Package ‘matchMulti’

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Type Package

Title Optimal Multilevel Matching using a Network Algorithm

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Description Performs multilevel matches for data with cluster-level treatments and individual-level outcomes using a network optimization algorithm. Functions for checking balance at the cluster and individual levels are also provided, as are methods for permutation-inference-based outcome analysis. Details in Pimentel et al. (2018) <doi:10.1214/17-AOAS1118>. The optmatch package, which is useful for running many of the provided functions, may be downloaded from Github at <https://github.com/markmfredrickson/optmatch> if not available on CRAN.

Depends R (>= 3.2.3), rlang, dplyr

Imports rcbsubset (>= 1.1.4), plyr, coin, weights, mvtnorm, MASS, sandwich, magrittr

Suggests optmatch, testthat, knitr, rrelaxiv

Additional_repositories https://errickson.net/rrelaxiv/

License MIT + file LICENSE

VignetteBuilder knitr

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Author Luke Keele [aut], Luke Miratrix [aut], Sam Pimentel [aut, cre], Paul Rosenbaum [ctb]

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matchMulti-package

Contents

matchMulti-package .................................................. 2
balanceMulti .......................................................... 4
buildCaliper ............................................................ 5
catholic_schools ....................................................... 6
describe_data_counts .................................................. 7
elastic ................................................................. 8
matchMulti ............................................................. 9
matchMultioutcome ...................................................... 12
matchMultiResult ....................................................... 14
matchMultisens ......................................................... 15
minischool ............................................................. 16
rematchSchools ......................................................... 17
tally_schools ........................................................... 19

Index 20

matchMulti-package

matchMulti Package

Description

matchMulti provides an easy to use set of functions to do matching with multilevel data. It is designed for use with grouped data such as students in schools, where the user wishes to match a set of treated groups to control groups to make the two groups more comparable.

Details

This package will match treated groups to control groups, but allows for trimming of both units and groups to increase balance. There are also functions for assessing balance after matching, estimating treatment effects and performing sensitivity analysis for hidden confounders.

Author(s)

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- Luke Keele <luke.keele@gmail.com>
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Other contributors:

- Paul Rosenbaum [contributor]

See Also

See also matchMulti, matchMultisens, balanceMulti, matchMultioutcome, rematchSchools
## Examples

```
## Not run:

# Load Catholic school data
data(catholic_schools)

student.cov <- c('minority', 'female', 'ses', 'mathach')

# Check balance student balance before matching
balanceTable(catholic_schools[c(student.cov, 'sector')], treatment = 'sector')

# Match schools but not students within schools
match.simple <- matchMulti(catholic_schools, treatment = 'sector',
                           school.id = 'school', match.students = FALSE)

# Check balance after matching - this checks both student and school balance
balanceMulti(match.simple, student.cov = student.cov)

# Estimate treatment effect
output <- matchMultioutcome(match.simple, out.name = "mathach",
                              schl_id_name = "school", treat.name = "sector")

# Perform sensitivity analysis using Rosenbaum bound -- increase Gamma to increase effect of
# possible hidden confounder
matchMultisens(match.simple, out.name = "mathach",
               schl_id_name = "school", treat.name = "sector", Gamma=1.3)

# Now match both schools and students within schools
match.out <- matchMulti(catholic_schools, treatment = 'sector',
                        school.id = 'school', match.students = TRUE, student.vars = student.cov)

# Check balance again
bal.tab <- balanceMulti(match.out, student.cov = student.cov)

# Now match with fine balance constraints on whether the school is large
# or has a high percentage of minority students
match.fb <- matchMulti(catholic_schools, treatment = 'sector', school.id = 'school',
                       match.students = TRUE, student.vars = student.cov,
                       school.fb = list(c('size_large'), c('size_large', 'minority_mean_large')))

# Estimate treatment effects
matchMultioutcome(match.fb, out.name = "mathach", schl_id_name = "school", treat.name = "sector")

# Check Balance
balanceMulti(match.fb, student.cov = student.cov)

## End(Not run)
```
balanceMulti

Performs balance checking after multilevel matching.

Description

This function checks balance after multilevel balance. It checks balance on both level-one (student) and level-two (school) covariates.

