

Package ‘DirectEffects’

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Title Estimating Controlled Direct Effects for Explaining Causal Findings

Imports stats, Formula, glue, Matching, generics, rlang, broom

Depends R (>= 3.5.0)

Suggests knitr, rmarkdown, dplyr, tidyverse, ggplot2, reshape2, scales, testthat, nnet, glmnet, hdm, ranger

Description A set of functions to estimate the controlled direct effect of treatment fixing a potential mediator to a specific value. Implements the sequential g-estimation estimator described in Vansteelandt (2009) <[doi:10.1097/EDE.0b013e3181b6f4c9](https://doi.org/10.1097/EDE.0b013e3181b6f4c9)> and Acharya, Blackwell, and Sen (2016) <[doi:10.1017/S0003055416000216](https://doi.org/10.1017/S0003055416000216)> and the telescope matching estimator described in Blackwell and Strezhnev (2020) <[doi:10.1111/rssa.12759](https://doi.org/10.1111/rssa.12759)>.

License GPL (>= 2)

URL <https://mattblackwell.github.io/DirectEffects/>

BugReports <https://github.com/mattblackwell/DirectEffects/issues>

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balance.tmatch	<i>Balance diagnostics for Telescope Match objects</i>
----------------	--

Description

Balance diagnostics for Telescope Match objects

Usage

```
balance.tmatch(object, vars, data, comparison = NULL)
```

Arguments

object	an object of class <code>tmatch</code> – results from a call to <code>telescope_match</code>
vars	a formula object containing either the treatment or the mediator as the dependent variable (which denotes whether first-stage or second-stage balance diagnostics are returned) and the covariates for which balance diagnostics are requested as the independent variables. Each covariate or function of covariates (e.g. higher-order polynomials or interactions) should be separated by a <code>+</code> .

data	the data frame used in the call to telescope_match
comparison	a binary indicator for if the function should return the balance for the treated group ('1'), for the control group ('0'), or for overall combined balanced ('NULL', the default).

Details

Provides matching balance diagnostics for tmatch objects returned by telescope_match

Value

Returns a data frame with the following columns.

- variable: Name of covariate
- before_0: Pre-matching average of the covariate in the mediator == 0 (if first stage balance) or treatment == 0 (if second stage balance) condition
- before_1: Pre-matching average of the covariate in the mediator == 1 (if first stage balance) or treatment == 1 (if second stage balance) condition
- after_0: Post-matching average of the covariate in the mediator == 0 (if first stage balance) or treatment == 0 (if second stage balance) condition
- after_1: Post-matching average of the covariate in the mediator == 1 (if first stage balance) or treatment == 1 (if second stage balance) condition
- before_sd: standard deviation of the outcome (pre-Matching)
- before_diff: Pre-matching covariate difference between mediator arms (if first stage balance) or treatment arms (if second stage balance).
- before_std_diff: Pre-matching standardized covariate difference between mediator arms (if first stage balance) or treatment arms (if second stage balance), Equal to Before_Diff/SD.
- after_diff: Post-matching covariate difference between mediator arms (if first stage balance) or treatment arms (if second stage balance).
- after_std_diff: Post-matching standardized covariate difference between mediator arms (if first stage balance) or treatment arms (if second stage balance), Equal to Before_Diff/SD.

balance_table

Balance diagnostics telescope matching

Description

Provides matching balance diagnostics for telescope matching CDE estimators

Usage

```
balance_table(object, vars, data, comparison = NULL)
```

Arguments

object	output from an estimated <code>cde_telescope_match</code> estimator
vars	a formula object containing either the treatment or the mediator as the dependent variable (which denotes whether first-stage or second-stage balance diagnostics are returned) and the covariates for which balance diagnostics are requested as the independent variables. Each covariate or function of covariates (e.g. higher-order polynomials or interactions) should be separated by a <code>+</code> .
data	the data frame used in the call to estimate on the <code>cde_telescope_match</code> object.
comparison	a binary indicator for if the function should return the balance for the treated group (<code>'1'</code>), for the control group (<code>'0'</code>), or for overall combined balanced (<code>'NULL'</code> , the default).

Value

Returns a data frame with the following columns.

- `variable`: Name of covariate
- `before_0`: Pre-matching average of the covariate in the mediator == 0 (if first stage balance) or treatment == 0 (if second stage balance) condition
- `before_1`: Pre-matching average of the covariate in the mediator == 1 (if first stage balance) or treatment == 1 (if second stage balance) condition
- `after_0`: Post-matching average of the covariate in the mediator == 0 (if first stage balance) or treatment == 0 (if second stage balance) condition
- `after_1`: Post-matching average of the covariate in the mediator == 1 (if first stage balance) or treatment == 1 (if second stage balance) condition
- `before_sd`: standard deviation of the outcome (pre-Matching)
- `before_diff`: Pre-matching covariate difference between mediator arms (if first stage balance) or treatment arms (if second stage balance).
- `before_std_diff`: Pre-matching standardized covariate difference between mediator arms (if first stage balance) or treatment arms (if second stage balance), Equal to `Before_Diff/SD`.
- `after_diff`: Post-matching covariate difference between mediator arms (if first stage balance) or treatment arms (if second stage balance).
- `after_std_diff`: Post-matching standardized covariate difference between mediator arms (if first stage balance) or treatment arms (if second stage balance), Equal to `Before_Diff/SD`.

 boots_g

Coefficient Estimates across Bootstrapped Samples

Description

Performs a simple bootstrap of a fitted `DirectEffects` model by re-estimating the model with bootstrap samples.

Usage

```
boots_g(seqg, boots = 1000)
```

Arguments

seqg A fitted sequential_g estimate, computed by [sequential_g](#).
boots The number of bootstrap replicates. Defaults to 1000.

Value

An object of type seqgboots which is a matrix with boots rows and columns for each coefficient in the seqg model. Use summary to provide summary statistics, such as mean and quantiles.

Examples

```
data(ploughs)
s1 <- sequential_g(women_politics ~ plow +
  agricultural_suitability + tropical_climate + large_animals + rugged |
  years_civil_conflict + years_interstate_conflict + oil_pc +
  european_descent + communist_dummy + polity2_2000 |
  centered_ln_inc + centered_ln_incsq, ploughs)

out.boots <- boots_g(s1, boots = 100)

summary(out.boots)
```

 boots_tm

Bootstrap Uncertainty Estimates for Telescope Matching

Description

Performs a weighted bootstrap procedure for the output of [telescope_match](#).

