Package 'nprobust'

October 13, 2022

Type Package

Title Nonparametric Robust Estimation and Inference Methods using Local Polynomial Regression and Kernel Density Estimation

Version 0.4.0

Date 2020-08-24

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Description Tools for data-driven statistical analysis using local polynomial regression and kernel density estimation methods as described in Calonico, Cattaneo and Farrell (2018, <doi:10.1080/01621459.2017.1285776>): lprobust() for local polynomial point estimation and robust bias-corrected inference, lpbwselect() for local polynomial bandwidth selection, kdrobust() for kernel density point estimation and robust bias-corrected inference, kdbwselect() for kernel density bandwidth selection, and nprobust.plot() for plotting results. The main methodological and numerical features of this package are described in Calonico, Cattaneo and Farrell (2019, <doi:10.18637/jss.v091.i08>).

Depends R (>= 3.1.1)

License GPL-2

Imports Rcpp, ggplot2

LinkingTo Rcpp, RcppArmadillo

NeedsCompilation yes

Repository CRAN

Date/Publication 2020-08-26 10:40:02 UTC

R topics documented:

`nprobust-package` *Nonparametric Robust Estimation and Inference Methods using Local Polynomial Regression and Kernel Density Estimation*

Description

This package provides tools for data-driven statistical analysis using local polynomial regression (LPR) and kernel density estimation (KDE) methods as described in Calonico, Cattaneo and Farrell (2018): `lprobust` for local polynomial point estimation and robust bias-corrected inference, `lpbwselect` for local polynomial bandwidth selection, `kdrobust` for kernel density point estimation and robust bias-corrected inference, `kdbwselect` for kernel density bandwidth selection, and `nprobust.plot` for plotting results. The main methodological and numerical features of this package are described in Calonico, Cattaneo and Farrell (2019).

Details

Package:	nprobust
Type:	Package
Version:	0.4.0
Date:	2020-08-24
License:	GPL-2

Function for LPR estimation and inference: `lprobust`
Function for LPR bandwidth selection: `lpbwselect`
Function for KDE estimation and inference: `kdrobust`
Function for KDE bandwidth selection: `kdbwselect`
Function for graphical analysis: `nprobust.plot`

Author(s)

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References

Calonico, S., M. D. Cattaneo, and M. H. Farrell. 2018. On the Effect of Bias Estimation on Coverage Accuracy in Nonparametric Inference. Journal of the American Statistical Association, 113(522): 767-779. doi: 10.1080/01621459.2017.1285776.

Calonico, S., M. D. Cattaneo, and M. H. Farrell. 2019. nprobust: Nonparametric Kernel-Based Estimation and Robust Bias-Corrected Inference. Journal of Statistical Software, 91(8): 1-33. doi: 10.18637/jss.v091.i08.

kdbwselect *Bandwidth Selection Procedures for Kernel Density Estimation and Inference*

Description

kdbwselect implements bandwidth selectors for kernel density point estimators and inference procedures developed in Calonico, Cattaneo and Farrell (2018). See also Calonico, Cattaneo and Farrell (2020) for related optimality results. It also implements other bandwidth selectors available in the literature. See Wand and Jones (1995) for background references.

Companion commands are: kdrobust for kernel density point estimation and inference procedures.

A detailed introduction to this command is given in Calonico, Cattaneo and Farrell (2019). For more details, and related Stata and R packages useful for empirical analysis, visit https://nppackages.github.io/.

Usage

```
kdbwselect(x, eval = NULL, neval = NULL, kernel = "epa",
bwselect = "mse-dpi", bwcheck=21, imsegrid=30, subset = NULL)
```

Arguments

x	independent variable.
eval	vector of evaluation point(s). By default it uses 30 equally spaced points over to support of x.
neval	number of quantile-spaced evaluation points on support of x. Default is neval=30.
kernel	kernel function used to construct the kernel estimators. Options are epa for the epanechnikov kernel, and uni for the uniform kernel. Default is kernel = epa.
bwselect	bandwidth selection procedure to be used. Options are: mse-dpi second-generation DPI implementation of MSE-optimal bandwidth. Default option. imse-dpi second-generation DPI implementation of IMSE-optimal bandwidth (computed using grid of evaluation points selected). imse-rot ROT implementation of IMSE-optimal bandwidth (computed using grid of evaluation points selected). ce-dpi second generation DPI implementation of CE-optimal bandwidth. ce-rot ROT implementation of CE-optimal bandwidth. all reports all available bandwidth selection procedures. Note: MSE = Mean Square Error; IMSE = Integrated Mean Squared Error; CE = Coverage Error; DPI = Direct Plug-in; ROT = Rule-of-Thumb. For details on implementation see Calonico, Cattaneo and Farrell (2019).
bwcheck	if a positive integer is provided, then the selected bandwidth is enlarged so that at least bwcheck effective observations are available at each evaluation point. Default is bwcheck = 15.