Usage

```
balanceMulti(
  match.obj,
  student.cov = NULL,
  school.cov = NULL,
  include.tests = TRUE,
  single.table = FALSE
)
```

Arguments

- **match.obj**: A multilevel match object
- **student.cov**: Names of student level covariates that you want to check balance
- **school.cov**: Names of school level covariates for which you want to check balance, if any.
- **include.tests**: If TRUE include tests for balance. FALSE just report the means and differences.
- **single.table**: If FALSE include a list of student and school covariates separately. TRUE means single balance table.

Details

This function returns a list which include balance checks for before and after matching for both level-one and level-two covariates. Balance statistics include treated and control means, standardized differences, which is the difference in means divided by the pooled standard deviation before matching, and p-values for mean differences. It extracts the matched data and calls `balanceTable` for student and school level covariates.

Value

- **students**: Balance table for student level covariates, as a dataframe.
- **schools**: Balance table for school level covariates, as a dataframe.

Author(s)

Luke Keele, Penn State University, <ljk20@psu.edu> Sam Pimentel, University of Pennsylvania, <spi@wharton.upenn.edu>
buildCaliper

Construct propensity score caliper

Description

Fits a propensity score for an individual-level or group-level treatment, computes a caliper for the propensity score (based on a fractional number of standard deviations provided by the user), and creates a matrix containing information about which treated-control pairings are excluded by the caliper.

Usage

buildCaliper(data, treatment, ps.vars, group.id = NULL, caliper = 0.2)

Arguments

data A data frame containing the treatment variable, the variables to be used in fitting the propensity score and (if treatment is at the group level) a group ID.
treatment Name of the treatment indicator.
ps.vars Vector of names of variables to use in fitting the propensity score.
group.id Name of group ID variable, if applicable.
caliper Desired size of caliper, in number of standard deviations of the fitted propensity score.

See Also

See also matchMulti, matchMultisens, matchMultioutcome, rematchSchools

Examples

```r
## Not run:
# Load Catholic school data
data(catholic_schools)

student.cov <- c('minority', 'female', 'ses', 'mathach')

# Check balance student balance before matching
balanceTable(catholic_schools[c(student.cov, 'sector')], treatment = 'sector')

# Match schools but not students within schools
match.simple <- matchMulti(catholic_schools, treatment = 'sector', school.id = 'school', match.students = FALSE)

# Check balance after matching - this checks both student and school balance
balanceMulti(match.simple, student.cov = student.cov)

## End(Not run)
```
Details

The treatment variable should be binary with 1 indicating treated units and 0 indicating controls. When group.id is NULL, treatment is assumed to be at the individual level and the propensity score is fitted using the matrix data. When a group ID is specified, data frame data is first aggregated into groups, with variables in ps.vars replaced by their within-group means, and the propensity score is fitted on the group matrix.

Value

A matrix with nrow equal to the number of treated individuals or groups and ncol equal to the number of control individuals, with 0 entries indicating pairings permitted by the caliper and Inf entries indicating forbidden pairings.

Author(s)

Luke Keele, Penn State University, <ljk20@psu.edu>
Sam Pimentel, University of California, Berkeley, <spi@berkeley.edu>

Examples

## Not run:
# Load Catholic school data
data(catholic_schools)

student.cov <- c('minority','female','ses','mathach')

# Check balance student balance before matching
balanceTable(catholic_schools[c(student.cov,'sector')], treatment = 'sector')

#fit a propensity score caliper on mean values of student covariates within schools
school.caliper <- buildCaliper(data = catholic_schools, treatment = 'sector',
                             ps.vars = student.cov, group.id = 'school')

#Match schools but not students within schools
match.simple <- matchMulti(catholic_schools, treatment = 'sector',
                           school.caliper = school.caliper, school.id = 'school', match.students = FALSE)

#Check balance after matching - this checks both student and school balance
balanceMulti(match.simple, student.cov = student.cov)

## End(Not run)
describe_data_counts

Format

A data.frame with 1595 observations on the following variables.
school: unique school level identifier
ses: student level socio-economic status scale ranges from approx. -3.578 to 2.692
mathach: senior year mathematics test score, outcome measure
female: student level indicator for sex
minority: student level indicator for minority
minority_mean: school level measure of percentage of student body that is minority
female_mean: school level measure of percentage of student body that is female
ses_mean: school level measure of average level of student socio-economic status
sector: treatment indicator 1 if catholic 0 if public
size: school level measure of total number of enrolled students
acad: school level measure of the percentage of students on the academic track
discrm: school level measure of disciplinary climate ranges from approx. -2.4 to 2.7
size_large: school level indicator for schools with more than 1000 students
minority_mean_large: school level indicator for schools with more than ten percent minority

Source


References


describe_data_counts  Print out summary of student and school counts

Description

Given a school ID and treatment variable, count up number of schools and students, print out a summary of the counts of students and schools.