Usage

```
boots_tm(obj, boots = 1000, ci_alpha = 0.05)
```

Arguments

obj A tmatch object, computed by [telescope_match](#).
boots The number of bootstrap replicates. Defaults to 1000.
ci_alpha alpha value for the bootstrapped confidence intervals. Corresponds to a 100 * (1-alpha) confidence interval.

Value

An `data.frame` with columns `'ci_low'` and `'ci_high'` which contain the bootstrapped confidence intervals for the estimated ACDEs in `obj$tau`.

Examples

```
data(jobcorps)

## Split male/female
jobcorps_female <- subset(jobcorps, female == 1)

## Telescope matching formula - First stage (X and Z)
tm_form <- exhealth30 ~ schobef + trainyrbef + jobeverbef |
  treat | emplq4 + emplq4full | work2year2q

### Estimate ACDE for women holding employment at 0
tm_out <- telescope_match(
  tm_form,
  data = jobcorps_female,
  L = 3,
  boot = FALSE,
  verbose = TRUE
)

out.boots <- boots_tm(tm_out)

out.boots
```

cdesens	<i>Estimate sensitivity of ACDE estimates under varying levels of unobserved confounding</i>
---------	--

Description

Estimate how the Average Controlled Direct Effect varies by various levels of unobserved confounding. For each value of unmeasured confounding, summarized as a correlation between residuals, `cdesens` computes the ACDE. Standard errors are computed by a simple bootstrap.

Usage

```
cdesens(
  seqg,
  var,
  rho = seq(-0.9, 0.9, by = 0.05),
  bootstrap = c("none", "standard"),
  boots_n = 1000,
  verbose = FALSE,
```

```
    ...
  )
```

Arguments

seqg	Output from sequential_g. The function only supports specifications with one mediator variable.
var	A character indicating the name of the variable for which the estimated ACDE is being evaluated.
rho	A numerical vector of correlations between errors to test for. The original model assumes $\rho = 0$
bootstrap	character of c("none", "standard"), indicating whether to include bootstrap standard errors. Default is "none".
boots_n	Number of bootstrap replicates, defaults to 100.
verbose	Whether to show progress and messages, defaults to FALSE
...	Other parameters to pass on to <code>lm.fit()</code> when refitting the model

Examples

```
data(civilwar)

# main formula: Y ~ A + X | Z | M
form_main <- onset ~ ethfrac + lmtnest + ncontig + Oil | war1 +
  gdpenl + lpop + polity2l + relfrac | instab

# estimate CDE
direct <- sequential_g(form_main, data = civilwar)

# sensitivity
out_sens <- cdesens(direct, var = "ethfrac")

# plot sensitivity
plot(out_sens)
```

cde_aipw

Initialize an AIPW CDE estimator

Description

Initializes the specification of a CDE estimator based on an augmented inverse probability weighting approach.

Usage

```
cde_aipw(trim = c(0.01, 0.99), aipw_blip = TRUE)
```

Arguments

trim	A vector of length 2 indicating what quantiles of the propensity scores should be trimmed. By default this is $c(0.01, 0.99)$ meaning that the top and bottom 1% of propensity scores are truncated to these quantiles. If NULL, no trimming occurs.
aipw_blip	If TRUE (the default), augmented inverse probability weighting estimators will be used to estimate intermediate outcome regressions (blip functions).

cde_did_aipw	<i>Initialize an AIPW DID-CDE estimator</i>
--------------	---

Description

Initializes the specification of a difference-in-differences estimator for the CDE based on an augmented inverse probability weighting.

Usage

```
cde_did_aipw(
  base_mediator,
  trim = c(0.01, 0.99),
  aipw_blip = TRUE,
  on_treated = FALSE
)
```

Arguments

base_mediator	The (unquoted) name of the variable that measures the mediator at baseline.
trim	A vector of length 2 indicating what quantiles of the propensity scores should be trimmed. By default this is $c(0.01, 0.99)$ meaning that the top and bottom 1% of propensity scores are truncated to these quantiles. If NULL, no trimming occurs.
aipw_blip	If TRUE (the default), augmented inverse probability weighting estimators will be used to estimate intermediate outcome regressions (blip functions).
on_treated	If FALSE (the default), the effects are average effects conditional on the levels of the baseline mediator. If TRUE, the effects are conditional on the treated path. For difference in identification, see Details below.

Details

This function, unlike other CDE estimators in the package, only returns the estimated effects of the first treatment variable. These effects are conditional on the baseline value of the mediator (`base_mediator`) when `on_treated` is TRUE. A marginalized CDE estimand is also estimated. When `on_treated` is FALSE, these estimates are conditional on the entire "treated" history. Identification requirements are slightly different between these two cases. When `on_treated` is FALSE, the confounders for the mediator cannot be affected by treatment. See Blackwell et al (2022) for more information.

cde_ipw	<i>Initialize an IPW CDE estimator</i>
---------	--

Description

Initializes the specification of a CDE estimator based on an inverse probability weighting approach.

Usage

```
cde_ipw(hajek = TRUE, trim = c(0.01, 0.99))
```

Arguments

hajek	If TRUE, normalized weights will be used as in the Hajek estimator. If FALSE, traditional IPW weights will be used.
trim	A vector of length 2 indicating what quantiles of the propensity scores should be trimmed. By default this is <code>c(0.01, 0.99)</code> meaning that the top and bottom 1% of propensity scores are truncated to these quantiles. If NULL, no trimming occurs.

cde_reg_impute	<i>Initialize an regression imputation CDE estimator</i>
----------------	--

Description

Initializes the specification of a CDE estimator based on an regression imputation approach

Usage

```
cde_reg_impute(...)
```

Arguments

... Optional arguments to pass to the regression imputation estimator.

cde_telescope_match *Initialize an telescope matching CDE estimator*

Description

Initializes the specification of a CDE estimator based on an telescope matching approach

Usage

```
cde_telescope_match(...)
```

Arguments

... Optional arguments to pass to the telescope matching estimator.

civilwar *Data on civil wars and internal conflict from 1945-1999.*

Description

A dataset to replicate the analysis in Fearon and Laitin (2003).

A dataset to replicate the analysis in Fearon and Laitin (2003).

Usage

```
data(civilwar)
```

```
data(civilwar)
```

Format

A data frame with 6610 observations and 69 variables.

