Package ‘CMmatching’

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Title Matching Algorithms for Causal Inference with Clustered Data

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Description
Provides functions to perform matching algorithms for causal inference with clustered data, as described in B. Arpino and M. Cannas (2016) <doi:10.1002/sim.6880>. Pure within-cluster and preferential within-cluster matching are implemented. Both algorithms provide causal estimates with cluster-adjusted estimates of standard errors.

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Description

Provides functions to perform matching algorithms for causal inference with clustered data, as described in B. Arpino and M. Cannas (2016) <doi:10.1002/sim.6880>. Pure within-cluster and preferential within-cluster matching are implemented. Both algorithms provide causal estimates with cluster-adjusted estimates of standard errors.

Details

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Arpino and Cannas (2016) described several strategies to handle unobserved cluster characteristics in causal inference estimation with clustered data. Depending on researcher’s belief about the strength of unobserved cluster level covariates it is possible to take into account clustering either in the estimation of the propensity score model (through the inclusion of fixed or random effects) and/or in the implementation of the matching algorithm. The package contains function CMatch to adapt classic matching algorithms for causal inference to clustered data and a customized summary function to analyze the output. Depending on the type argument function CMatch either calls either MatchW implementing a pure within-cluster matching or function MatchPW implementing an approach which can be called "preferential" within-cluster matching. The preferential approach first searches for matchable units within the same cluster. If no match was found the algorithm searches in other clusters. The functions also provide causal estimands with cluster-adjusted standard errors from fitting a multilevel model on matched data. CMatch returns an object of class "CMatch" which can be be summarized and used as input of the CMatchBalance function to examine how much the procedure resulted in improved covariate balance. Although CMatch has been designed for dealing with clustered data, these algorithms can be used to force a perfect balance or to improve the balance of categorical variables, respectively. In this case, the “clusters” correspond to the levels of the categorical variable(s). When used for this purpose the user should ignore the standard error (if provided). Note that Matchby from package Matching can be used for the same purpose.

Author(s)

Massimo Cannas [aut, cre], Bruno Arpino [ctb], Elena Colicino [ctb] and a special thanks to Thomas W. Yee for his precious help.

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References


See Also

match, matchbalance

CMatch

Within and preferential-within cluster matching.

Description

This function implements multivariate and propensity score matching in clusters defined by the group variable. It returns an object of class "CMatch" which can be be summarized and used as input of the CMatchBalance function to examine how much the procedure resulted in improved covariate balance.

Usage

CMatch(type, y = NULL, tr, x, group = NULL, estimand = "ATT", M = 1, exact = NULL, caliper = 0.25, weights = NULL, replace = TRUE, ties = TRUE, ...)

Arguments

type The type of matching desired. "within" for a pure within-cluster matching and "pwithin" for matching preferentially within. The preferential approach first searches for matchable units within the same cluster. If no match was found the algorithm searches in other clusters.
y A vector containing the outcome of interest.
tr A vector indicating the treated and control units.
x A matrix of covariates we wish to match on. This matrix should contain all confounders or the propensity score or a combination of both.
group A vector describing the clustering structure (typically the cluster ID). This can be any numeric vector of the same length of Tr and X containing integer numbers in ascending order otherwise an error message will be returned. Default is NULL, however if Group is missing, NULL or it contains only one value the output of the Match function is returned with a warning.
estimand The causal estimand desired, one of "ATE", "ATT" and "ATC", which stand for Average Treatment Effect, Average Treatment effect on the Treated and on the Controls, respectively. Default is "ATT".
The number of matches which are sought for each unit. Default is 1 ("one-to-one matching").

exact An indicator for whether exact matching on the variables contained in $X$ is desired. Default is FALSE. This option has precedence over the caliper option.

caliper A maximum allowed distance for matching units. Units for which no match was found within caliper distance are discarded. Default is 0.25. The caliper is interpreted in standard deviation units of the unclustered data for each variable. For example, if caliper=0.25 all matches at distance bigger than 0.25 times the standard deviation for any of the variables in $X$ are discarded.

weights A vector of specific observation weights.

replace Matching can be with or without replacement depending on whether matches can be re-used or not. Default is TRUE.

ties An indicator for dealing with multiple matches. If more than M matches are found for each unit the additional matches are a) wholly retained with equal weights if ties=TRUE; b) a random one is chosen if ties=FALSE. Default is TRUE.