Usage

describe_data_counts(data, school.id, treatment)

Arguments

data Dataset (student level)
school.id String name of ID column in data (the grouping variable)
treatment String name of the treatment variable.
**Value**

List of three numbers, # control, # Tx, # Total

**See Also**

tally_schools

---

**elastic**  
*Optimal Subset Matching without Balance Constraints*

**Description**

Conducts optimal subset matching as described in the reference.

**Usage**

```
elastic(mdist, n = 0, val = 0)
pairmatchelastic(mdist, n = 0, val = 0)
```

**Arguments**

- `mdist`  
  distance matrix with rows corresponding to treated units and columns corresponding to controls.

- `n`  
  maximum number of treated units that can be excluded.

- `val`  
  cost of excluding a treated unit (i.e. we prefer to exclude a treated unit if it increases the total matched distance by more than `val`).

**Details**

`pairmatchelastic` is the main function, which conducts an entire match. `elastic` is a helper function which augments the original distance matrix as described in the reference.

The original versions of these functions were written by Paul Rosenbaum and distributed in the supplemental material to the paper: "Optimal Matching of an Optimally Chosen Subset in Observational Studies," Paul R. Rosenbaum, Journal of Computational and Graphical Statistics, Vol. 21, Iss. 1, 2012.

**Value**

`elastic` returns an augmented version of the input matrix `mdist`. `pairmatchelastic` returns a matrix of 1 column whose values are the column numbers of matched controls and whose rownames are the row numbers of matched treated units.

**Author(s)**

Paul R. Rosenbaum (original forms), modifications by Luke Keele and Sam Pimentel
References


matchMulti

A function that performs multilevel matching.

Description

This is the workhorse function in the package which matches groups and units within groups. For example, it will match both schools and students in schools, where the goal is to make units more comparable to estimate treatment effects.

Usage

matchMulti(
  data,
  treatment,
  school.id,
  match.students = TRUE,
  student-vars = NULL,
  school.caliper = NULL,
  school.fb = NULL,
  verbose = FALSE,
  keep.target = NULL,
  student.penalty.qtile = 0.05,
  min.keep.pctg = 0.8,
  school.penalty = NULL,
  save.first.stage = TRUE,
  tol = 10,
  solver = "rlemon"
)

Arguments

data
  A data frame for use in matching.

treatment
  Name of covariate that defines treated and control groups.

school.id
  Identifier for groups (for example schools)

match.students
  Logical flag for whether units within groups should also be matched. If set to FALSE, all units will be retained in both groups.

student.vars
  Names of student level covariates on which to measure balance. School-level distances will be penalized when student matches are imbalanced on these variables. In addition, when match.students is TRUE, students are matched on a distance computed from these covariates.
school.caliper matrix with one row for each treated school and one column for each control school, containing zeroes for pairings allowed by the caliper and Inf values for forbidden pairings. When NULL no caliper is imposed.

school.fb A list of discrete group-level covariates on which to enforce fine balance, i.e., ensure marginal distributions are balanced. First group is most important, second is second most, etc. If a simple list of variable names, one group is assumed. A list of list will give this hierarchy.

verbose Logical flag for whether to give detailed output.

keep.target an optional numeric value specifying the number of treated schools desired in the final match.

student.penalty.qtile This helps exclude students if they are difficult to match. Default is 0.05, which implies that in the match we would prefer to exclude students rather than match them at distances larger than this quantile of the overall student-student robust Mahalanobis distance distribution

min.keep.pctg Minimum percentage of students (from smaller school) to keep when matching students in each school pair.

school.penalty A penalty to remove groups (schools) in the group (school) match

save.first.stage Should first stage matches be saved.

tol a numeric tolerance value for comparing distances, used in the school match. It may need to be raised above the default when matching with many levels of refined balance or in very large problems (when these distances will often be at least on the order of the tens of thousands).

solver Name of package used to solve underlying network flow problem for the school match, one of 'rlemon' and 'rrelaxiv'. rrelaxiv carries an academic license and is not hosted on CRAN so it must be installed separately.