A data frame with 6610 observations and 69 variables.

Details

- ccode. COW country id number
- country. country name
- cname. abbreviated country name
- cmark. 1 for first in each country series
- year. start year of war/conflict
- wars. number wars in progress in country year
- war. 1 if war ongoing in country year

- warl. lagged war, w/ 0 for start of country series
- onset. 1 for civil war onset
- ethonset. 1 if onset = 1 & ethwar != 0
- durest. estimated war duration
- aim. 1 = rebels aim at center, 3 = aim at exit or autonomy, 2 = mixed or ambig.
- casename. Id for case, usually name of rebel group(s)
- ended. war ends = 1, 0 = ongoing
- ethwar. 0 = not ethnic, 1 = ambig/mixed, 2 = ethnic
- waryrs. war years for each onset
- pop. population, in 1000s
- lpop. log of pop
- polity2. revised polity score
- gdpen. gdp/pop based on pwt5.6, wdi2001, cow energy data
- gdptype. source/type of gdp/pop estimate
- gdpenl. lagged gdpenl, except for first in country series
- lgdpenl1. log of lagged gdpen
- lpopl1. log population, lagged except for first in country series
- region. country's region, based on MAR project
- western. Dummy for Western Democracies & Japan
- eeurop. Dummy for Eastern Europe
- lamerica. Dummy for Latin America
- ssafrica. Dummy for Sub-Saharan Africa
- asia. Dummy for Asia (not including Japan)
- nafrme. Dummy for North Africa/Middle East
- colbrit. Former British colony
- colfra. former French colony
- mtneest. Estimated percent mountainous terrain
- lmtneest. log of mtneest
- elevdiff. high - low elevation, in meters
- Oil. more than 1/3 export revenues from fuels
- ncontig. noncontiguous state
- ethfrac. ethnic frac. based on Soviet Atlas, plus estimates for missing in 1964
- ef. ethnic fractionalization based on Fearon 2002 APSA paper
- plural. share of largest ethnic group (Fearon 2002 APSA)
- second. share of 2nd largest ethnic group (Fearon 2002 APSA)
- numlang. number languages in Ethnologue > min(1
- relfrac. religious fractionalization

- plurrel. size of largest confession
- minrelpc. size of second largest confession
- muslim. percent muslim
- nwstate. 1 in 1st 2 years of state's existence
- polity2l. lagged polity2, except 1st in country series
- instab. > 2 change in Polity measure in last 3 yrs
- anocl. lagged anocracy ($-6 < polity2l < 6$)
- deml. lagged democracy ($polity2l > 5$)
- empethfrac. ethfrac coded for colonial empires
- empwarl. warl coded for data with empires
- emponset. onset coded for data with empires
- empgdpenl. gdpenl coded for empires data
- emplpopl. lpopl coded for empires data
- emplmtnest. lmtnest coded for empires data
- empncontig. ncontig coded for empires
- empolity2l. polity2l adjusted for empires (see fn38 in paper)
- sdwars. number Sambanis/Doyle civ wars in progress
- sdonset. onset of Sambanis/Doyle war
- colwars. number Collier/Hoeffler wars in progress
- colonset. onset of Collier/Hoeffler war
- cowwars. number COW civ wars in progress
- cowonset. onset of COW civ war
- cowwarl. 1 if COW war ongoing in last period
- sdwarl. 1 if S/D war ongoing in last period
- colwarl. 1 if C/H war ongoing in last period

- ccode. COW country id number
- country. country name
- cname. abbreviated country name
- cmark. 1 for first in each country series
- year. start year of war/conflict
- wars. number wars in progress in country year
- war. 1 if war ongoing in country year
- warl. lagged war, w/ 0 for start of country series
- onset. 1 for civil war onset
- ethonset. 1 if onset = 1 & ethwar ~= 0
- durest. estimated war duration
- aim. 1 = rebels aim at center, 3 = aim at exit or autonomy, 2 = mixed or ambig.

- casename. Id for case, usually name of rebel group(s)
- ended. war ends = 1, 0 = ongoing
- ethwar. 0 = not ethnic, 1 = ambig/mixed, 2 = ethnic
- waryrs. war years for each onset
- pop. population, in 1000s
- lpop. log of pop
- polity2. revised polity score
- gdpen. gdp/pop based on pwt5.6, wdi2001, cow energy data
- gdptype. source/type of gdp/pop estimate
- gdpenl. lagged gdpen, except for first in country series
- lgdpenl. log of lagged gdpen
- lpopl. log population, lagged except for first in country series
- region. country's region, based on MAR project
- western. Dummy for Western Democracies & Japan
- eeuro. Dummy for Eastern Europe
- lamerica. Dummy for Latin America
- ssafrika. Dummy for Sub-Saharan Africa
- asia. Dummy for Asia (not including Japan)
- nafme. Dummy for North Africa/Middle East
- colbrit. Former British colony
- colfra. former French colony
- mtnest. Estimated percent mountainous terrain
- lmtnest. log of mtnest
- elevdiff. high - low elevation, in meters
- Oil. more than 1/3 export revenues from fuels
- ncontig. noncontiguous state
- ethfrac. ethnic frac. based on Soviet Atlas, plus estimates for missing in 1964
- ef. ethnic fractionalization based on Fearon 2002 APSA paper
- plural. share of largest ethnic group (Fearon 2002 APSA)
- second. share of 2nd largest ethnic group (Fearon 2002 APSA)
- numlang. number languages in Ethnologue > min(1
- relfrac. religious fractionalization
- plurrel. size of largest confession
- minrelpc. size of second largest confession
- muslim. percent muslim
- nwstate. 1 in 1st 2 years of state's existence
- polity2l. lagged polity2, except 1st in country series

- instab. > 2 change in Polity measure in last 3 yrs
- anocl. lagged anocracy (-6 < polity2l < 6)
- deml. lagged democracy (polity2l > 5)
- empethfrac. ethfrac coded for colonial empires
- empwarl. warl coded for data with empires
- emponset. onset coded for data with empires
- empgdpenl. gdpenl coded for empires data
- emplpopl. lpopl coded for empires data
- emplmtnest. lmtnest coded for empires data
- empncontig. ncontig coded for empires
- empolity2l. polity2l adjusted for empires (see fn38 in paper)
- sdwars. number Sambanis/Doyle civ wars in progress
- sdonset. onset of Sambanis/Doyle war
- colwars. number Collier/Hoeffler wars in progress
- colonset. onset of Collier/Hoeffler war
- cowwars. number COW civ wars in progress
- cowonset. onset of COW civ war
- cowwarl. 1 if COW war ongoing in last period
- sdwarl. 1 if S/D war ongoing in last period
- colwarl. 1 if C/H war ongoing in last period