Additional arguments to be passed to the Match function (not all of them can be used).

Details

This function is meant to be a natural extension of the Match function to clustered data. It retains the main arguments of Match but it has additional output showing matching results cluster by cluster. It differs from wrapper Matchby in package Matching in the way standard errors are calculated and because the caliper is in standard deviation units of the covariates on the overall dataset (so the caliper is the same for all clusters). Moreover, observation weights are available.

Value

index.control The index of control observations in the matched dataset.

index.treated The index of control observations in the matched dataset.

index.dropped The index of dropped observations due to the exact or caliper option. Note that these observations are treated if estimand is "ATT", controls if "ATC".

est The causal estimate. This is provided only if $Y$ is not null. If estimand is "ATT" it is the (weighted) mean of $Y$ in matched treated units minus the (weighted) mean of $Y$ in matched controls. Equivalently, it is the weighted average of the within-cluster ATTs, with weights given by cluster sizes in the matched dataset.

se A model-based standard error for the causal estimand. This is a cluster robust estimator of the standard error for the linear model: $Y \sim constant+Tr$, run on the matched dataset (see cluster.vcov for details on how this estimator is obtained). Note that these standard errors differ from a weighted average of cluster specific standard errors provided by the Matchby function, which are generally larger. Estimating standard errors for causal parameters with clustered data is an active field of research and there is no perfect solution to date.
mdata

A list containing the matched datasets produced by CMatch. Three datasets are included in this list: Y, Tr and X. The matched dataset for Group can be recovered by rbind(Group[index.treated],Group[index.control]).

orig.treated.nobs.by.group

The original number of treated observations by group in the dataset.

orig.control.nobs.by.group

The original number of control observations by group in the dataset.

orig.dropped.nobs.by.group

The number of dropped observations by group after within cluster matching.

orig.nobs

The original number of observations in the dataset.

orig.wnobs

The original number of weighted observations in the dataset.

orig.treated.nobs

The original number of treated observations in the dataset.

orig.control.nobs

The original number of control observations in the dataset.

wnobs

The number of weighted observations in the matched dataset.

caliper

The caliper used.

intcaliper

The internal caliper used.

exact

The value of the exact argument.

ndrops.matches

The number of matches dropped either because of the caliper or exact option (or because of forcing the match within-clusters).

estimand

The estimand required.

Note

The function returns an object of class CMatch. The CMatchBalance function can be used to examine the covariate balance before and after matching (see the examples below).

Author(s)

Massimo Cannas <massimo.cannas@unica.it>

References


See Also

See also Match, MatchBalance
Examples

data(schools)

# The data set is the subsample of NELS-88 data consisting of 10 handpicked schools
# from the 1003 schools in the full data set.

# Suppose that the effect of homeworks on math score is unconfounded conditional on X
# and unobserved school features (we assume this only for illustrative purpose).

# Let us consider the following variables:

X<-schools$ses # or X<-as.matrix(schools[,c("ses","white","public")])
Y<-schools$math
Tr<-ifelse(schools$homework>1,1,0)
Group<-schools$schid

# When Group is missing or there is only one Group CMatch returns
# the output of the Match function with a warning.

# Let us assume that the effect of homeworks (Tr) on math score (Y)
# is unconfounded conditional on X and other unobserved school features.
# Several strategies to handle unobserved group characteristics
# are described in Arpino & Cannas, 2016 (see References).

# Multivariate Matching on covariates in X
# default parameters: one-to-one matching on X with replacement with a caliper of 0.25

### Matching within schools

mw<-CMatch(type="within",Y=Y, Tr=Tr, X=X, Group=Group, caliper=0.1)

# compare balance before and after matching
bmw <- CM_matchBalance(Tr~X,data=schools,match.out=mw)

# calculate proportion of matched observations
(mw$orig.treated.nobs-mw$ndrops)/mw$orig.treated.nobs

# check number of drops by school
mw$orig.dropped.nobs.by.group

# examine output
mw  # complete list of results
summary(mw)  # basic statistics

### Match preferentially within school
# i.e. first match within schools
# then (try to) match remaining units between schools
mpw <- CMatch(type="pwithin",Y=schools$math, Tr=Tr, X=schools$ses, Group=schools$schid, caliper=0.1)

