)$ with probability 1, and g_0 is an unknown nuisance function.

In this model, the average treatment effect is defined as

$\theta_0^{\text{ATE}} \equiv E[g_0(1, X) - g_0(0, X)]$.

and the average treatment effect on the treated is defined as

$\theta_0^{\text{ATT}} \equiv E[g_0(1, X) - g_0(0, X)|D = 1]$.

Value

`ddml_ate` and `ddml_att` return an object of S3 class `ddml_ate` and `ddml_att`, respectively. An object of class `ddml_ate` or `ddml_att` is a list containing the following components:

`ate` / `att` A vector with the average treatment effect / average treatment effect on the treated estimates.

`weights` A list of matrices, providing the weight assigned to each base learner (in chronological order) by the ensemble procedure.

`mspe` A list of matrices, providing the MSPE of each base learner (in chronological order) computed by the cross-validation step in the ensemble construction.

`psi_a`, `psi_b` Matrices needed for the computation of scores. Used in `summary.ddml_ate()` or `summary.ddml_att()`.

`oos_pred` List of matrices, providing the reduced form predicted values.

`learners`,`learners_DX`,`cluster_variable`, `subsamples_D0`,`subsamples_D1`, `cv_subsamples_list_D0`,`cv_subsamples` Pass-through of selected user-provided arguments. See above.

References

Chernozhukov V, Chetverikov D, Demirer M, Duflo E, Hansen C B, Newey W, Robins J (2018). "Double/debiased machine learning for treatment and structural parameters." The Econometrics Journal, 21(1), C1-C68.

Wolpert D H (1992). "Stacked generalization." Neural Networks, 5(2), 241-259.

See Also

`summary.ddml_ate()`, `summary.ddml_att()`

Other ddml: `ddml_fpliv()`, `ddml_late()`, `ddml_pliv()`, `ddml_plm()`

Examples

```
# Construct variables from the included Angrist & Evans (1998) data
y = AE98[, "worked"]
D = AE98[, "morekids"]
X = AE98[, c("age","agefst","black","hisp","othrace","educ")]

# Estimate the average treatment effect using a single base learner, ridge.
ate_fit <- ddml_ate(y, D, X,
                    learners = list(what = mdl_glmnet,
                                    args = list(alpha = 0)),
                    sample_folds = 2,
                    silent = TRUE)
summary(ate_fit)

# Estimate the average treatment effect using short-stacking with base
#     learners ols, lasso, and ridge. We can also use custom_ensemble_weights
#     to estimate the ATE using every individual base learner.
weights_everylearner <- diag(1, 3)
colnames(weights_everylearner) <- c("mdl:ols", "mdl:lasso", "mdl:ridge")
ate_fit <- ddml_ate(y, D, X,
                    learners = list(list(fun = ols),
                                    list(fun = mdl_glmnet),
                                    list(fun = mdl_glmnet,
                                         args = list(alpha = 0))),
                    ensemble_type = 'nnls',
                    custom_ensemble_weights = weights_everylearner,
                    shortstack = TRUE,
                    sample_folds = 2,
                    silent = TRUE)
summary(ate_fit)
```

---

ddml_fpliv — *Estimator for the Flexible Partially Linear IV Model.*

Description

Estimator for the flexible partially linear IV model.

Usage

```
ddml_fpliv(
  y,
  D,
  Z,
  X,
  learners,
  learners_DXZ = learners,
  learners_DX = learners,
  sample_folds = 10,
```

```
  ensemble_type = "nnls",
  shortstack = FALSE,
  cv_folds = 10,
  enforce_LIE = TRUE,
  custom_ensemble_weights = NULL,
  custom_ensemble_weights_DXZ = custom_ensemble_weights,
  custom_ensemble_weights_DX = custom_ensemble_weights,
  cluster_variable = seq_along(y),
  subsamples = NULL,
  cv_subsamples_list = NULL,
  silent = FALSE
)
```

Arguments

`y` The outcome variable.

`D` A matrix of endogenous variables.

`Z` A (sparse) matrix of instruments.

`X` A (sparse) matrix of control variables.

`learners` May take one of two forms, depending on whether a single learner or stacking with multiple learners is used for estimation of the conditional expectation functions. If a single learner is used, `learners` is a list with two named elements:

- `what` The base learner function. The function must be such that it predicts a named input `y` using a named input `X`.
- `args` Optional arguments to be passed to `what`.

If stacking with multiple learners is used, `learners` is a list of lists, each containing four named elements:

- `fun` The base learner function. The function must be such that it predicts a named input `y` using a named input `X`.
- `args` Optional arguments to be passed to `fun`.
- `assign_X` An optional vector of column indices corresponding to control variables in `X` that are passed to the base learner.
- `assign_Z` An optional vector of column indices corresponding to instruments in `Z` that are passed to the base learner.

Omission of the `args` element results in default arguments being used in `fun`. Omission of `assign_X` (and/or `assign_Z`) results in inclusion of all variables in `X` (and/or `Z`).

`learners_DXZ`, `learners_DX`

Optional arguments to allow for different estimators of $E[D|X,Z]$, $E[D|X]$. Setup is identical to `learners`.

`sample_folds` Number of cross-fitting folds.

`ensemble_type` Ensemble method to combine base learners into final estimate of the conditional expectation functions. Possible values are:

- `"nnls"` Non-negative least squares.

- "nnls1" Non-negative least squares with the constraint that all weights sum to one.
- "singlebest" Select base learner with minimum MSPE.
- "ols" Ordinary least squares.
- "average" Simple average over base learners.