Source

[doi:10.1017/S0003055403000534](https://doi.org/10.1017/S0003055403000534)

[doi:10.1017/S0003055403000534](https://doi.org/10.1017/S0003055403000534)

References

Fearon, James D., and David A. Laitin (2003). Ethnicity, Insurgency, and Civil War. *American Political Science Review*, 97(1), 75-90. [doi:10.1017/S0003055403000534](https://doi.org/10.1017/S0003055403000534)

Fearon, James D., and David A. Laitin (2003). Ethnicity, Insurgency, and Civil War. *American Political Science Review*, 97(1), 75-90. [doi:10.1017/S0003055403000534](https://doi.org/10.1017/S0003055403000534)

estimate	<i>Fit a specified CDE estimator</i>
----------	--------------------------------------

Description

Fit a CDE estimator with the engines specified in the `model_spec` object.

Usage

```
estimate(
  object,
  formula,
  data,
  subset,
  crossfit = TRUE,
  n_folds,
  n_splits = 1L
)
```

Arguments

<code>object</code>	A <code>cde_estimator</code> object that has already been passed to at least one call to <code>set_treatment</code> .
<code>formula</code>	A formula object with describing the outcome of interest on the left-hand side and the treatment variables the user wants to estimate effects for (which might be a subset of the treatment variables specified).
<code>data</code>	A <code>data.frame</code> containing all variables, including treatment variables and co-variates specified.
<code>subset</code>	An optional vector specifying a subset of observations to be used in the fitting process.
<code>crossfit</code>	A logical indicator for if cross-fitting should be used in estimating the effects.
<code>n_folds</code>	The number of folds to use within a given instance of the cross-fitting algorithm.
<code>n_splits</code>	The number of times the cross-fitting procedure should be repeated. Overall estimates use the median value of these repeated estimates.

<code>jobcorps</code>	<i>Data on health and employment outcomes measured as part of the U.S. Job Corps employment training experiment.</i>
-----------------------	--

Description

A dataset to replicate the analysis in Huber (2014).

A dataset to replicate the analysis in Huber (2014).

Usage

```
data(jobcorps)
```

```
data(jobcorps)
```

Format

A data frame with 10025 observations and 62 variables.

A data frame with 10025 observations and 62 variables.

Details

- treat. 1 = in program group. 0 = in control group.
- schobef. "in school 1yr before eligibility"
- trainyrbef. "training in year before Job Corps"
- jobeverbef. "ever had a job before Job Corps"
- jobyrbef. "job in year before job corps"
- health012. "good or very good health at assignment"
- health0mis. "general health at assignment missing"
- pe_prb0. "physical/emotional problems at assignment"
- pe_prb0mis. "missing - physical/emotional problems at assignment"
- everalc. "ever abused alcohol before assignment"
- alc12. "alcohol abuse one yr after assignment"
- everilldrugs. "ever took illegal drugs before assignment"
- age_cat. "age at application in years 16-24"
- edumis. "education missing"
- eduhigh. "higher education"
- rwhite. "white"
- everarr. "ever arrested before Job Corps"
- hhsize. "household size at assignment"
- hhsizemis. "household size at assignment missing"
- hhinc12. "low household income at assignment"
- hhinc8. "high household income at assignment"
- fdstamp. "received foodstamps in yr before assignment"
- welf1. "once on welfare while growing up"
- welf2. "twice on welfare while growing up"
- publicass. "public assistance in yr before assignment"
- emplq. "worked some time 9-12 months after assignment"
- emplq4full. "worked all the time in 9-12 months after assignment"
- pemplq4. "proportion of weeks worked 9-12 months after assignment"

- pemplq4mis. "missing - proportion of weeks worked 9-12 months after assignment"
 - vocq4. "in vocational training 9-12 months after assignment"
 - vocq4mis. "missing - in vocational training 9-12 months after assignment"
 - health1212. "very good or good health 1 yr after assignment"
 - health123. "fair health 1 yr after assignment"
 - pe_prb12. "1=phys/emot probs at 12 mths 0=no prob"
 - pe_prb12mis. "missing - physical/emotional problems 1 yr after assignment"
 - narry1. "number of arrests in year 1"
 - numkidhhf1zero. "no own kids living in household 1 yr after assignment"
 - numkidhhf1onetwo. "one or two own kids living in household 1 yr after assignment"
 - pubhse12. "1=in public housing 1 yr after assignment, 0=not in"
 - h_ins12a. "afdc and other transfers one yr after assignment"
 - h_ins12amis. "missing - afdc and other transfers one yr after assignment"
 - ... other variables as annotated in the source.
-
- treat. 1 = in program group. 0 = in control group.
 - schobef. "in school 1yr before eligibility"
 - trainyrbef. "training in year before Job Corps"
 - jobeverbef. "ever had a job before Job Corps"
 - jobyrbef. "job in year before job corps"
 - health012. "good or very good health at assignment"
 - health0mis. "general health at assignment missing"
 - pe_prb0. "physical/emotional problems at assignment"
 - pe_prb0mis. "missing - physical/emotional problems at assignment"
 - everalc. "ever abused alcohol before assignment"
 - alc12. "alcohol abuse one yr after assignment"
 - everilldrugs. "ever took illegal drugs before assignment"
 - age_cat. "age at application in years 16-24"
 - edumis. "education missing"
 - eduhigh. "higher education"
 - rwhite. "white"
 - everarr. "ever arrested before Job Corps"
 - hhsize. "household size at assignment"
 - hhsizemis. "household size at assignment missing"
 - hhinc12. "low household income at assignment"
 - hhinc8. "high household income at assignment"
 - fdstamp. "received foodstamps in yr before assignment"
 - welf1. "once on welfare while growing up"

- welf2. "twice on welfare while growing up"
- publicass. "public assistance in yr before assignment"
- emplq. "worked some time 9-12 months after assignment"
- emplq4full. "worked all the time in 9-12 months after assignment"
- pemplq4. "proportion of weeks worked 9-12 months after assignment"
- pemplq4mis. "missing - proportion of weeks worked 9-12 months after assignment"
- vocq4. "in vocational training 9-12 months after assignment"
- vocq4mis. "missing - in vocational training 9-12 months after assignment"
- health1212. "very good or good health 1 yr after assignment"
- health123. "fair health 1 yr after assignment"
- pe_prb12. "1=phys/emot probs at 12 mths 0=no prob"
- pe_prb12mis. "missing - physical/emotional problems 1 yr after assignment"
- narry1. "number of arrests in year 1"
- numkidhhf1zero. "no own kids living in household 1 yr after assignment"
- numkidhhf1onetwo. "one or two own kids living in household 1 yr after assignment"
- pubhse12. "1=in public housing 1 yr after assignment, 0=not in"
- h_ins12a. "afdc and other transfers one yr after assignment"
- h_ins12amis. "missing - afdc and other transfers one yr after assignment"
- ... other variables as annotated in the source.