# examine covariate balance
bmpw<- CM_matchBalance(Tr~ses,data=schools,match.out=mpw)
proportion of matched observations
(mpw$orig.treated.nobs - mpw$ndrops) / mpw$orig.treated.nobs
# check drops by school
mpw$orig.dropped.nobs.by.group.after.pref.within
# proportion of matched observations after match-within only
(mpw$orig.treated.nobs - sum(mpw$orig.dropped.nobs.by.group.after.within)) / mpw$orig.treated.nobs
# see complete output
mpw
# or use summary method for main results
summary(mpw)

### Propensity score matching

# estimate the ps model
mod <- glm(Tr ~ ses + parented + public + sex + race + urban,
          family = binomial(link = "logit"), data = schools)
eps <- fitted(mod)

# eg 1: within school propensity score matching
psmw <- CMatch(type = "within", Y = schools$math, Tr = Tr, X = eps,
               Group = schools$schid, caliper = 0.1)
# equivalent to direct call at MatchW(Y = schools$math, Tr = Tr, X = eps,
# Group = schools$schid, caliper = 0.1)

# eg 2: preferential within school propensity score matching
psmw <- CMatch(type = "pwithin", Y = schools$math, Tr = Tr, X = eps,
               Group = schools$schid, caliper = 0.1)

# Other strategies for controlling unobserved cluster covariates
# via different specifications of propensity score (see Arpino and Mealli):

# eg 3: propensity score matching using ps estimated from a logit model with dummies for hospitals
mod <- glm(Tr ~ ses + parented + public + sex + race + urban
          + schid - 1, family = binomial(link = "logit"), data = schools)
eps <- fitted(mod)

dpsm <- CMatch(type = "within", Y = schools$math, Tr = Tr, X = eps,
               Group = NULL, caliper = 0.1)
# this is equivalent to run Match with X = eps

# eg4: propensity score matching using ps estimated from multilevel logit model
# (random intercept at the hospital level)
require(lme4)
mod <- glmer(Tr ~ ses + parented + public + sex + race + urban + (1 | schid),
              family = binomial(link = "logit"), data = schools)
eps <- fitted(mod)

mpsm <- CMatch(type = "within", Y = schools$math, Tr = Tr, X = eps,
                Group = NULL, caliper = 0.1)
# this is equivalent to run Match with X = eps
CMatchBalance

Analyze covariate balance before and after matching.

Description

Generic function for analyzing covariate balance. If match.out is NULL only balance statistics for the unmatched data are returned otherwise both before and after matching balance are given. The function is simply a wrapper calling MatchBalance, possibly after coercing the class of match.out. See MatchBalance for more detailed description.

Usage

CMatchBalance(match.out, formula, data = NULL, ks = TRUE, nboots = 500, weights = NULL, digits = 5, paired = TRUE, print.level = 1)

Arguments

- **match.out**: A matched data set, i.e., the result of a call to Match or CMatch.
- **formula**: This formula does not estimate a model. It is a compact way to describe which variables should be compared between the treated and control group. See MatchBalance.
- **data**: An optional data set for the variables indicated in the formula argument.
- **ks**: A flag for whether Kolmogorov-Smirnov tests should be calculated.
- **weights**: A vector of observation-specific weights.
- **nboots**: The number of bootstrap replication to be used.
- **digits**: The number of digits to be displayed in the output.
- **paired**: A flag for whether a paired t.test should be used for the matched data. An unpaired t.test is always used for unmatched data.
- **print.level**: The amount of printing, taking values 0 (no printing), 1 (summary) and 2 (detailed results). Default to 1.

Details

The function is a wrapper of the MatchBalance function. If match.out is of class Match (or NULL) then it calls MatchBalance. If match.out is of class CMatch then it coerces the class to Match before calling MatchBalance. This function is meant to exploit MatchBalance for CMatch objects for which MatchBalance would not work.

Value

Balance statistics for the covariates specified in the right side of formula argument. Statistics are compared between the two groups specified by the binary variable in the left side of formula.
Author(s)

Massimo Cannas <massimo.cannas@unica.it> and a special thanks to Thomas W. Yee for his precious help.

References


See Also

MatchBalance

Examples

data(schools)

# The data set is the subsample of NELS-88 data consisting of 10 handpicked schools
# from the 1003 schools in the full data set.
# Suppose that the effect of homeworks on math score is unconfounded conditional on X
# and unobserved school features (we assume this only for illustrative purpose).