Multiple ensemble types may be passed as a vector of strings.

shortstack
: Boolean to use short-stacking.

cv_folds
: Number of folds used for cross-validation in ensemble construction.

enforce_LIE
: Indicator equal to 1 if the law of iterated expectations is enforced in the first stage.

custom_ensemble_weights
: A numerical matrix with user-specified ensemble weights. Each column corresponds to a custom ensemble specification, each row corresponds to a base learner in learners (in chronological order). Optional column names are used to name the estimation results corresponding the custom ensemble specification.

custom_ensemble_weights_DXZ, custom_ensemble_weights_DX
: Optional arguments to allow for different custom ensemble weights for learners_DXZ,learners_DX. Setup is identical to custom_ensemble_weights. Note: custom_ensemble_weights and custom_ensemble_weights_DXZ,custom_ensemble_weights_DX must have the same number of columns.

cluster_variable
: A vector of cluster indices.

subsamples
: List of vectors with sample indices for cross-fitting.

cv_subsamples_list
: List of lists, each corresponding to a subsample containing vectors with subsample indices for cross-validation.

silent
: Boolean to silence estimation updates.

Details

ddml_fpliv provides a double/debiased machine learning estimator for the parameter of interest θ_0 in the partially linear IV model given by

$Y = \theta_0 D + g_0(X) + U,$

where (Y, D, X, Z, U) is a random vector such that $E[U|X, Z] = 0$ and $E[Var(E[D|X, Z]|X)] \neq 0$, and g_0 is an unknown nuisance function.

Value

ddml_fpliv returns an object of S3 class ddml_fpliv. An object of class ddml_fpliv is a list containing the following components:

coef
: A vector with the θ_0 estimates.

weights
: A list of matrices, providing the weight assigned to each base learner (in chronological order) by the ensemble procedure.

mspe
: A list of matrices, providing the MSPE of each base learner (in chronological order) computed by the cross-validation step in the ensemble construction.

`iv_fit` Object of class `ivreg` from the IV regression of $Y - \hat{E}[Y|X]$ on $D - \hat{E}[D|X]$ using $\hat{E}[D|X, Z] - \hat{E}[D|X]$ as the instrument.

`learners`,`learners_DX`,`learners_DXZ`, `cluster_variable`,`subsamples`, `cv_subsamples_list`,`ensemble_type` Pass-through of selected user-provided arguments. See above.

References

Ahrens A, Hansen C B, Schaffer M E, Wiemann T (2024). "Model Averaging and Double Machine Learning." Journal of Applied Econometrics, 40(3): 249-269.

Chernozhukov V, Chetverikov D, Demirer M, Duflo E, Hansen C B, Newey W, Robins J (2018). "Double/debiased machine learning for treatment and structural parameters." The Econometrics Journal, 21(1), C1-C68.

Wolpert D H (1992). "Stacked generalization." Neural Networks, 5(2), 241-259.

See Also

`summary.ddml_fpliv()`, `AER::ivreg()`

Other ddml: `ddml_ate()`, `ddml_late()`, `ddml_pliv()`, `ddml_plm()`

Examples

```
# Construct variables from the included Angrist & Evans (1998) data
y = AE98[, "worked"]
D = AE98[, "morekids"]
Z = AE98[, "samesex", drop = FALSE]
X = AE98[, c("age","agefst","black","hisp","othrace","educ")]

# Estimate the partially linear IV model using a single base learner: Ridge.
fpliv_fit <- ddml_fpliv(y, D, Z, X,
                        learners = list(what = mdl_glmnet,
                                        args = list(alpha = 0)),
                        sample_folds = 2,
                        silent = TRUE)
summary(fpliv_fit)
```

`ddml_late` *Estimator of the Local Average Treatment Effect.*

Description

Estimator of the local average treatment effect.

Usage

```
ddml_late(
  y,
  D,
  Z,
  X,
  learners,
  learners_DXZ = learners,
  learners_ZX = learners,
  sample_folds = 10,
  ensemble_type = "nnls",
  shortstack = FALSE,
  cv_folds = 10,
  custom_ensemble_weights = NULL,
  custom_ensemble_weights_DXZ = custom_ensemble_weights,
  custom_ensemble_weights_ZX = custom_ensemble_weights,
  cluster_variable = seq_along(y),
  subsamples_byZ = NULL,
  cv_subsamples_byZ = NULL,
  trim = 0.01,
  silent = FALSE
)
```

Arguments

`y` The outcome variable.

`D` The binary endogenous variable of interest.

`Z` Binary instrumental variable.

`X` A (sparse) matrix of control variables.

`learners` May take one of two forms, depending on whether a single learner or stacking with multiple learners is used for estimation of the conditional expectation functions. If a single learner is used, `learners` is a list with two named elements:

- `what` The base learner function. The function must be such that it predicts a named input `y` using a named input `X`.
- `args` Optional arguments to be passed to `what`.

If stacking with multiple learners is used, `learners` is a list of lists, each containing four named elements:

- `fun` The base learner function. The function must be such that it predicts a named input `y` using a named input `X`.
- `args` Optional arguments to be passed to `fun`.
- `assign_X` An optional vector of column indices corresponding to control variables in `X` that are passed to the base learner.
- `assign_Z` An optional vector of column indices corresponding to instruments in `Z` that are passed to the base learner.