Source

[doi:10.1002/jae.2341](https://doi.org/10.1002/jae.2341)

[doi:10.1002/jae.2341](https://doi.org/10.1002/jae.2341)

References

Huber, M. (2014). Identifying causal mechanisms (primarily) based on inverse probability weighting. *Journal of Applied Econometrics*, 29(6), 920-943. [doi:10.1002/jae.2341](https://doi.org/10.1002/jae.2341)

Huber, M. (2014). Identifying causal mechanisms (primarily) based on inverse probability weighting. *Journal of Applied Econometrics*, 29(6), 920-943. [doi:10.1002/jae.2341](https://doi.org/10.1002/jae.2341)

outreg_model	<i>Specify the outcome regression model for a CDE treatment</i>
--------------	---

Description

Specifies the functional form and estimation engine for an outcome regression of a treatment previously specified by `set_treatment()` and the past history of covariates.

Usage

```
outreg_model(
  object,
  formula,
  engine,
  separate = TRUE,
  include_past = TRUE,
  ...
)
```

Arguments

object	A <code>cde_estimator</code> object that contains output from a previous call to <code>set_treatment()</code> .
formula	A formula specifying the design matrix of the covariates. Passed to fitting engine or used with <code>stats::model.frame()</code> and <code>stats::model.matrix()</code> to create the design matrix for fitting engines that do not take formulas.
engine	String indicating the name of the fitting engine.
separate	Logical indicating whether the fitting algorithm should be applied separately to each history of the treatment variables up to this point (default) or not.
include_past	A logical value where TRUE indicates that formulas passed to previous <code>treat_model</code> calls should be appended to the formula given.
...	Other arguments to be passed to the engine algorithms.

plot.cdesens	<i>Plot output from cdesens</i>
--------------	---------------------------------

Description

Plot output from `cdesens`

Usage

```
## S3 method for class 'cdesens'
plot(
  x,
  level = 0.95,
  xlim = NULL,
  ylim = NULL,
  xlab = NULL,
  ylab = "Estimated ACDE",
  bty = "n",
  col = "black",
  lwd = 2,
  ci.col = "grey70",
  ref.lines = TRUE,
  ...
)
```

Arguments

x	output from cdesens
level	level of confidence interval to plot
xlim	the x limits (x1, x2) of the plot for the sensitivity analysis parameter, rho. Default is to use the range of rho.
ylim	the y limits of the plot for the estimated CDEs. Default is to show the all of the confidence intervals.
xlab	label for the x axis.
ylab	label for the y axis.
bty	a character string which determined the type of box which is drawn about plots. Defaults to not drawing a box. See par for more information.
col	color for the line indicating the point estimates of the bias-adjusted ACDE.
lwd	line width for the line indicating the point estimates of the bias-adjusted ACDE.
ci.col	color for the polygon that shows the confidence intervals.
ref.lines	a logical indicating whether horizontal and vertical lines at 0 should be plotted.
...	Other parameters to pass on to plot()

plotDiag.tmatch

Histograms of matching weights

Description

Histograms of matching weights

Usage

```
plotDiag.tmatch(object, stage)
```

Arguments

`object` an object of class `tmatch` – results from a call to `telescope_match`
`stage` a character vector equal to the name of one treatment from the ‘object’.

Details

Provides histograms of the number of times each unit is used as a match given a `tmatch` object returned by `telescope_match`

Value

Outputs a ‘plot()’ object containing the histogram of match counts

ploughs *Data on historical plough use and the socioeconomic status of women.*

Description

A dataset to replicate the analysis in Alesina, Giuliano, and Nunn (2013).

A dataset to replicate the analysis in Alesina, Giuliano, and Nunn (2013).

Usage

```
data(ploughs)
```

```
data(ploughs)
```

Format

A data frame with 234 observations and 57 variables.

A data frame with 234 observations and 57 variables.

Details

- `isocode`. 3-letter code for the country.
- `ffp2000`. Female labor force participation in 2000
- `female_ownership`. Percent of firms with female ownership (in latest survey year)
- `women_politics`. Women in Politics in 2000, WDI
- `plow`. Animal plow cultivation variable (v39): Using Ethnologue - pop weighted
- `agricultural_suitability`. overall (millets, sorghum, wheat, barley, rye): share defined as suitable

- tropical_climate. Frac land: tropics and subtropics: using Ethnologue - pop weighted
- large_animals. presence of large animals
- political_hierarchies. Jurisdictional hierarchy beyond local community (v33): Using Ethnologue - pop weighted
- economic_complexity. Settlement patterns (v30)
- ln_income. $\ln(\text{income})$
- ln_income_squared. $\ln(\text{income})^2$
- centered_ln_inc. de-meanded \ln_{inc}
- centered_ln_incsq. de-meanded \ln_{inc} squared
- country. country name
- communist_dummy. Communism indicator variable
- rugged. Ruggedness (Terrain Ruggedness Index, 100 m.)
- years_interstate_conflict. Years of interstate conflict, 1800-2007 - from COW
- serv_va_gdp2000. Value Added in Service/GDP in 2000
- polity2_2000. Polity 2 measure taken from the Polity IV dataset
- oil_pc. oil production/GDP
- ... other variables as annotated in the source.