# Let us consider the following variables:
X<-schools$ses # or X<-as.matrix(schools[,c("ses","white","public")])
Y<-schools$math
Tr<-ifelse(schools$homework>1,1,0)
Group<-schools$schid
# When Group is missing or there is only one Group CMATCH returns
# the output of the Match function with a warning.

# Let us assume that the effect of homeworks (Tr) on math score (Y)
# is unconfounded conditional on X and other unobserved school features.
# Several strategies to handle unobserved group characteristics
# are described in Arpino & Cannas, 2016 (see References).

# Multivariate Matching on covariates in X
# default parameters: one-to-one matching on X with replacement with a caliper of 0.25.

### Matching within schools
mw<-CMatch(type="within",Y=Y, Tr=Tr, X=X, Group=Group, caliper=0.1)

# compare balance before and after matching
bmw <- CMatchBalance(Tr~X, data=schools, match.out=mw)

# calculate proportion of matched observations
(mw$orig.treated.nobs-mw$ndrops)/mw$orig.treated.nobs
# check number of drops by school
mw$orig.ndrops.by.group

### Match preferentially within school
# i.e. first match within schools
# then (try to) match remaining units between schools
mpw <- CMatch(type="pwithin", Y=schools$math, Tr=Tr, X=schools$ses, 
Group=schools$schid, caliper=0.1)

# examine covariate balance
bmpw<- CMatchBalance(Tr=ses, data=schools, match.out=mpw)
# equivalent to MatchBalance(...) with mpw coerced to class "Match"

# proportion of matched observations
(mpw$orig.treated.nobs-mpw$ndrops) / mpw$orig.treated.nobs
# check drops by school
mpw$orig.ndrops.by.group
# proportion of matched observations after match-within only
(mpw$orig.treated.nobs-sum(mpw$orig.ndrops.by.group.after.within)) / mpw$orig.treated.nobs

---

**MatchPW**

**Preferential Within-cluster Matching**

**Description**

This function implements preferential within-cluster matching. In other words, units that do not match within clusters (as defined by the Group variable) can match between cluster in the second step.

**Usage**

MatchPW(Y = NULL, Tr, X, Group = NULL, estimand = "ATT", M = 1, 
exact = NULL, caliper = 0.25, replace = TRUE, ties = TRUE, weights = NULL, ...)

**Arguments**

- **Y**  
  A vector containing the outcome of interest.

- **Tr**  
  A vector indicating the treated and control units.

- **X**  
  A matrix of covariates we wish to match on. This matrix should contain all confounders or the propensity score or a combination of both.

- **Group**  
  A vector describing the clustering structure (typically the cluster ID). This can be any numeric vector of the same length of Tr and X containing integer numbers in ascending order otherwise an error message will be returned. Default is NULL, however if Group is missing, NULL or contains only one value the output of the *Match* function is returned with a warning.
estimand The causal estimand desired, one of "ATE", "ATT" and "ATC", which stand for Average Treatment Effect, Average Treatment effect on the Treated and on the Controls, respectively. Default is "ATT".

M The number of matches which are sought for each unit. Default is 1 ("one-to-one matching").

exact An indicator for whether exact matching on the variables contained in \( X \) is desired. Default is FALSE. This option has precedence over the caliper option.

caliper A maximum allowed distance for matching units. Units for which no match was found within caliper distance are discarded. Default is 0.25. The caliper is interpreted in standard deviation units of the unclustered data for each variable. For example, if caliper=0.25 all matches at distance bigger than 0.25 times the standard deviation for any of the variables in \( X \) are discarded. The caliper is used for both within and between clusters matching.

replace Default is TRUE. Note that setting the parameter to FALSE would give a warning since only the within-matching part can be performed without replacement (see Details).

ties An indicator for dealing with multiple matches. If more than M matches are found for each unit the additional matches are a) wholly retained with equal weights if ties=TRUE; b) a random one is chosen if ties=FALSE. Default is TRUE.

weights A vector of observation specific weights.

... Please note that all additional arguments of the Match function are not used.

Details

The function performs preferential within-cluster matching in the clusters defined by the variable Group. In the first phase matching within clusters is performed (see MatchW) and in the second the unmatched treated (or controls if estimand="ATC") are matched with all controls (treated) units. This can be helpful to avoid dropping many units in small clusters.