`imsegrid`	number of evaluations points used to compute the IMSE bandwidth selector. Default is `imsegrid = 30`.
`subset`	optional rule specifying a subset of observations to be used.

Value

`Estimate`	A matrix containing `eval` (grid points), `h` and `b` (bandwidths).
`opt`	A list containing options passed to the function.

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Calonico, S., M. D. Cattaneo, and M. H. Farrell. 2019. nprobust: Nonparametric Kernel-Based Estimation and Robust Bias-Corrected Inference. Journal of Statistical Software, 91(8). doi: 10.18637/jss.v091.i08.

Calonico, S., M. D. Cattaneo, and M. H. Farrell. 2020. Coverage Error Optimal Confidence Intervals for Local Polynomial Regression. Working Paper.

Fan, J., and Gijbels, I. 1996. Local polynomial modelling and its applications, London: Chapman and Hall.

Wand, M., and Jones, M. 1995. Kernel Smoothing, Florida: Chapman & Hall/CRC.

See Also

`kdrobust`

Examples

```
x   <- rnorm(500)
est <- kdbwselect(x)
summary(est)
```

kdrobust *Kernel Density Methods with Robust Bias-Corrected Inference*

Description

kdrobust implements kernel density point estimators, with robust bias-corrected confidence intervals and inference procedures developed in Calonico, Cattaneo and Farrell (2018). See also Calonico, Cattaneo and Farrell (2020) for related optimality results. It also implements other estimation and inference procedures available in the literature. See Wand and Jones (1995) for background references.

Companion commands: kdbwselect for kernel density data-driven bandwidth selection, and nprobust.plot for plotting results.

A detailed introduction to this command is given in Calonico, Cattaneo and Farrell (2019). For more details, and related Stata and R packages useful for empirical analysis, visit https://nppackages.github.io/.

Usage

```
kdrobust(x, eval = NULL, neval = NULL, h = NULL, b = NULL, rho = 1,
kernel = "epa", bwselect = NULL, bwcheck = 21, imsegrid=30, level = 95, subset = NULL)
```

Arguments

x	independent variable.
eval	vector of evaluation point(s). By default it uses 30 equally spaced points over to support of x.
neval	number of quantile-spaced evaluation points on support of x. Default is neval=30.
h	main bandwidth used to construct the kernel density point estimator. Can be either scalar (same bandwidth for all evaluation points), or vector of same dimension as eval. If not specified, bandwidth h is computed by the companion command kdbwselect.
b	bias bandwidth used to construct the bias-correction estimator. Can be either scalar (same bandwidth for all evaluation points), or vector of same dimension as eval. By default it is set equal to h. If rho is set to zero, b is computed by the companion command kdbwselect.
rho	Sets b=h/rho. Default is rho = 1.
kernel	kernel function used to construct local polynomial estimators. Options are epa for the epanechnikov kernel, tri for the triangular kernel and uni for the uniform kernel. Default is kernel = epa.
bwselect	bandwidth selection procedure to be used via lpbwselect. By default it computes h and sets b=h/rho (with rho=1 by default). It computes both h and b if rho is set equal to zero. Options are: mse-dpi second-generation DPI implementation of MSE-optimal bandwidth. Default option if only one evaluation point is chosen.

`imse-dpi` second-generation DPI implementation of IMSE-optimal bandwidth (computed using a grid of evaluation points). Default option if more than one evaluation point is chosen.

`imse-rot` ROT implementation of IMSE-optimal bandwidth (computed using a grid of evaluation points).

`ce-dpi` second generation DPI implementation of CE-optimal bandwidth.

`ce-rot` ROT implementation of CE-optimal bandwidth.

`all` reports all available bandwidth selection procedures.

Note: MSE = Mean Square Error; IMSE = Integrated Mean Squared Error; CE = Coverage Error; DPI = Direct Plug-in; ROT = Rule-of-Thumb. For details on implementation see Calonico, Cattaneo and Farrell (2019).