Omission of the args element results in default arguments being used in fun. Omission of assign_X (and/or assign_Z) results in inclusion of all variables in X (and/or Z).

learners_DXZ, learners_ZX
: Optional arguments to allow for different estimators of $E[D|X, Z]$, $E[Z|X]$. Setup is identical to learners.

sample_folds
: Number of cross-fitting folds.

ensemble_type
: Ensemble method to combine base learners into final estimate of the conditional expectation functions. Possible values are:
  - "nnls" Non-negative least squares.
  - "nnls1" Non-negative least squares with the constraint that all weights sum to one.
  - "singlebest" Select base learner with minimum MSPE.
  - "ols" Ordinary least squares.
  - "average" Simple average over base learners.

  Multiple ensemble types may be passed as a vector of strings.

shortstack
: Boolean to use short-stacking.

cv_folds
: Number of folds used for cross-validation in ensemble construction.

custom_ensemble_weights
: A numerical matrix with user-specified ensemble weights. Each column corresponds to a custom ensemble specification, each row corresponds to a base learner in learners (in chronological order). Optional column names are used to name the estimation results corresponding the custom ensemble specification.

custom_ensemble_weights_DXZ, custom_ensemble_weights_ZX
: Optional arguments to allow for different custom ensemble weights for learners_DXZ,learners_ZX. Setup is identical to custom_ensemble_weights. Note: custom_ensemble_weights and custom_ensemble_weights_DXZ,custom_ensemble_weights_ZX must have the same number of columns.

cluster_variable
: A vector of cluster indices.

subsamples_byZ
: List of two lists corresponding to the two instrument levels. Each list contains vectors with sample indices for cross-fitting.

cv_subsamples_byZ
: List of two lists, each corresponding to one of the two instrument levels. Each of the two lists contains lists, each corresponding to a subsample and contains vectors with subsample indices for cross-validation.

trim
: Number in (0, 1) for trimming the estimated propensity scores at trim and 1-trim.

silent
: Boolean to silence estimation updates.

Details

ddml_late provides a double/debiased machine learning estimator for the local average treatment effect in the interactive model given by

$Y = g_0(D, X) + U,$

where (Y, D, X, Z, U) is a random vector such that $\operatorname{supp} D = \operatorname{supp} Z = \{0, 1\}$, $E[U|X, Z] = 0$, $E[Var(E[D|X, Z]|X)] \neq 0$, $\Pr(Z = 1|X) \in (0, 1)$ with probability 1, $p_0(1, X) \geq p_0(0, X)$ with probability 1 where $p_0(Z, X) \equiv \Pr(D = 1|Z, X)$, and g_0 is an unknown nuisance function.

In this model, the local average treatment effect is defined as

$\theta_0^{\textrm{LATE}} \equiv E[g_0(1, X) - g_0(0, X)|p_0(1, X) > p(0, X)].$

Value

ddml_late returns an object of S3 class ddml_late. An object of class ddml_late is a list containing the following components:

- `late` A vector with the average treatment effect estimates.
- `weights` A list of matrices, providing the weight assigned to each base learner (in chronological order) by the ensemble procedure.
- `mspe` A list of matrices, providing the MSPE of each base learner (in chronological order) computed by the cross-validation step in the ensemble construction.
- `psi_a`, `psi_b` Matrices needed for the computation of scores. Used in summary.ddml_late().
- `oos_pred` List of matrices, providing the reduced form predicted values.
- `learners`,`learners_DXZ`,`learners_ZX`, `cluster_variable`,`subsamples_Z0`, `subsamples_Z1`,`cv_subsamples_list_Z0`, Pass-through of selected user-provided arguments. See above.

References

Ahrens A, Hansen C B, Schaffer M E, Wiemann T (2024). "Model Averaging and Double Machine Learning." Journal of Applied Econometrics, 40(3): 249-269.

Chernozhukov V, Chetverikov D, Demirer M, Duflo E, Hansen C B, Newey W, Robins J (2018). "Double/debiased machine learning for treatment and structural parameters." The Econometrics Journal, 21(1), C1-C68.

Imbens G, Angrist J (1004). "Identification and Estimation of Local Average Treatment Effects." Econometrica, 62(2), 467-475.

Wolpert D H (1992). "Stacked generalization." Neural Networks, 5(2), 241-259.

See Also

summary.ddml_late()

Other ddml: ddml_ate(), ddml_fpliv(), ddml_pliv(), ddml_plm()

Examples

```
# Construct variables from the included Angrist & Evans (1998) data
y = AE98[, "worked"]
D = AE98[, "morekids"]
Z = AE98[, "samesex"]
X = AE98[, c("age","agefst","black","hisp","othrace","educ")]
```

```
# Estimate the local average treatment effect using a single base learner,
#     ridge.
late_fit <- ddml_late(y, D, Z, X,
                      learners = list(what = mdl_glmnet,
                                      args = list(alpha = 0)),
                      sample_folds = 2,
                      silent = TRUE)
summary(late_fit)

# Estimate the local average treatment effect using short-stacking with base
#     learners ols, lasso, and ridge. We can also use custom_ensemble_weights
#     to estimate the ATE using every individual base learner.
weights_everylearner <- diag(1, 3)
colnames(weights_everylearner) <- c("mdl:ols", "mdl:lasso", "mdl:ridge")
late_fit <- ddml_late(y, D, Z, X,
                      learners = list(list(fun = ols),
                                      list(fun = mdl_glmnet),
                                      list(fun = mdl_glmnet,
                                           args = list(alpha = 0))),
                      ensemble_type = 'nnls',
                      custom_ensemble_weights = weights_everylearner,
                      shortstack = TRUE,
                      sample_folds = 2,
                      silent = TRUE)
summary(late_fit)
```

---

ddml_pliv *Estimator for the Partially Linear IV Model.*

Description

Estimator for the partially linear IV model.