Value

index.control The index of control observations in the matched dataset.

index.treated The index of control observations in the matched dataset.

index.dropped The index of dropped observations due to the exact or caliper option. Note that these observations are treated if estimand is "ATT", controls if "ATC".

est The causal estimate. This is provided only if \( Y \) is not null. If estimand is "ATT" it is the (weighted) mean of \( Y \) in matched treated minus the (weighted) mean of \( Y \) in matched controls. Equivalently it is the weighted average of the within-cluster ATTs, with weights given by cluster sizes in the matched dataset.

se A model-based standard error for the causal estimand. This is a cluster robust estimator of the standard error for the linear model: \( y \sim \text{constant} + \text{Tt} \), run on the matched dataset (see cluster.vcov for details on how this estimator is obtained).
A list containing the matched datasets produced by `MatchPW`. Three datasets are included in this list: Y, Tr and X. The matched dataset for Group can be recovered by `rbind(Group[index.treated],Group[index.control])`.

### orig.treated.nobs.by.group
The original number of treated observations by group in the dataset.

### orig.control.nobs.by.group
The original number of control observations by group in the dataset.

### orig.dropped.nobs.by.group
The number of dropped observations by group after within cluster matching.

### orig.dropped.nobs.by.group.after.pref.within
The number of dropped observations by group after preferential within group matching.

### orig.nobs
The original number of observations in the dataset.

### orig.wnobs
The original number of weighted observations in the dataset.

### orig.treated.nobs
The original number of treated observations in the dataset.

### orig.control.nobs
The original number of control observations in the dataset.

### wnobs
The number of weighted observations in the matched dataset.

### caliper
The caliper used.

### intcaliper
The internal caliper used.

### exact
The value of the exact argument.

### ndrops.matches
The number of matches dropped either because of the caliper or exact option.

### estimand
The estimand required.

### Note
The function returns an object of class CMatch. The CMatchBalance function can be used to examine the covariate balance before and after matching. See the examples below.

### Author(s)
Massimo Cannas <massimo.cannas@unica.it>

### References


### See Also
See also `Match, MatchBalance`
Examples

data(schools)

# The data set is the subsample of NELS-88 data consisting of 10 handpicked schools
# from the 1003 schools in the full data set.

# Let us consider the following variables:

X<-schools$ses
X<-as.matrix(schools[,c("ses","white","public")])
Y<-schools$math
Tr<-ifelse(schools$homework>1,1,0)
Group<-schools$schid

# Note that when Group is missing, NULL or there is only one Group the function
# returns the output of the Match function with a warning.

# Suppose that the effect of homeworks (Tr) on math score (Y)
# is unconfounded conditional on X and other unobserved schools features.
# Several strategies to handle unobserved group characteristics
# are described in Arpinio and Cannas, 2016 (see References).

# Multivariate Matching on covariates in X
# default parameters: one-to-one matching on X
# with replacement with a caliper of 0.25; see also \code{Match}).

### Match preferentially within school
# first match within schools
# then (try to) match remaining units between schools
mpw <- matchPW(Y=schools$math, Tr=Tr, X=schools$ses, Group=schools$schid, caliper=0.1)
# equivalent to
# CMatch(type="pwithin",Y=schools$math, Tr=Tr, X=schools$ses,
# Group=schools$schid, caliper=0.1)

# examine covariate balance
bmpw<- CMatchBalance(Tr~ses,data=schools,match.out=mpw)

# proportion of matched observations
(mpw$orig.treated.nobs-mpw$ndrops) / mpw$orig.treated.nobs

# check drops by school
mpw$orig.ndrops.by.group

# proportion of matched observations after match-within only
(mpw$orig.treated.nobs-sum(mpw$orig.ndrops.by.group.after.within)) / mpw$orig.treated.nobs

# complete output
mpw

# or use summary method for main results
summary(mpw)
### Propensity score matching

# estimate the propensity score (ps) model

```r
mod <- glm(Tr~ses+parented+public+sex+race+urban,
family=binomial(link="logit"),data=schools)
eps <- fitted(mod)
```

# eg 1: preferential within-school propensity score matching

```r
psmw <- MatchPW(Y=schools$math, Tr=Tr, X=eps, Group=schools$schid, caliper=0.1)
```

# We can use other strategies for controlling unobserved cluster covariates
# by using different specifications of ps (see Arpino and Mealli for details):