Details

matchMulti first matches students (or other individual units) within each pairwise combination of schools (or other groups); based on these matches a distance matrix is generated for the schools. Then schools are matched on this distance matrix and the student matches for the selected school pairs are combined into a single matched sample.

School covariates are not used to compute the distance matrix for schools (since it is generated from the student match). Instead imbalances in school covariates should be addressed through the school.fb argument, which encodes a refined covariate balance constraint. School covariates in school.fb should be given in order of priority for balance, since the matching algorithm optimally balances the variables in the first list element, then attempts to further balance the those in the second element, and so on.

Value

raw The unmatched data before matching.

matched The matched dataset of both units and groups. Outcome analysis and balance checks are performed on this item.
school.match  Object with two parts. The first lists which treated groups (schools) are matched
to which control groups. The second lists the population of groups used in the
match.
school.id     Name of school identifier
treatment     Name of treatment variable

Author(s)

Luke Keele, Penn State University, <ljk20@psu.edu>
Sam Pimentel, University of California, Berkeley, <spi@berkeley.edu>

See Also

See also `matchMulti, matchMultisens, balanceMulti, matchMultioutcome, rematchSchools`

Examples

```r
#toy example with short runtime
library(matchMulti)

#Load Catholic school data
data(catholic_schools)

# Trim data to speed up example
catholic_schools <- catholic_schools[catholic_schools$female_mean > .45 &
catholic_schools$female_mean < .60,]

#match on a single covariate
student.cov <- c('minority')

match.simple <-
matchMulti(catholic_schools, treatment = 'sector',
school.id = 'school', match.students = FALSE,
student.vars = student.cov, verbose=TRUE, tol=.01)

#Check balance after matching - this checks both student and school balance
balanceMulti(match.simple, student.cov = student.cov)

## Not run:
#larger example
data(catholic_schools)

student.cov <- c('minority','female','ses')

# Check balance student balance before matching
balanceTable(catholic_schools[c(student.cov,'sector')], treatment = 'sector')

#Match schools but not students within schools
match.simple <- matchMulti(catholic_schools, treatment = 'sector',
```

school.id = 'school', match.students = FALSE)

# Check balance after matching - this checks both student and school balance
balanceMulti(match.simple, student.cov = student.cov)

# Estimate treatment effect
output <- matchMultioutcome(match.simple, out.name = "mathach",
    schl_id_name = "school", treat.name = "sector")

# Perform sensitivity analysis using Rosenbaum bound -- increase Gamma to increase effect of
# possible hidden confounder
matchMultisens(match.simple, out.name = "mathach",
    schl_id_name = "school",
    treat.name = "sector", Gamma = 1.3)

# Now match both schools and students within schools
match.out <- matchMulti(catholic_schools, treatment = 'sector',
    school.id = 'school', match.students = TRUE, student.vars = student.cov)

# Check balance again
bal.tab <- balanceMulti(match.out, student.cov = student.cov)

# Now match with fine balance constraints on whether the school is large
# or has a high percentage of minority students
match.fb <- matchMulti(catholic_schools, treatment = 'sector', school.id = 'school',
    match.students = TRUE, student.vars = student.cov,
    school.fb = list( c('size_large'), c('minority_mean_large') )

# Estimate treatment effects
matchMultioutcome(match.fb, out.name = "mathach", schl_id_name = "school", treat.name = "sector")

# Check Balance
balanceMulti(match.fb, student.cov = student.cov)

## End(Not run)

---

**matchMultioutcome**

*Performs an outcome analysis after multilevel matching.*

**Description**

This function returns a point estimate, 95% confidence interval, and p-values for the matched multi-level data. All results are based on randomization inference.
matchMultioutcome

Usage

matchMultioutcome(
  obj,
  out.name = NULL,
  schl_id_name = NULL,
  treat.name = NULL,
  end.1 = -1000,
  end.2 = 1000
)

Arguments

obj      A multilevel match object.
out.name Outcome variable name
schl_id_name Level 2 ID variable name. This variable identifies the clusters in the data that you want to match.
treat.name Treatment variable name, must be zero or one.
end.1    Lower bound for point estimate search, default is -1000.
end.2    Upper bound for point estimate search, default is 1000.