`bwcheck` if a positive integer is provided, then the selected bandwidth is enlarged so that at least `bwcheck` effective observations are available at each evaluation point. Default is `bwcheck = 21`.

`imsegrid` number of evaluations points used to compute the IMSE bandwidth selector. Default is `imsegrid = 30`.

`level` confidence level used for confidence intervals; default is `level = 95`.

`subset` optional rule specifying a subset of observations to be used.

Value

`Estimate` A matrix containing `eval` (grid points), `h`, `b` (bandwidths), `N` (effective sample sizes), `tau.us` (point estimates with p-th order kernel function), `tau.bc` (bias corrected point estimates, `se.us` (standard error corresponding to `tau.us`), and `se.rb` (robust standard error).

`opt` A list containing options passed to the function.

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References

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Calonico, S., M. D. Cattaneo, and M. H. Farrell. 2019. nprobust: Nonparametric Kernel-Based Estimation and Robust Bias-Corrected Inference. Journal of Statistical Software, 91(8): 1-33. doi: 10.18637/jss.v091.i08.

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Fan, J., and Gijbels, I. 1996. Local polynomial modelling and its applications, London: Chapman and Hall.

Wand, M., and Jones, M. 1995. Kernel Smoothing, Florida: Chapman & Hall/CRC.

See Also

kdbwselect

Examples

```
x   <- rnorm(500)
est <- kdrobust(x)
summary(est)
```

---

lpbwselect *Bandwidth Selection Procedures for Local Polynomial Regression Estimation and Inference*

Description

lpbwselect implements bandwidth selectors for local polynomial regression point estimators and inference procedures developed in Calonico, Cattaneo and Farrell (2018). See also Calonico, Cattaneo and Farrell (2020) for related optimality results. It also implements other bandwidth selectors available in the literature. See Wand and Jones (1995) and Fan and Gijbels (1996) for background references.

Companion commands: lprobust for local polynomial point estimation and inference procedures.

A detailed introduction to this command is given in Calonico, Cattaneo and Farrell (2019). For more details, and related Stata and R packages useful for empirical analysis, visit https://nppackages.github.io/.

Usage

```
lpbwselect(y, x, eval = NULL, neval = NULL, p = NULL, deriv = NULL,
kernel = "epa", bwselect = "mse-dpi", bwcheck = 21, bwregul = 1,
imsegrid = 30, vce = "nn", cluster = NULL,
nnmatch = 3, interior = FALSE, subset = NULL)
```

Arguments

y	dependent variable.
x	independent variable.
eval	vector of evaluation point(s). By default it uses 30 equally spaced points over to support of x.
neval	number of quantile-spaced evaluation points on support of x. Default is neval=30.
p	polynomial order used to construct point estimator; default is p = 1 (local linear regression).
deriv	derivative order of the regression function to be estimated. Default is deriv=0 (regression function).

kernel	kernel function used to construct local polynomial estimators. Options are epa for the epanechnikov kernel, tri for the triangular kernel, uni for the uniform kernel and gau for the gaussian kernel. Default is kernel = epa.
bwselect	bandwidth selection procedure to be used. Options are: mse-dpi second-generation DPI implementation of MSE-optimal bandwidth. Default option. mse-rot ROT implementation of MSE-optimal bandwidth. imse-dpi second-generation DPI implementation of IMSE-optimal bandwidth (computed using grid of evaluation points selected). imse-rot ROT implementation of IMSE-optimal bandwidth (computed using grid of evaluation points selected). ce-dpi second generation DPI implementation of CE-optimal bandwidth. ce-rot ROT implementation of CE-optimal bandwidth. all reports all available bandwidth selection procedures. Note: MSE = Mean Square Error; IMSE = Integrated Mean Squared Error; CE = Coverage Error; DPI = Direct Plug-in; ROT = Rule-of-Thumb. For details on implementation see Calonico, Cattaneo and Farrell (2019).
bwcheck	if a positive integer is provided, then the selected bandwidth is enlarged so that at least bwcheck effective observations are available at each evaluation point. Default is bwcheck = 21.
bwregul	specifies scaling factor for the regularization term added to the denominator of bandwidth selectors. Setting bwregul = 0 removes the regularization term from the bandwidth selectors. Default is bwregul = 1.
imsegrid	number of evaluations points used to compute the IMSE bandwidth selector. Default is imsegrid = 30.
vce	procedure used to compute the variance-covariance matrix estimator. Options are: nn heteroskedasticity-robust nearest neighbor variance estimator with nnmatch the (minimum) number of neighbors to be used. Default choice. hc0 heteroskedasticity-robust plug-in residuals variance estimator without weights. hc1 heteroskedasticity-robust plug-in residuals variance estimator with hc1 weights. hc2 heteroskedasticity-robust plug-in residuals variance estimator with hc2 weights. hc3 heteroskedasticity-robust plug-in residuals variance estimator with hc3 weights.
cluster	indicates the cluster ID variable used for cluster-robust variance estimation with degrees-of-freedom weights. By default it is combined with vce=nn for cluster-robust nearest neighbor variance estimation. Another option is plug-in residuals combined with vce=hc1.
nnmatch	to be combined with for vce=nn for heteroskedasticity-robust nearest neighbor variance estimator with nnmatch indicating the minimum number of neighbors to be used. Default is nnmatch=3.
interior	if TRUE, all evaluation points are assumed to be interior points. This option affects only data-driven bandwidth selection via lpbwselect. Default is interior = FALSE.
subset	optional rule specifying a subset of observations to be used.