# eg 2: standard propensity score matching using ps estimated
# from a logit model with dummies for schools

```r
mod <- glm(Tr ~ ses + parented + public + sex + race + urban + schid - 1,
family=binomial(link="logit"),data=schools)
eps <- fitted(mod)
```

```r
dpsm <- MatchPW(Y=schools$math, Tr=Tr, X=eps, caliper=0.1)
```

# this is equivalent to run Match with X=eps

# eg3: standard propensity score matching using ps estimated from
# multilevel logit model (random intercept at the school level)

```r
require(lme4)
mod<-glmer(Tr ~ ses + parented + public + sex + race + urban + (1|schid),
family=binomial(link="logit"), data=schools)
eps <- fitted(mod)
```

```r
mpsm <- MatchPW(Y=schools$math, Tr=Tr, X=eps, Group=NULL, caliper=0.1)
```

# this is equivalent to run Match with X=eps

---

**MatchW**

**Within-cluster Matching**

### Description

This function implements multivariate and propensity score matching within clusters defined by the Group variable.
**Usage**

`MatchW(Y = NULL, Tr, X, Group = NULL, estimand = "ATT", M = 1, exact = NULL, caliper = 0.25, weights = NULL, replace = TRUE, ties = TRUE, ...)`

**Arguments**

- **Y**
  A vector containing the outcome of interest.

- **Tr**
  A vector indicating the treated and control units.

- **X**
  A matrix of covariates we wish to match on. This matrix should contain all confounders or the propensity score or a combination of both.

- **Group**
  A vector describing the clustering structure (typically the cluster ID). This can be any numeric vector of the same length of `Tr` and `X` containing integer numbers in ascending order otherwise an error message will be returned. Default is NULL, however if `Group` is missing, NULL or it contains only one value the output of the `Match` function is returned with a warning.

- **estimand**
  The causal estimand desired, one of "ATE", "ATT" and "ATC", which stand for Average Treatment Effect, Average Treatment effect on the Treated and on the Controls, respectively. Default is "ATT".

- **M**
  The number of matches which are sought for each unit. Default is 1 ("one-to-one matching").

- **exact**
  An indicator for whether exact matching on the variables contained in `X` is desired. Default is FALSE. This option has precedence over the caliper option.

- **caliper**
  A maximum allowed distance for matching units. Units for which no match was found within caliper distance are discarded. Default is 0.25. The caliper is interpreted in standard deviation units of the unclustered data for each variable. For example, if caliper=0.25 all matches at distance bigger than 0.25 times the standard deviation for any of the variables in `X` are discarded.

- **weights**
  A vector of specific observation weights.

- **replace**
  Matching can be with or without replacement depending on whether matches can be re-used or not. Default is TRUE.

- **ties**
  An indicator for dealing with multiple matches. If more than M matches are found for each unit the additional matches are a) wholly retained with equal weights if ties=TRUE; b) a random one is chosen if ties=FALSE. Default is TRUE.

- **...**
  Note that additional arguments of the `Match` function are not used.

**Details**

This function is meant to be a natural extension of the `Match` function to clustered data. It retains the main arguments of `Match` but it has additional output showing matching results cluster by cluster. It differs from wrapper `Matchby` in package `Matching` in the way standard errors are calculated and because the caliper is in standard deviation units of the covariates on the overall dataset (so the caliper is the same for all clusters). Moreover, observation weights are available.
Value

index.control The index of control observations in the matched dataset.

index.treated The index of control observations in the matched dataset.

index.dropped The index of dropped observations due to the exact or caliper option. Note that these observations are treated if estimand is "ATT", controls if "ATC".

est The causal estimate. This is provided only if Y is not null. If estimand is "ATT" it is the (weighted) mean of Y in matched treated units minus the (weighted) mean of Y in matched controls. Equivalently, it is the weighted average of the within-cluster ATTs, with weights given by cluster sizes in the matched dataset.

se A model-based standard error for the causal estimand. This is a cluster robust estimator of the standard error for the linear model: Y \sim constant+Tr, run on the matched dataset (see \texttt{cluster.vcov} for details on how this estimator is obtained). Note that these standard errors differ from a weighted average of cluster specific standard errors provided by the Matchby function, which are generally larger. Estimating standard errors for causal parameters with clustered data is an active field of research and there is no perfect solution to date.

ndata A list containing the matched datasets produced by MatchPW. Three datasets are included in this list: Y, Tr and X. The matched dataset for Group can be recovered by \texttt{rbind(Group[index.treated], Group[index.control])}.