Details

It may be necessary to adjust the lower and upper bounds if one expects the treatment effect confidence interval to be outside the range of -1000 or 1000.

Value

pval.c  One-sided approximate p-value for test of the sharp null.
pval.p  One-sided approximate p-value for test of the sharp null assuming treatment effects vary with cluster size
ci1     Lower bound for 95% confidence interval.
ci2     Upper bound for 95% confidence interval.
p.est   Point estimate for the group level treatment effect.

Author(s)

Luke Keele, Penn State University, ljk20@psu.edu
Sam Pimentel, University of California, Berkeley, <spi@berkeley.edu>

References


See Also

See Also as matchMulti, matchMultisens
**Examples**

```r
## Not run:
# Load Catholic school data
data(catholic_schools)

student.cov <- c('minority','female','ses','mathach')

# Check balance student balance before matching
balanceTable(catholic_schools[c(student.cov,'sector')], treatment = 'sector')

#Match schools but not students within schools
match.simple <- matchMulti(catholic_schools, treatment = 'sector',
school.id = 'school', match.students = FALSE)

#Check balance after matching - this checks both student and school balance
balanceMulti(match.simple, student.cov = student.cov)

#Estimate treatment effect
output <- matchMultioutcome(match.simple, out.name = "mathach",
schl_id_name = "school", treat.name = "sector")

## End(Not run)
```

---

**matchMultiResult**

*matchMultiResult object for results of power calculations*

**Description**

The matchMultiResult object is an S3 class that holds the results from the matchMulti call. matchMulti result objects have the matched datasets inside of them.

**Usage**

```r
is.matchMultiResult(x)

## S3 method for class 'matchMultiResult'
print(x, ...)

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

**Arguments**

- `x` a matchMultiResult object (except for is.matchMultiResult, where it is a generic object to check).
- `...` Extra options passed to print.matchMultiResult
- `object` Object to summarize.
matchMultisens

Value

is.matchMultiResult: TRUE if object is a matchMultiResult object.

Description

Function to calculate Rosenbaum bounds for continuous outcomes after multilevel matching.

Usage

matchMultisens(
  obj,
  out.name = NULL,
  schl_id_name = NULL,
  treat.name = NULL,
  Gamma = 1
)

Arguments

obj A multilevel match object
out.name Outcome variable name
schl_id_name Level 2 ID variable name, that is this variable identifies clusters matched in the data.
treat.name Treatment indicator name
Gamma Sensitivity analysis parameter value. Default is one.

Details

This function returns a single p-value, but actually conducts two tests. The first assumes that the treatment effect does not vary with cluster size. The second allows the treatment effect to vary with cluster size. The function returns a single p-value that is corrected for multiple testing. This p-value is the upper bound for a single Gamma value.

Value

pval Upper bound on one-sided approximate p-value for test of the sharp null.

Author(s)

Luke Keele, University of Pennsylvania, <luke.keele@gmail.com>
Sam Pimentel, University of California, Berkeley, <spi@berkeley.edu>
References


See Also

See Also as `matchMulti, matchMultioutcome`

Examples

```r
## Not run:
# Load Catholic school data
data(catholic_schools)

student.cov <- c('minority','female','ses','mathach')

# Check balance student balance before matching
balanceTable(catholic_schools[,c(student.cov,'sector')], treatment = 'sector')

# Match schools but not students within schools
match.simple <- matchMulti(catholic_schools, treatment = 'sector',
school.id = 'school', match.students = FALSE)

# Check balance after matching - this checks both student and school balance
balanceMulti(match.simple, student.cov = student.cov)

# Estimate treatment effect
output <- matchMultioutcome(match.simple, out.name = "mathach",
schl_id_name = "school", treat.name = "sector")

# Perform sensitivity analysis using Rosenbaum bound -- increase Gamma to increase effect of 
# possible hidden confounder
matchMultisens(match.simple, out.name = "mathach",
schl_id_name = "school", treat.name = "sector", Gamma=1.3)