Usage

```
ddml_pliv(
  y,
  D,
  Z,
  X,
  learners,
  learners_DX = learners,
  learners_ZX = learners,
  sample_folds = 10,
  ensemble_type = "nnls",
  shortstack = FALSE,
  cv_folds = 10,
  custom_ensemble_weights = NULL,
  custom_ensemble_weights_DX = custom_ensemble_weights,
```

```
  custom_ensemble_weights_ZX = custom_ensemble_weights,
  cluster_variable = seq_along(y),
  subsamples = NULL,
  cv_subsamples_list = NULL,
  silent = FALSE
)
```

Arguments

`y` The outcome variable.

`D` A matrix of endogenous variables.

`Z` A matrix of instruments.

`X` A (sparse) matrix of control variables.

`learners` May take one of two forms, depending on whether a single learner or stacking with multiple learners is used for estimation of the conditional expectation functions. If a single learner is used, `learners` is a list with two named elements:

- `what` The base learner function. The function must be such that it predicts a named input `y` using a named input `X`.
- `args` Optional arguments to be passed to `what`.

If stacking with multiple learners is used, `learners` is a list of lists, each containing four named elements:

- `fun` The base learner function. The function must be such that it predicts a named input `y` using a named input `X`.
- `args` Optional arguments to be passed to `fun`.
- `assign_X` An optional vector of column indices corresponding to control variables in `X` that are passed to the base learner.
- `assign_Z` An optional vector of column indices corresponding to instruments in `Z` that are passed to the base learner.

Omission of the `args` element results in default arguments being used in `fun`. Omission of `assign_X` (and/or `assign_Z`) results in inclusion of all variables in `X` (and/or `Z`).

`learners_DX`, `learners_ZX` Optional arguments to allow for different base learners for estimation of $E[D|X]$, $E[Z|X]$. Setup is identical to `learners`.

`sample_folds` Number of cross-fitting folds.

`ensemble_type` Ensemble method to combine base learners into final estimate of the conditional expectation functions. Possible values are:

- `"nnls"` Non-negative least squares.
- `"nnls1"` Non-negative least squares with the constraint that all weights sum to one.
- `"singlebest"` Select base learner with minimum MSPE.
- `"ols"` Ordinary least squares.
- `"average"` Simple average over base learners.

Multiple ensemble types may be passed as a vector of strings.

shortstack Boolean to use short-stacking.

cv_folds Number of folds used for cross-validation in ensemble construction.

custom_ensemble_weights
A numerical matrix with user-specified ensemble weights. Each column corresponds to a custom ensemble specification, each row corresponds to a base learner in learners (in chronological order). Optional column names are used to name the estimation results corresponding the custom ensemble specification.

custom_ensemble_weights_DX, custom_ensemble_weights_ZX
Optional arguments to allow for different custom ensemble weights for learners_DX,learners_ZX. Setup is identical to custom_ensemble_weights. Note: custom_ensemble_weights and custom_ensemble_weights_DX,custom_ensemble_weights_ZX must have the same number of columns.

cluster_variable
A vector of cluster indices.

subsamples List of vectors with sample indices for cross-fitting.

cv_subsamples_list
List of lists, each corresponding to a subsample containing vectors with subsample indices for cross-validation.

silent Boolean to silence estimation updates.

Details

ddml_pliv provides a double/debiased machine learning estimator for the parameter of interest θ_0 in the partially linear IV model given by

$Y = \theta_0 D + g_0(X) + U,$

where (Y, D, X, Z, U) is a random vector such that $E[Cov(U, Z|X)] = 0$ and $E[Cov(D, Z|X)] \neq 0$, and g_0 is an unknown nuisance function.

Value

ddml_pliv returns an object of S3 class ddml_pliv. An object of class ddml_pliv is a list containing the following components:

coef A vector with the θ_0 estimates.

weights A list of matrices, providing the weight assigned to each base learner (in chronological order) by the ensemble procedure.

mspe A list of matrices, providing the MSPE of each base learner (in chronological order) computed by the cross-validation step in the ensemble construction.

iv_fit Object of class ivreg from the IV regression of $Y - \hat{E}[Y|X]$ on $D - \hat{E}[D|X]$ using $Z - \hat{E}[Z|X]$ as the instrument. See also AER::ivreg() for details.

learners,learners_DX,learners_ZX, cluster_variable, subsamples, cv_subsamples_list,ensemble_type
Pass-through of selected user-provided arguments. See above.

References

Ahrens A, Hansen C B, Schaffer M E, Wiemann T (2024). "Model Averaging and Double Machine Learning." Journal of Applied Econometrics, 40(3): 249-269.

Chernozhukov V, Chetverikov D, Demirer M, Duflo E, Hansen C B, Newey W, Robins J (2018). "Double/debiased machine learning for treatment and structural parameters." The Econometrics Journal, 21(1), C1-C68.

Kleiber C, Zeileis A (2008). Applied Econometrics with R. Springer-Verlag, New York.

Wolpert D H (1992). "Stacked generalization." Neural Networks, 5(2), 241-259.

See Also

summary.ddml_pliv(), AER::ivreg()

Other ddml: ddml_ate(), ddml_fpliv(), ddml_late(), ddml_plm()

Examples

```
# Construct variables from the included Angrist & Evans (1998) data
y = AE98[, "worked"]
D = AE98[, "morekids"]
Z = AE98[, "samesex"]
X = AE98[, c("age","agefst","black","hisp","othrace","educ")]

# Estimate the partially linear IV model using a single base learner, ridge.
pliv_fit <- ddml_pliv(y, D, Z, X,
                      learners = list(what = mdl_glmnet,
                                      args = list(alpha = 0)),
                      sample_folds = 2,
                      silent = TRUE)
summary(pliv_fit)
```

`ddml_plm` *Estimator for the Partially Linear Model.*

Description

Estimator for the partially linear model.