- isocode. 3-letter code for the country.
- flfp2000. Female labor force participation in 2000
- female_ownership. Percent of firms with female ownership (in latest survey year)
- women_politics. Women in Politics in 2000, WDI
- plow. Animal plow cultivation variable (v39): Using Ethnologue - pop weighted
- agricultural_suitability. overall (millets, sorghum, wheat, barley, rye): share defined as suitable
- tropical_climate. Frac land: tropics and subtropics: using Ethnologue - pop weighted
- large_animals. presence of large animals
- political_hierarchies. Jurisdictional hierarchy beyond local community (v33): Using Ethnologue - pop weighted
- economic_complexity. Settlement patterns (v30)
- ln_income. $\ln(\text{income})$
- ln_income_squared. $\ln(\text{income})^2$
- centered_ln_inc. de-meanded \ln_{inc}
- centered_ln_incsq. de-meanded \ln_{inc} squared
- country. country name
- communist_dummy. Communism indicator variable
- rugged. Ruggedness (Terrain Ruggedness Index, 100 m.)
- years_interstate_conflict. Years of interstate conflict, 1800-2007 - from COW
- serv_va_gdp2000. Value Added in Service/GDP in 2000
- polity2_2000. Polity 2 measure taken from the Polity IV dataset
- oil_pc. oil production/GDP
- ... other variables as annotated in the source.

Source

[doi:10.1093/qje/qjt005](https://doi.org/10.1093/qje/qjt005)

[doi:10.1093/qje/qjt005](https://doi.org/10.1093/qje/qjt005)

References

Alesina, A., Giuliano, P., & Nunn, N. (2013). On the Origins of Gender Roles: Women and the Plough. *The Quarterly Journal of Economics*, 128(2), 469-530. [doi:10.1093/qje/qjt005](https://doi.org/10.1093/qje/qjt005)

Alesina, A., Giuliano, P., & Nunn, N. (2013). On the Origins of Gender Roles: Women and the Plough. *The Quarterly Journal of Economics*, 128(2), 469-530. [doi:10.1093/qje/qjt005](https://doi.org/10.1093/qje/qjt005)

sequential_g	<i>Perform linear sequential g-estimation to estimate the controlled direct effect of a treatment net the effect of a mediator.</i>
--------------	---

Description

Perform linear sequential g-estimation to estimate the controlled direct effect of a treatment net the effect of a mediator.

Usage

```
sequential_g(  
  formula,  
  data,  
  subset,  
  weights,  
  na.action,  
  offset,  
  contrasts = NULL,  
  verbose = TRUE,  
  ...  
)
```

Arguments

formula	formula specification of the first-stage, second-stage, and blip-down models. The right-hand side of the formula should have three components separated by the , with the first component specifying the first-stage model with treatment and any baseline covariates, the second component specifying the intermediate covariates for the first-stage, and the third component specifying the blip-down model. See Details below for more information.
data	A dataframe to apply formula on.
subset	A vector of logicals indicating which rows of data to keep.

weights	an optional vector of weights to be used in the fitting process. Should be NULL or a numeric vector. If non-NULL, weighted least squares is used with weights weights (that is, minimizing $\sum(w * e^2)$); otherwise ordinary least squares is used. See also ‘Details’,
na.action	a function which indicates what should happen when the data contain NAs. The default is set by the na.action setting of <code>options</code> , and is <code>na.fail</code> if that is unset. The ‘factory-fresh’ default is <code>na.omit</code> . Another possible value is NULL, no action. Value <code>na.exclude</code> can be useful.
offset	this can be used to specify an <i>a priori</i> known component to be included in the linear predictor during fitting. This should be NULL or a numeric vector or matrix of extents matching those of the response. One or more <code>offset</code> terms can be included in the formula instead or as well, and if more than one are specified their sum is used. See <code>model.offset</code> .
contrasts	an optional list. See the <code>contrasts.arg</code> of <code>model.matrix.default</code> .
verbose	logical indicating whether to suppress progress bar. Default is FALSE.
...	For <code>lm()</code> : additional arguments to be passed to the low level regression fitting functions (see below).

Details

The `sequential_g` function implements the linear sequential g-estimator developed by Vansteelandt (2009) with the consistent variance estimator developed by Acharya, Blackwell, and Sen (2016).

The formula specifies the full first-stage model including treatment, baseline confounders, intermediate confounders, and the mediators. The user places | bars to separate out these different components of the model. For example, the formula should have the form $y \sim tr + x1 + x2 \mid z1 + z2 \mid m1 + m2$. where `tr` is the name of the treatment variable, `x1` and `x2` are baseline covariates, `z1` and `z2` are intermediate covariates, and `m1` and `m2` are the names of the mediator variables. This last set of variables specify the ‘blip-down’ or ‘demediation’ function that is used to remove the average effect of the mediator (possibly interacted) from the outcome to create the blipped-down outcome. This blipped-down outcome is the passed to a standard linear model with the covariates as specified for the direct effects model.

See the references below for more details.

Value

Returns an object of class A “seq”. Similar to the output of a call to `lm`. Contains the following components:

- `coefficients`: a vector of named coefficients for the direct effects model.
- `residuals`: the residuals, that is the blipped-down outcome minus the fitted values.
- `rank`: the numeric rank of the fitted linear direct effects model.
- `fitted.values`: the fitted mean values of the direct effects model.
- `weights`: (only for weighted fits) the specified weights.
- `df.residual`: the residual degrees of freedom for the direct effects model.

- `aliased`: logical vector indicating if any of the terms were dropped or aliased due to perfect collinearity.
- `terms`: the list of terms object used. One for the baseline covariates and treatment (X) and one for the variables in the blip-down model (M).
- `formula`: the formula object used, possibly modified to drop a constant in the blip-down model.
- `call`: the matched call.
- `na.action`: (where relevant) information returned by `model.frame` of the special handling of NAs.
- `xlevels`: the levels of the factor variables.
- `contrasts`: the contrasts used for the factor variables.
- `first_mod`: the output from the first-stage regression model.
- `model`: full model frame, including all variables.
- `Ytilde`: the blipped-down response vector.
- `X`: the model matrix for the second stage.
- `M`: the model matrix for demediation/blip-down function.

In addition, non-null fits will have components `assign`, `effects`, and `qr` from the output of `lm.fit` or `lm.wfit`, whichever is used.

References

Vansteelandt, S. (2009). Estimating Direct Effects in Cohort and Case-Control Studies. *Epidemiology*, 20(6), 851-860.