## End(Not run)
```

minischool

Mini-data set for illustration

Description

The Catholic schools dataset subset to a smaller number of schools (with only 6 Catholic schools). See full dataset documentation for more information.
rematchSchools

Format

A data frame with 1500 rows and 12 variables, as described in the ‘catholic_schools’ dataset.

Source

See documentation page for ‘catholic_schools’ dataset.

See Also

catholic_schools

---

rematchSchools  Repeat School Match Only

Description

After matchMulti has been called, repeats the school match (with possibly different parameters) without repeating the more computationally intensive student match.

Usage

rematchSchools(
  match.out,
  students,
  school.fb = NULL,
  verbose = FALSE,
  keep.target = NULL,
  school.penalty = NULL,
  tol = 0.001
)

Arguments

match.out  an object returned by a call to matchMulti.
students  a dataframe containing student and school covariates, with a different row for each student.
school.fb  an optional list of character vectors, each containing a subset of the column names of students. Each element of the list should contain all the names in previous elements (producing a nested structure).
verbose  a logical value indicating whether detailed output should be printed.
keep.target  an optional numeric value specifying the number of treated schools desired in the final match.
school.penalty  an optional numeric value, treated as the cost (to the objective function in the underlying optimization problem) of excluding a treated school. If it is set lower, more schools will be excluded.
tol  a numeric tolerance value for comparing distances. It may need to be raised above the default when matching with many levels of refined balance.
Details

The `school.fb` argument encodes a refined covariate balance constraint: the matching algorithm optimally balances the interaction of the variables in the first list element, then attempts to further balance the interaction in the second element, and so on. As such variables should be added in order of priority for balance.

The `keep.target` and `school.penalty` parameters allow optimal subset matching within the school match. When the `keep.target` argument is specified, the school match is repeated for different values of the `school.penalty` parameter in a form of binary search until an optimal match is obtained with the desired number of treated schools or a stopping rule is reached. The `tol` parameter controls the stopping rule; smaller values provide a stronger guarantee of obtaining the exact number of treated schools desired but may lead to greater computational costs.

It is not recommended that users specify the `school.penalty` parameter directly in most cases. Instead the `keep.target` parameter provides an easier way to consider excluding schools.

Author(s)

Luke Keele, Penn State University, <ljk20@psu.edu>
Sam Pimentel, University of California, Berkeley, <spi@berkeley.edu>

References


See Also

`matchMulti`.

Examples

```r
## Not run:
# Load Catholic school data
data(catholic_schools)

student.cov <- c('minority','female','ses')
school.cov <- c('minority_mean','female_mean','ses_mean','size','acad')

#Match schools but not students within schools
match.simple <- matchMulti(catholic_schools, treatment = 'sector',
                           school.id = 'school', match.students = FALSE)

#Check balance after matching - this checks both student and school balance
balanceMulti(match.simple, student.cov = student.cov, school.cov = school.cov)

#now rematch excluding 2 schools
match.trimmed <- rematchSchools(match.simple, catholic_schools, keep.target = 13)
match.trimmed$dropped$schools.t
```
tally_schools

## End(Not run)

### tally_schools

Tally schools and students in a given dataset

#### Description

Returns a count of schools, without printing anything.

#### Usage

`tally_schools(data, school.id, treatment)`

#### Arguments

- `data`: Dataset (student level)
- `school.id`: String name of ID column in data (the grouping variable)
- `treatment`: String name of the treatment variable.

#### Value

List of two things: school and student counts (invisible).

#### Author(s)

Luke Miratrix

#### See Also

`describe_data_counts`
Index

* balance
  balanceMulti, 4
  buildCaliper, 5
* datasets
  catholic_schools, 6
* matchMulti
  matchMulti-package, 2
* outcomes
  matchMultioutcome, 12

balanceMulti, 2, 4, 11
buildCaliper, 5
catholic_schools, 6
describe_data_counts, 7
elastic, 8

is.matchMultiResult (matchMultiResult), 14

matchMulti, 2, 5, 9, 11, 13, 16, 18
matchMulti-package, 2
matchMultioutcome, 2, 5, 11, 12, 16
matchMultiResult, 14
matchMultisens, 2, 5, 11, 13, 15
minischool, 16

pairmatchelastic (elastic), 8
print.matchMultiResult
  (matchMultiResult), 14

rematchSchools, 2, 5, 11, 17

summary.matchMultiResult
  (matchMultiResult), 14

tally_schools, 19