Usage

```
ddml_plm(
  y,
  D,
  X,
  learners,
  learners_DX = learners,
  sample_folds = 10,
  ensemble_type = "nnls",
```

```
  shortstack = FALSE,
  cv_folds = 10,
  custom_ensemble_weights = NULL,
  custom_ensemble_weights_DX = custom_ensemble_weights,
  cluster_variable = seq_along(y),
  subsamples = NULL,
  cv_subsamples_list = NULL,
  silent = FALSE
)
```

Arguments

`y` The outcome variable.

`D` A matrix of endogenous variables.

`X` A (sparse) matrix of control variables.

`learners` May take one of two forms, depending on whether a single learner or stacking with multiple learners is used for estimation of the conditional expectation functions. If a single learner is used, `learners` is a list with two named elements:

- `what` The base learner function. The function must be such that it predicts a named input `y` using a named input `X`.
- `args` Optional arguments to be passed to `what`.

If stacking with multiple learners is used, `learners` is a list of lists, each containing four named elements:

- `fun` The base learner function. The function must be such that it predicts a named input `y` using a named input `X`.
- `args` Optional arguments to be passed to `fun`.
- `assign_X` An optional vector of column indices corresponding to control variables in `X` that are passed to the base learner.

Omission of the `args` element results in default arguments being used in `fun`. Omission of `assign_X` results in inclusion of all variables in `X`.

`learners_DX` Optional argument to allow for different estimators of $E[D|X]$. Setup is identical to `learners`.

`sample_folds` Number of cross-fitting folds.

`ensemble_type` Ensemble method to combine base learners into final estimate of the conditional expectation functions. Possible values are:

- `"nnls"` Non-negative least squares.
- `"nnls1"` Non-negative least squares with the constraint that all weights sum to one.
- `"singlebest"` Select base learner with minimum MSPE.
- `"ols"` Ordinary least squares.
- `"average"` Simple average over base learners.

Multiple ensemble types may be passed as a vector of strings.

`shortstack` Boolean to use short-stacking.

`cv_folds` Number of folds used for cross-validation in ensemble construction.

`custom_ensemble_weights`
A numerical matrix with user-specified ensemble weights. Each column corresponds to a custom ensemble specification, each row corresponds to a base learner in `learners` (in chronological order). Optional column names are used to name the estimation results corresponding the custom ensemble specification.

`custom_ensemble_weights_DX`
Optional argument to allow for different custom ensemble weights for `learners_DX`. Setup is identical to `custom_ensemble_weights`. Note: `custom_ensemble_weights` and `custom_ensemble_weights_DX` must have the same number of columns.

`cluster_variable`
A vector of cluster indices.

`subsamples` List of vectors with sample indices for cross-fitting.

`cv_subsamples_list`
List of lists, each corresponding to a subsample containing vectors with subsample indices for cross-validation.

`silent` Boolean to silence estimation updates.

Details

`ddml_plm` provides a double/debiased machine learning estimator for the parameter of interest θ_0 in the partially linear model given by

$Y = \theta_0 D + g_0(X) + U,$

where (Y, D, X, U) is a random vector such that $E[Cov(U, D|X)] = 0$ and $E[Var(D|X)] \neq 0$, and g_0 is an unknown nuisance function.

Value

`ddml_plm` returns an object of S3 class `ddml_plm`. An object of class `ddml_plm` is a list containing the following components:

`coef` A vector with the θ_0 estimates.

`weights` A list of matrices, providing the weight assigned to each base learner (in chronological order) by the ensemble procedure.

`mspe` A list of matrices, providing the MSPE of each base learner (in chronological order) computed by the cross-validation step in the ensemble construction.

`ols_fit` Object of class `lm` from the second stage regression of $Y - \hat{E}[Y|X]$ on $D - \hat{E}[D|X]$.

`learners`,`learners_DX`,`cluster_variable`, `subsamples`, `cv_subsamples_list`, `ensemble_type`
Pass-through of selected user-provided arguments. See above.

References

Ahrens A, Hansen C B, Schaffer M E, Wiemann T (2024). "Model Averaging and Double Machine Learning." Journal of Applied Econometrics, 40(3): 249-269.

Chernozhukov V, Chetverikov D, Demirer M, Duflo E, Hansen C B, Newey W, Robins J (2018). "Double/debiased machine learning for treatment and structural parameters." The Econometrics Journal, 21(1), C1-C68.

Wolpert D H (1992). "Stacked generalization." Neural Networks, 5(2), 241-259.