Value

`Estimate`	A matrix containing `grid` (grid points), `h` and `b` (bandwidths), `N` (sample size)
`opt`	A list containing options passed to the function.

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Wand, M., and Jones, M. 1995. Kernel Smoothing, Florida: Chapman & Hall/CRC.

See Also

`lprobust`

Examples

```
x   <- runif(500)
y   <- sin(4*x) + rnorm(500)
est <- lpbwselect(y,x)
summary(est)
```

`lprobust` *Local Polynomial Methods with Robust Bias-Corrected Inference*

Description

lprobust implements local polynomial regression point estimators, with robust bias-corrected confidence intervals and inference procedures developed in Calonico, Cattaneo and Farrell (2018). See also Calonico, Cattaneo and Farrell (2020) for related optimality results. It also implements other estimation and inference procedures available in the literature. See Wand and Jones (1995) and Fan and Gijbels (1996) for background references.

Companion commands: lpbwselect for local polynomial data-driven bandwidth selection, and nprobust.plot for plotting results.

A detailed introduction to this command is given in Calonico, Cattaneo and Farrell (2019). For more details, and related Stata and R packages useful for empirical analysis, visit https://nppackages.github.io/.

Usage

```
lprobust(y, x, eval = NULL, neval = NULL, p = NULL, deriv = NULL,
h = NULL, b = NULL, rho = 1, kernel = "epa", bwselect = NULL,
bwcheck = 21, bwregul = 1, imsegrid = 30, vce = "nn", covgrid = FALSE,
cluster = NULL, nnmatch = 3, level = 95, interior = FALSE, subset = NULL)
```

Arguments

y	dependent variable.
x	independent variable.
eval	vector of evaluation point(s). By default it uses 30 equally spaced points over to support of x.
neval	number of quantile-spaced evaluation points on support of x. Default is neval=30.
p	polynomial order used to construct point estimator; default is p = 1 (local linear regression).
deriv	derivative order of the regression function to be estimated. Default is deriv=0 (regression function).
h	main bandwidth used to construct local polynomial point estimator. Can be either scalar (same bandwidth for all evaluation points), or vector of same dimension as eval. If not specified, bandwidth h is computed by the companion command lpbwselect.
b	bias bandwidth used to construct the bias-correction estimator. Can be either scalar (same bandwidth for all evaluation points), or vector of same dimension as eval. By default it is set equal to h. If rho is set to zero, b is computed by the companion command lpbwselect.
rho	Sets b=h/rho. Default is rho = 1.
kernel	kernel function used to construct local polynomial estimators. Options are epa for the epanechnikov kernel, tri for the triangular kernel, uni for the uniform kernel and gau for the gaussian kernel. Default is kernel = epa.
bwselect	bandwidth selection procedure to be used via lpbwselect. By default it computes h and sets b=h/rho (with rho=1 by default). It computes both h and b if rho is set equal to zero. Options are:

mse-dpi second-generation DPI implementation of MSE-optimal bandwidth. Default option if only one evaluation point is chosen.

mse-rot ROT implementation of MSE-optimal bandwidth.

imse-dpi second-generation DPI implementation of IMSE-optimal bandwidth (computed using a grid of evaluation points). Default option if more than one evaluation point is chosen.

imse-rot ROT implementation of IMSE-optimal bandwidth (computed using a grid of evaluation points).

ce-dpi second generation DPI implementation of CE-optimal bandwidth.

ce-rot ROT implementation of CE-optimal bandwidth.

all reports all available bandwidth selection procedures.