orig.treated.nobs.by.group The original number of treated observations by group in the dataset.

orig.control.nobs.by.group The original number of control observations by group in the dataset.

orig.dropped.nobs.by.group The original number of dropped observations by group after within cluster matching.

orig.nobs The original number of observations in the dataset.

orig.wnobs The original number of weighted observations in the dataset.

orig.treated.nobs The original number of treated observations in the dataset.

orig.control.nobs The original number of control observations in the dataset.

wnobs The number of weighted observations in the matched dataset.

caliper The caliper used.

intcaliper The internal caliper used.

exact The value of the exact argument.

ndrops.matches The number of matches dropped either because of the caliper or exact option (or because of forcing the match within-clusters).

estimand The estimand required.

Note

The function returns an object of class \texttt{CMatch}. The \texttt{CMatchBalance} function can be used to examine the covariate balance before and after matching (see the examples below).
Author(s)
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References

See Also
See also Match, MatchBalance

Examples
data(schools)

# The data set is the subsample of NELS-88 data consisting of 10 handpicked schools
# from the 1003 schools in the full data set.

# Let us consider the following variables:

X<-schools$ses #X<-as.matrix(schools[,c("ses","white","public")])
Y<-schools$math
Tr<-ifelse(schools$homework>1,1,0)
Group<-schools$schid

# Note that when Group is missing, NULL or there is only one group the function returns
# the output of the Match function with a warning.

# Suppose that the effect of homeworks (Tr) on math score (Y)
# is unconfounded conditional on X and other unobserved schools features.
# Several strategies to handle unobserved group characteristics
# are described in Arpino and Cannas, 2016 (see References).

# Multivariate Matching on covariates in X
# default parameters: one-to-one matching on X
# with replacement with a caliper of 0.25; see also \code{Match}.

### Matching within schools
mw<-MatchW(Y=Y, Tr=Tr, X=X, Group=Group, caliper=0.1)
# equivalent to \code{CMatch(type="within",Y=Y, Tr=Tr, X=X, Group=Group, caliper=0.1)}

# compare balance before and after matching
bmw <- CMatchBalance(Tr~X,data=schools,match.out=mw)
# proportion of matched observations
# check number of drops by school
mw$orig.ndrops.by.group

# examine output
mw <- summary(mw) # basic statistics  

### Propensity score matching

# estimate the propensity score (ps) model
mod <- glm(Tr ~ ses + parented + public + sex + race + urban,
    family = binomial(link = "logit"), data = schools)
eps <- fitted(mod)

# eg 1: within-school propensity score matching
psmw <- MatchW(Y = schools$math, Tr = Tr, X = eps, Group = schools$schid, caliper = 0.1)

# We can use other strategies for controlling unobserved cluster covariates
# by using different specifications of ps:

# eg 2: standard propensity score matching using ps estimated
# from a logit model with dummies for schools
mod <- glm(Tr ~ ses + parented + public + sex + race + urban + schid - 1,
    family = binomial(link = "logit"), data = schools)
eps <- fitted(mod)

dpsm <- MatchW(Y = schools$math, Tr = Tr, X = eps, caliper = 0.1)  
# this is equivalent to run Match with X = eps

# eg 3: standard propensity score matching using ps estimated from
# multilevel logit model (random intercept at the school level)
require(lme4)
mod <- glmer(Tr ~ ses + parented + public + sex + race + urban + (1|schid),
    family = binomial(link = "logit"), data = schools)
eps <- fitted(mod)

mpsm <- MatchW(Y = schools$math, Tr = Tr, X = eps, Group = NULL, caliper = 0.1)  
# this is equivalent to run Match with X = eps
Description

Data set used by Kreft and De Leeuw in their book *Introducing Multilevel Modeling, Sage (1988)* to analyse the relationship between math score and time spent by students to do math homework. The data set is a subsample of NELS-88 data consisting of 10 handpicked schools from the 1003 schools in the full data set. Students are nested within schools and information is available both at the school and student level.

Usage

data("schools")

Format

A data frame with 260 observations on the following 19 variables.