See Also

summary.ddml_plm()

Other ddml: ddml_ate(), ddml_fpliv(), ddml_late(), ddml_pliv()

Examples

```
# Construct variables from the included Angrist & Evans (1998) data
y = AE98[, "worked"]
D = AE98[, "morekids"]
X = AE98[, c("age","agefst","black","hisp","othrace","educ")]

# Estimate the partially linear model using a single base learner, ridge.
plm_fit <- ddml_plm(y, D, X,
                    learners = list(what = mdl_glmnet,
                                    args = list(alpha = 0)),
                    sample_folds = 2,
                    silent = TRUE)
summary(plm_fit)

# Estimate the partially linear model using short-stacking with base learners
#     ols, lasso, and ridge. We can also use custom_ensemble_weights
#     to estimate the ATE using every individual base learner.
weights_everylearner <- diag(1, 3)
colnames(weights_everylearner) <- c("mdl:ols", "mdl:lasso", "mdl:ridge")
plm_fit <- ddml_plm(y, D, X,
                    learners = list(list(fun = ols),
                                    list(fun = mdl_glmnet),
                                    list(fun = mdl_glmnet,
                                         args = list(alpha = 0))),
                    ensemble_type = 'nnls',
                    custom_ensemble_weights = weights_everylearner,
                    shortstack = TRUE,
                    sample_folds = 2,
                    silent = TRUE)
summary(plm_fit)
```

---

mdl_glm *Wrapper for* stats::glm().

Description

Simple wrapper for stats::glm().

Usage

```
mdl_glm(y, X, ...)
```

Arguments

y	The outcome variable.
X	The feature matrix.
...	Additional arguments passed to glm. See stats::glm() for a complete list of arguments.

Value

mdl_glm returns an object of S3 class mdl_glm as a simple mask of the return object of stats::glm().

See Also

stats::glm()

Other ml_wrapper: mdl_glmnet(), mdl_ranger(), mdl_xgboost(), ols()

Examples

```
glm_fit <- mdl_glm(sample(0:1, 100, replace = TRUE),
                   matrix(rnorm(1000), 100, 10))
class(glm_fit)
```

---

mdl_glmnet *Wrapper for glmnet::glmnet().*

Description

Simple wrapper for glmnet::glmnet() and glmnet::cv.glmnet().

Usage

```
mdl_glmnet(y, X, cv = TRUE, ...)
```

Arguments

y	The outcome variable.
X	The (sparse) feature matrix.
cv	Boolean to indicate use of lasso with cross-validated penalty.
...	Additional arguments passed to glmnet. See glmnet::glmnet() and glmnet::cv.glmnet() for a complete list of arguments.

Value

mdl_glmnet returns an object of S3 class mdl_glmnet as a simple mask of the return object of glmnet::glmnet() or glmnet::cv.glmnet().

References

Friedman J, Hastie T, Tibshirani R (2010). "Regularization Paths for Generalized Linear Models via Coordinate Descent." Journal of Statistical Software, 33(1), 1–22.

Simon N, Friedman J, Hastie T, Tibshirani R (2011). "Regularization Paths for Cox's Proportional Hazards Model via Coordinate Descent." Journal of Statistical Software, 39(5), 1–13.

See Also

glmnet::glmnet(),glmnet::cv.glmnet()

Other ml_wrapper: mdl_glm(), mdl_ranger(), mdl_xgboost(), ols()

Examples

```
glmnet_fit <- mdl_glmnet(rnorm(100), matrix(rnorm(1000), 100, 10))
class(glmnet_fit)
```

---

mdl_ranger *Wrapper for* ranger::ranger().

Description

Simple wrapper for ranger::ranger(). Supports regression (default) and probability forests (set probability = TRUE).

Usage

```
mdl_ranger(y, X, ...)
```

Arguments

y	The outcome variable.
X	The feature matrix.
...	Additional arguments passed to ranger. See ranger::ranger() for a complete list of arguments.

Value

mdl_ranger returns an object of S3 class ranger as a simple mask of the return object of ranger::ranger().

References

Wright M N, Ziegler A (2017). "ranger: A fast implementation of random forests for high dimensional data in C++ and R." Journal of Statistical Software 77(1), 1-17.

See Also

ranger::ranger()

Other ml_wrapper: mdl_glm(), mdl_glmnet(), mdl_xgboost(), ols()

Examples

```
ranger_fit <- mdl_ranger(rnorm(100), matrix(rnorm(1000), 100, 10))
class(ranger_fit)
```

---

mdl_xgboost *Wrapper for xgboost::xgboost().*

Description

Simple wrapper for xgboost::xgboost() with some changes to the default arguments.

Usage

```
mdl_xgboost(y, X, nrounds = 500, verbosity = 0, ...)
```

Arguments

y	The outcome variable.
X	The (sparse) feature matrix.
nrounds	Number of boosting iterations / rounds. Note that the number of default boosting rounds here is not automatically tuned, and different problems will have vastly different optimal numbers of boosting rounds.
verbosity	Verbosity of printing messages. Valid values of 0 (silent), 1 (warning), 2 (info), and 3 (debug).
...	Additional arguments passed to xgboost. See xgboost::xgboost() for a complete list of arguments.

Value

mdl_xgboost returns an object of S3 class mdl_xgboost as a simple mask to the return object of xgboost::xgboost().

References

Chen T, Guestrin C (2011). "Xgboost: A Scalable Tree Boosting System." Proceedings of the 22nd ACM SIGKDD International Conference on Knowledge Discovery and Data Mining, 785–794.

See Also

xgboost::xgboost()

Other ml_wrapper: mdl_glm(), mdl_glmnet(), mdl_ranger(), ols()

Examples

```
xgboost_fit <- mdl_xgboost(rnorm(50), matrix(rnorm(150), 50, 3),
                           nrounds = 1)
class(xgboost_fit)
```

`ols` *Ordinary least squares.*

Description

Simple implementation of ordinary least squares that computes with sparse feature matrices.

Usage

```
ols(y, X, const = TRUE, w = NULL)
```

Arguments

`y`	The outcome variable.
`X`	The feature matrix.
`const`	Boolean equal to `TRUE` if a constant should be included.
`w`	A vector of weights for weighted least squares.