Acharya, Avidit, Blackwell, Matthew, and Sen, Maya. (2016) "Explaining Causal Effects Without Bias: Detecting and Assessing Direct Effects." *American Political Science Review* 110:3 pp. 512-529

Examples

```
data(ploughs)

form_main <- women_politics ~ plow +
  agricultural_suitability + tropical_climate + large_animals +
  political_hierarchies + economic_complexity +
  rugged | years_civil_conflict +
  years_interstate_conflict + oil_pc +
  european_descent + communist_dummy + polity2_2000 +
  serv_va_gdp2000 | centered_ln_inc + centered_ln_incsq

direct <- sequential_g(form_main, ploughs)

summary(direct)
```

set_treatment	<i>Specify a treatment variable for a controlled direct effect</i>
---------------	--

Description

This function specifies a treatment variable in the sequence of treatment variables that define the controlled direct effect of interest.

Usage

```
set_treatment(
  object,
  treat,
  formula = NULL,
  treat_type = "categorical",
  eval_vals = NULL
)
```

Arguments

object	A <code>cde_estimator</code> object that may or may have previous treatment variables specified/
treat	Name of the treatment variable (not quoted).
formula	One-sided formula giving the covariates that are pre-treatment to this treatment, but post-treatment to any previous treatment. Unless overridden by the arguments to <code>treat_model()</code> or <code>outreg_model()</code> , this formula will be the specification used in the modeling of the propensity scores or outcome regressions.
treat_type	A string indicating the type of variable this is. Takes either the values "categorical" or "regression" (the latter is not yet implemented). of
eval_vals	A numeric vector of values of this variable to evaluate the controlled direct effect. If NULL (the default), this will be set to all observed values of the variable.

Value

An updated `cde_estimator` with this information about the treatment specified.

Author(s)

Matthew Blackwell

summary.seqg	<i>Computes standard errors and p-values of DirectEffects estimates</i>
--------------	---

Description

Computes standard errors and p-values of DirectEffects estimates

Usage

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

Arguments

object	An object of class seqg, computed by sequential_g .
...	additional arguments affecting the summary produced.

summary.seqgboots	<i>Summary of DirectEffect Bootstrap Estimates</i>
-------------------	--

Description

Summary of DirectEffect Bootstrap Estimates

Usage

```
## S3 method for class 'seqgboots'  
summary(object, level = 0.95, ...)
```

Arguments

object	An output of class seqg estimated by boots_g .
level	level of intervals to estimate. Defaults to 0.95
...	additional arguments affecting the summary produced.

summary.tmatch	<i>Summarize telescope match objects</i>
----------------	--

Description

Summarize telescope match objects

Usage

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

Arguments

object	an object of class tmatch – results from a call to telescope_match
...	additional arguments affecting the summary produced.

Details

summary method for tmatch objects returned by telescope_match

Returns a summary data frame containing the estimate and standard errors from the ‘telescope_match’ object.

Value

Returns an object of class summary.tmatch. Contains the following components

- call: matched call.
- m_summary: data.frame summarizes the matching ratios (`{ratio}`), number of units `n_1`, `n_0`, and number of matched units (`matched_1`, `matched_0`) for each treatment/mediator (term).
- K: K data frame from the object telescope matching output.
- L: L vector from the object telescope matching output.
- a_names: character vector of the names of the treatment/mediator variables used in matching.
- estimates: matrix of estimated ACDEs with and without bias correction and the estimated standard errors.

telescope_match	<i>Perform telescope matching to estimate the controlled direct effect of a binary treatment net the effect of binary mediators</i>
-----------------	---

Description

Perform telescope matching to estimate the controlled direct effect of a binary treatment net the effect of binary mediators

Usage

```
telescope_match(
  formula,
  data,
  caliper = NULL,
  L = 5,
  verbose = TRUE,
  subset,
  contrasts = NULL,
  separate_bc = TRUE,
  ...
)
```

Arguments

formula	A formula object that specifies the covariates and treatment variables (or mediators) in causal ordering from oldest to newest with each group separated by . See below for more details.
data	A dataframe containing variables referenced by formula.
caliper	A scalar denoting the caliper to be used in matching in the treatment stage (calipers cannot be used for matching on the mediator). Observations outside of the caliper are dropped. Calipers are specified in standard deviations of the covariates. NULL by default (no caliper).
L	Number of matches to use for each unit. Must be a numeric vector of either length 1 or 2. If length 1, L sets the number of matches used in both the first stage (matching on mediator) and in the second stage (matching on treatment). If length 2, the first element sets the number of matches used in the first stage (matching on mediator) and the second element sets the number of matches used in the second stage (matching on treatment) Default is 5.
verbose	logical indicating whether to display progress information. Default is TRUE.
subset	A vector of logicals indicating which rows of data to keep.
contrasts	a list to be passed to the contrasts.arg argument of model.matrix() when generating the data matrix.

separate_bc	logical indicating whether or not bias correction regressions should be run separately within levels of the treatment and mediator. Defaults to TRUE. If TRUE, any interactions between treatment/mediator and covariates in the specification should be omitted.
...	For <code>lm()</code> : additional arguments to be passed to the low level regression fitting functions (see below).

Details

The `telescope_match` function implements the two-stage "telescope matching" procedure developed by Blackwell and Strezhnev (2021).

The procedure first estimates a demediated outcome using a combination of matching and a regression bias-correction. The `data.frame` passed to `data` should be in the wide format so that each row corresponds to a single unit and treatments and covariates from different time periods appear as different columns. The `formula` argument specifies both the causal ordering of the variables and the regression specifications for the bias correction. It should be of the form $Y \sim X1 \mid A1 \mid X2 \mid A2$, where Y is the outcome, $X1$ is a formula of baseline covariates, $A1$ is a single variable name indicating the binary treatment in the first period, $X2$ is a formula of covariates in period 2, and $A2$ is a single variable name indicating treatment in period 2 (which is also sometimes called the mediator). Note that it is possible to add more covariate/treatment pairs for additional time periods.

Under the default `separate_bc == TRUE`, the function will match for each treatment/mediator based on the the covariates up to that point within levels of past treatments (so for $A2$ this matching finds units with similar values of $X1$ and $X2$ and the same value of $A1$). Once this matching is complete, the function moves backward through treatments and imputes potential outcomes using matches and bias-correction regressions, which regress the current imputed potential outcome on the past covariates, within levels of the treatment history up to the current period. The functional form comes from the specification in `formula`. Controlled direct effects of $A1$ are estimated for every possible combination of future treatments.