- **schid**: School ID: a numeric vector identifying each school.
- **stuid**: The student ID.
- **ses**: Socioeconomic status.
- **meanses**: Mean ses for the school.
- **homework**: The number of hours spent weekly doing homeworks.
- **white**: A dummy for white race (=1) versus non-white (=0).
- **parented**: Parents highest education level.
- **public**: Public school: 1=public, 0=non public.
- **ratio**: Student-teacher ratio.
- **percmnin**: Percent minority in school.
- **math**: Math score
- **sex**: Sex: 1=male, 2=female.
- **race**: Race of student, 1=asian, 2=Hispanic, 3=Black, 4=White, 5=Native American.
- **sctype**: Type of school: 1=public, 2=catholic, 3= Private other religion, 4=Private non-r.
- **cstr**: Classroom environment structure: ordinal from 1=not accurate to 5=very much accurate.
- **scsize**: School size: ordinal from 1=[1,199) to 7=[1200+).
- **urban**: Urbanicity: 1=Urban, 2=Suburban, 3=Rural.
- **region**: Geographic region of the school: NE=1,NC=2,South=3,West=4.
- **schnum**: Standardized school ID.

Source

Examples

data(schools)

# The data set is the subsample of NELS-88 data consisting of 10 handpicked schools
# from the 1003 schools in the full data set.

# Suppose that the effect of homeworks on math score is unconfounded conditional on X and
# unobserved school features (we assume this only for illustrative purpose)

# Let us consider the following variables:

X<-schools$ses #X<-as.matrix(schools[,c("ses","white","public")])
Y<-schools$math
Tr<-ifelse(schools$homework>1,1,0)
Group<-schools$schid
# Note that when Group is missing, NULL or there is only one Group the function
# returns the output of the Match function with a warning.

# Let us assume that the effect of homeworks (Tr) on math score (Y)
# is unconfounded conditional on X and other unobserved schools features.
# Several strategies to handle unobserved group characteristics
# are described in Arpino & Cannas, 2016 (see References).

# Multivariate Matching on covariates in X
#(default parameters: one-to-one matching on X with replacement with a caliper of 0.25).

### Matching within schools
mw<-MatchW(Y=Y, Tr=Tr, X=X, Group=Group, caliper=0.1)

# compare balance before and after matching
bmw <- MatchBalance(Tr~X, data=schools, match.out=mw)

# calculate proportion of matched observations
(mw$orig.treated.nobs-mw$ndrops)/mw$orig.treated.nobs

# check number of drops by school
mw$orig.ndrops.by.group

# examine output
mw     # complete list of results
summary(mw)  # basic statistics

#### Propensity score matching

# estimate the propensity score (ps) model
mod <- glm(Tr~ses+parented+public+sex+race+urban,
family=binomial(link="logit"),data=schools)
eps <- fitted(mod)
# eg 1: within-school propensity score matching
psmw <- MatchW(Y=schools$math, Tr=Tr, X=eps, Group=schools$schid, caliper=0.1)

# We can use other strategies for controlling unobserved cluster covariates
# by using different specifications of ps (see Arpino and Mealli for details):

# eg 2: standard propensity score matching using ps estimated
# from a logit model with dummies for schools
mod <- glm(Tr ~ ses + parented + public + sex + race + urban + schid - 1, family=binomial(link="logit"), data=schools)
eps <- fitted(mod)
dpsm <- MatchW(Y=schools$math, Tr=Tr, X=eps, caliper=0.1)
# this is equivalent to run Match with X=eps

# eg3: standard propensity score matching using ps estimated from
# multilevel logit model (random intercept at the school level)
require(lme4)
mod <- glmer(Tr ~ ses + parented + public + sex + race + urban + (1|schid), family=binomial(link="logit"), data=schools)
eps <- fitted(mod)
mpsm <- MatchW(Y=schools$math, Tr=Tr, X=eps, Group=NULL, caliper=0.1)
# this is equivalent to run Match with X=eps

summary.CMatch

## S3 method for class 'CMatch'
summary(object, ..., full = FALSE, digits = 5)

**Arguments**

object An object of class "CMatch".

... Other options for the generic summary function.

full A flag for whether the unadjusted estimates and naive standard errors should also be summarized.

digits The number of significant digits that should be displayed.
Details

A summary of most important output from a "CMatch" object, including size of matched dataset and estimates (if Y is not NULL). If Group contains only one value the output is the same of the summary method of package Matching. Otherwise the output shows also the distribution of treated (control) observations by group and the distribution of dropped (because of 'caliper' or 'exact' option), also by group.

Note

Naive standard errors are not available when there is more than one group so the full parameter is ineffective in that case.

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References


See Also

See also Match, MatchW, MatchPW, MatchBalance
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