Value

`ols` returns an object of S3 class `ols`. An object of class `ols` is a list containing the following components:

`coef` A vector with the regression coefficents.

`y`, `X`, `const`, `w` Pass-through of the user-provided arguments. See above.

See Also

Other ml_wrapper: `mdl_glm()`, `mdl_glmnet()`, `mdl_ranger()`, `mdl_xgboost()`

Examples

```
ols_fit <- ols(rnorm(100), cbind(rnorm(100), rnorm(100)), const = TRUE)
ols_fit$coef
```

---

print.summary.ddml_ate *Print Methods for Treatment Effect Estimators.*

Description

Print methods for treatment effect estimators.

Usage

```
## S3 method for class 'summary.ddml_ate'
print(x, digits = 3, ...)

## S3 method for class 'summary.ddml_att'
print(x, digits = 3, ...)

## S3 method for class 'summary.ddml_late'
print(x, digits = 3, ...)
```

Arguments

x	An object of class summary.ddml_ate, summary.ddml_att, and ddml_late, as returned by summary.ddml_ate(), summary.ddml_att(), and summary.ddml_late(), respectively.
digits	The number of significant digits used for printing.
...	Currently unused.

Value

NULL.

Examples

```
# Construct variables from the included Angrist & Evans (1998) data
y = AE98[, "worked"]
D = AE98[, "morekids"]
X = AE98[, c("age","agefst","black","hisp","othrace","educ")]

# Estimate the average treatment effect using a single base learner, ridge.
ate_fit <- ddml_ate(y, D, X,
                    learners = list(what = mdl_glmnet,
                                    args = list(alpha = 0)),
                    sample_folds = 2,
                    silent = TRUE)
summary(ate_fit)
```

`print.summary.ddml_fpliv`

Print Methods for Treatment Effect Estimators.

Description

Print methods for treatment effect estimators.

Usage

```
## S3 method for class 'summary.ddml_fpliv'
print(x, digits = 3, ...)

## S3 method for class 'summary.ddml_pliv'
print(x, digits = 3, ...)

## S3 method for class 'summary.ddml_plm'
print(x, digits = 3, ...)
```

Arguments

x	An object of class `summary.ddml_plm`, `summary.ddml_pliv`, and `summary.ddml_fpliv`, as returned by `summary.ddml_plm()`, `summary.ddml_pliv()`, and `summary.ddml_fpliv()`, respectively.
digits	Number of significant digits used for priniting.
...	Currently unused.

Value

NULL.

Examples

```
# Construct variables from the included Angrist & Evans (1998) data
y = AE98[, "worked"]
D = AE98[, "morekids"]
X = AE98[, c("age","agefst","black","hisp","othrace","educ")]

# Estimate the partially linear model using a single base learner, ridge.
plm_fit <- ddml_plm(y, D, X,
                    learners = list(what = mdl_glmnet,
                                    args = list(alpha = 0)),
                    sample_folds = 2,
                    silent = TRUE)
summary(plm_fit)
```

shortstacking *Predictions using Short-Stacking.*

Description

Predictions using short-stacking.

Usage

```
shortstacking(
  y,
  X,
  Z = NULL,
  learners,
  sample_folds = 2,
  ensemble_type = "average",
  custom_ensemble_weights = NULL,
  compute_insample_predictions = FALSE,
  subsamples = NULL,
  silent = FALSE,
  progress = NULL,
  auxiliary_X = NULL,
  shortstack_y = y
)
```

Arguments

`y` The outcome variable.

`X` A (sparse) matrix of predictive variables.

`Z` Optional additional (sparse) matrix of predictive variables.

`learners` May take one of two forms, depending on whether a single learner or stacking with multiple learners is used for estimation of the predictor. If a single learner is used, `learners` is a list with two named elements:

- `what` The base learner function. The function must be such that it predicts a named input `y` using a named input `X`.
- `args` Optional arguments to be passed to `what`.

If stacking with multiple learners is used, `learners` is a list of lists, each containing four named elements:

- `fun` The base learner function. The function must be such that it predicts a named input `y` using a named input `X`.
- `args` Optional arguments to be passed to `fun`.
- `assign_X` An optional vector of column indices corresponding to predictive variables in `X` that are passed to the base learner.
- `assign_Z` An optional vector of column indices corresponding to predictive in `Z` that are passed to the base learner.

Omission of the args element results in default arguments being used in fun. Omission of assign_X (and/or assign_Z) results in inclusion of all variables in X (and/or Z).

sample_folds
: Number of cross-fitting folds.

ensemble_type
: Ensemble method to combine base learners into final estimate of the conditional expectation functions. Possible values are:
  - "nnls" Non-negative least squares.
  - "nnls1" Non-negative least squares with the constraint that all weights sum to one.
  - "singlebest" Select base learner with minimum MSPE.
  - "ols" Ordinary least squares.
  - "average" Simple average over base learners.

  Multiple ensemble types may be passed as a vector of strings.

custom_ensemble_weights
: A numerical matrix with user-specified ensemble weights. Each column corresponds to a custom ensemble specification, each row corresponds to a base learner in learners (in chronological order). Optional column names are used to name the estimation results corresponding the custom ensemble specification.

compute_insample_predictions
: Indicator equal to 1 if in-sample predictions should also be computed.

subsamples
: List of vectors with sample indices for cross-fitting.

silent
: Boolean to silence estimation updates.

progress
: String to print before learner and cv fold progress.

auxiliary_X
: An optional list of matrices of length sample_folds, each containing additional observations to calculate predictions for.

shortstack_y
: Optional vector of the outcome variable to form short-stacking predictions for. Base learners are always trained on y.