When `separate_bc` is `FALSE`, the bias correction regressions are not broken out by the treatments/mediators and those variables are simply included as separate regressors as specified in `formula`. In this setting, interactions between the treatment/mediator and covariates can be added on a selective basis to the covariate block ($X1$ or $X2$ and so on) specifications.

Matching is performed using the `Match()` routine from the `Matching` package. By default, matching is L-to-1 nearest neighbor with replacement using Mahalanobis distance.

See the references below for more details.

Value

Returns an object of class `tmatch`. Contains the following components

- `call`: the matched call.
- `formula`: formula used to fit the model.
- `m_out`: list of matching solutions at each time point. Each member of the list has a 'matches' list giving the units matched to that unit, a 'donors' list with the units to which the unit is matched, and a 'tr' vector which is just the treatment vector being matched.
- `K`: data.frame of indicating how many times a unit has been used as a match, directly in each period and indirectly across periods.

- L: vector of matching ratios used in each period.
- r_out: nested list of regression imputations used in the bias correction. The first level of the list varies across different controlled direct effects (different sequences of future treatments/mediators). Each of these is a list of time periods and each of these time periods is a list of 'yhat_r_0' and 'yhat_r_1' that give the regression predictions for the potential outcomes at that time point when the treatment at that time point is 0 or 1, respectively, along with 'n_coefs' giving the number of coefficients estimated in those models.
- tau: vector of bias-corrected estimates of average controlled direct effects for different vectors of future treatments/mediators.
- tau_raw: vector of standard matching estimates of average controlled direct effects for different vectors of future treatments/mediators without using bias correction.
- tau_se: vector of estimated standard errors for the average controlled direct effects estimates for different vectors of future treatments/mediators.
- tau_i: matrix of individuals contributions to the ACDE estimates (units on rows, different ACDEs on columns). Used for weighted bootstrap.
- included: logical vector indicating if each row of data was included in estimating tau.
- effects: data frame where each row describes the different ACDEs in tau. The active column describes the which variable's direct effect is being assessed and the rest of the columns describe the fixed values of the future treatments/mediators for that ACDE.
- a_names: character vector with the names of the treatment/mediator variables used in estimation.
- caliper: caliper (if any) used in matching to drop distant observations.

References

Blackwell, Matthew, and Strezhnev, Anton (2020) "Telescope Matching: Reducing Model Dependence in the Estimation of Direct Effects." *Journal of the Royal Statistical Society (Series A)*. doi:[10.1111/rssa.12759](https://doi.org/10.1111/rssa.12759)

Examples

```
data(jobcorps)

## Split male/female
jobcorps_female <- subset(jobcorps, female == 1)

## Telescope matching formula - First stage (X and Z)
tm_form <- exhealth30 ~ schobef + trainyrbef + jobeverbef |
  treat | emplq4 + emplq4full | work2year2q

### Estimate ACDE for women holding employment at 0
tm_out <- telescope_match(
  tm_form,
  data = jobcorps_female,
  L = 2,
  boot = FALSE,
  verbose = TRUE
```

)

transphobia

*Data from a randomized experiment on transgender rights.***Description**

A dataset from Broockman and Kalla (2016).

Usage

```
data(transphobia)
```

Format

A data frame with 501 observations and 19 variables.

Details

- treated. Indicator of transgender rights script (1) vs recycling script (0).
- nondiscrim_law_t3. Support for transgender nondiscrimination law six weeks after treatment.
- therm_trans_t2. Subjective feelings about transgender people three weeks after treatment (0 = cool, 1 = neutral, 2 = warm).
- therm_obama_t1. Feeling thermometer score (0-100) for feeling warmth or coolness toward Barack Obama 3 days after treatment.
- gender_norm_moral_t1. Index of moral attitudes about gender 3 days after treatment.
- nondiscrim_law_t0. Baseline support for transgender nondiscrimination law.
- therm_trans_t0. Baseline subjective feelings about transgender people (0 = cool, 1 = neutral, 2 = warm).
- therm_obama_t0. Baseline feeling thermometer score (0-100) for feeling warmth or coolness toward Barack Obama.
- gender_norm_moral_t0. Baseline index of moral attitudes about gender.
- ideology_t0. Baseline measure of ideology (conservative is higher).
- religious_t0. Baseline measure of religiosity.
- exposure_trans_t0. Baseline indicator for personal exposure to transgender people (1) or not (0).
- pid_t0. Baseline party identification (-3 = Strong Democrat, 3 = Strong Republican).
- vf_democrat. Indicator for if the unit identifies as a Democrat in the voter file (1) or not (0).
- vf_female. Indicator for if the unit identifies as a woman in the voter file (1) or not (0).
- vf_hispanic. Indicator for if the unit identifies as Hispanic in the voter file (1) or not (0).
- vf_black. Indicator for if the unit identifies as Black in the voter file (1) or not (0).
- vf_age. Age of the citizen in the voter file.
- nondiscrim_law_diff. Difference between nondiscrim_law_t3 and nondiscrim_law_t0

Source

[doi:10.1126/science.aad9713](https://doi.org/10.1126/science.aad9713)

References

Broockman, D. & Kalla, J. (2016). Durably reducing transphobia: A field experiment on door-to-door canvassing. *Science*, 352(6282), 220-224. [doi:10.1126/science.aad9713](https://doi.org/10.1126/science.aad9713)

treat_model	<i>Specify the propensity score model for a CDE treatment</i>
-------------	---

Description

Specifies the functional form and estimation engine for a treatment previously specified by `set_treatment()`.

Usage

```
treat_model(object, formula, engine, separate = TRUE, include_past = TRUE, ...)
```

Arguments

object	A <code>cde_estimator</code> object that contains output from a previous call to <code>set_treatment()</code> .
formula	A formula specifying the design matrix of the covariates. Passed to fitting engine or used with <code>stats::model.frame()</code> and <code>stats::model.matrix()</code> to create the design matrix for fitting engines that do not take formulas.
engine	String indicating the name of the fitting engine.
separate	Logical indicating whether the fitting algorithm should be applied separately to each history of the treatment variables up to this point (default) or not.
include_past	A logical value where TRUE indicates that formulas passed to previous <code>treat_model</code> calls should be appended to the formula given.
...	Other arguments to be passed to the engine algorithms.

Author(s)

Matthew Blackwell

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