Value

shortstack returns a list containing the following components:

oos_fitted A matrix of out-of-sample predictions, each column corresponding to an ensemble type (in chronological order).

weights An array, providing the weight assigned to each base learner (in chronological order) by the ensemble procedures.

is_fitted When compute_insample_predictions = T. a list of matrices with in-sample predictions by sample fold.

auxiliary_fitted When auxiliary_X is not NULL, a list of matrices with additional predictions.

oos_fitted_bylearner A matrix of out-of-sample predictions, each column corresponding to a base learner (in chronological order).

is_fitted_bylearner When compute_insample_predictions = T, a list of matrices with in-sample predictions by sample fold.

auxiliary_fitted_bylearner When auxiliary_X is not NULL, a list of matrices with additional predictions for each learner.

Note that unlike crosspred, shortstack always computes out-of-sample predictions for each base learner (at no additional computational cost).

References

Ahrens A, Hansen C B, Schaffer M E, Wiemann T (2024). "Model Averaging and Double Machine Learning." Journal of Applied Econometrics, 40(3): 249-269.

Wolpert D H (1992). "Stacked generalization." Neural Networks, 5(2), 241-259.

See Also

Other utilities: crosspred(), crossval()

Examples

```
# Construct variables from the included Angrist & Evans (1998) data
y = AE98[, "worked"]
X = AE98[, c("morekids", "age","agefst","black","hisp","othrace","educ")]

# Compute predictions using shortstacking with base learners ols and lasso.
#     Two stacking approaches are simultaneously computed: Equally
#     weighted (ensemble_type = "average") and MSPE-minimizing with weights
#     in the unit simplex (ensemble_type = "nnls1"). Predictions for each
#     learner are also calculated.
shortstack_res <- shortstacking(y, X,
                                learners = list(list(fun = ols),
                                                list(fun = mdl_glmnet)),
                                ensemble_type = c("average",
                                                  "nnls1",
                                                  "singlebest"),
                                sample_folds = 2,
                                silent = TRUE)
dim(shortstack_res$oos_fitted) # = length(y) by length(ensemble_type)
dim(shortstack_res$oos_fitted_bylearner) # = length(y) by length(learners)
```

---

summary.ddml_ate *Inference Methods for Treatment Effect Estimators.*

Description

Inference methods for treatment effect estimators. By default, standard errors are heteroskedasiticty-robust. If the ddml estimator was computed using a cluster_variable, the standard errors are also cluster-robust by default.

Usage

```
## S3 method for class 'ddml_ate'
summary(object, ...)

## S3 method for class 'ddml_att'
summary(object, ...)

## S3 method for class 'ddml_late'
summary(object, ...)
```

Arguments

object	An object of class ddml_ate, ddml_att, and ddml_late, as fitted by ddml_ate(), ddml_att(), and ddml_late(), respectively.
...	Currently unused.

Value

A matrix with inference results.

Examples

```
# Construct variables from the included Angrist & Evans (1998) data
y = AE98[, "worked"]
D = AE98[, "morekids"]
X = AE98[, c("age","agefst","black","hisp","othrace","educ")]

# Estimate the average treatment effect using a single base learner, ridge.
ate_fit <- ddml_ate(y, D, X,
                    learners = list(what = mdl_glmnet,
                                    args = list(alpha = 0)),
                    sample_folds = 2,
                    silent = TRUE)
summary(ate_fit)
```

---

summary.ddml_fpliv *Inference Methods for Partially Linear Estimators.*

Description

Inference methods for partially linear estimators. Simple wrapper for sandwich::vcovHC() and sandwich::vcovCL(). Default standard errors are heteroskedasiticty-robust. If the ddml estimator was computed using a cluster_variable, the standard errors are also cluster-robust by default.

Usage

```
## S3 method for class 'ddml_fpliv'
summary(object, ...)

## S3 method for class 'ddml_pliv'
summary(object, ...)

## S3 method for class 'ddml_plm'
summary(object, ...)
```

Arguments

`object`	An object of class `ddml_plm`, `ddml_pliv`, or `ddml_fpliv` as fitted by `ddml_plm()`, `ddml_pliv()`, and `ddml_fpliv()`, respectively.
`...`	Additional arguments passed to `vcovHC` and `vcovCL`. See `sandwich::vcovHC()` and `sandwich::vcovCL()` for a complete list of arguments.

Value

An array with inference results for each `ensemble_type`.

References

Zeileis A (2004). "Econometric Computing with HC and HAC Covariance Matrix Estimators." Journal of Statistical Software, 11(10), 1-17.

Zeileis A (2006). "Object-Oriented Computation of Sandwich Estimators." Journal of Statistical Software, 16(9), 1-16.

Zeileis A, Köll S, Graham N (2020). "Various Versatile Variances: An Object-Oriented Implementation of Clustered Covariances in R." Journal of Statistical Software, 95(1), 1-36.

See Also

`sandwich::vcovHC()`, `sandwich::vcovCL()`

Examples

```
# Construct variables from the included Angrist & Evans (1998) data
y = AE98[, "worked"]
D = AE98[, "morekids"]
X = AE98[, c("age","agefst","black","hisp","othrace","educ")]

# Estimate the partially linear model using a single base learner, ridge.
plm_fit <- ddml_plm(y, D, X,
                    learners = list(what = mdl_glmnet,
                                    args = list(alpha = 0)),
                    sample_folds = 2,
                    silent = TRUE)
summary(plm_fit)
```

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