Note: MSE = Mean Square Error; IMSE = Integrated Mean Squared Error; CE = Coverage Error; DPI = Direct Plug-in; ROT = Rule-of-Thumb. For details on implementation see Calonico, Cattaneo and Farrell (2019).

bwcheck — if a positive integer is provided, then the selected bandwidth is enlarged so that at least bwcheck effective observations are available at each evaluation point. Default is bwcheck = 21.

bwregul — specifies scaling factor for the regularization term added to the denominator of bandwidth selectors. Setting bwregul = 0 removes the regularization term from the bandwidth selectors. Default is bwregul = 1.

imsegrid — number of evaluations points used to compute the IMSE bandwidth selector. Default is imsegrid = 30.

vce — procedure used to compute the variance-covariance matrix estimator. Options are:

nn heteroskedasticity-robust nearest neighbor variance estimator with nnmatch the (minimum) number of neighbors to be used. Default choice.

hc0 heteroskedasticity-robust plug-in residuals variance estimator without weights.

hc1 heteroskedasticity-robust plug-in residuals variance estimator with hc1 weights.

hc2 heteroskedasticity-robust plug-in residuals variance estimator with hc2 weights.

hc3 heteroskedasticity-robust plug-in residuals variance estimator with hc3 weights.

covgrid — if TRUE, it computes two covariance matrices (cov.us and cov.rb) for classical and robust covariances across point estimators over the grid of evaluation points.

cluster — indicates the cluster ID variable used for cluster-robust variance estimation with degrees-of-freedom weights. By default it is combined with vce=nn for cluster-robust nearest neighbor variance estimation. Another option is plug-in residuals combined with vce=hc1.

nnmatch — to be combined with for vce=nn for heteroskedasticity-robust nearest neighbor variance estimator with nnmatch indicating the minimum number of neighbors to be used. Default is nnmatch=3.

level — confidence level used for confidence intervals; default is level = 95.

interior — if TRUE, all evaluation points are assumed to be interior points. This option affects only data-driven bandwidth selection via lpbwselect. Default is interior = FALSE.

subset — optional rule specifying a subset of observations to be used.

Value

`Estimate`	A matrix containing `eval` (grid points), `h`, `b` (bandwidths), `N` (effective sample sizes), `m.us` (point estimates with p-th order local polynomial), `tau.bc` (bias corrected point estimates with (p+1)-th order local polynomial, `se.us` (standard error corresponding to `tau.us`), and `se.rb` (robust standard error).
`opt`	A list containing options passed to the function.

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Wand, M., and Jones, M. 1995. Kernel Smoothing, Florida: Chapman & Hall/CRC.

See Also

`lpbwselect`

Examples

```
x   <- runif(500)
y   <- sin(4*x) + rnorm(500)
est <- lprobust(y,x)
summary(est)
```

nprobust.plot *Graphical Presentation of Results from* nprobust *Package.*

Description

nprobust.plot plots estimated density and regression function using the nprobust package. A detailed introduction to this command is given in Calonico, Cattaneo and Farrell (2019).

Companion commands: lprobust for local polynomial point estimation and inference procedures, and kdrobust for kernel density point estimation and inference procedures.

For more details, and related Stata and R packages useful for empirical analysis, visit https://nppackages.github.io/.

Usage

```
nprobust.plot(..., alpha = NULL, type = NULL, CItype = NULL,
  title = "", xlabel = "", ylabel = "", lty = NULL, lwd = NULL,
  lcol = NULL, pty = NULL, pwd = NULL, pcol = NULL, CIshade = NULL,
  CIcol = NULL, legendTitle = NULL, legendGroups = NULL)
```

Arguments

...	Objects returned by kdrobust or lprobust.
alpha	Numeric scalar between 0 and 1, the significance level for plotting confidence regions. If more than one is provided, they will be applied to data series accordingly.
type	String, one of "line" (default), "points" or "both", how the point estimates are plotted. If more than one is provided, they will be applied to data series accordingly.
CItype	String, one of "region" (shaded region, default), "line" (dashed lines), "ebar" (error bars), "all" (all of the previous) or "none" (no confidence region), how the confidence region should be plotted. If more than one is provided, they will be applied to data series accordingly.
title, xlabel, ylabel	Strings, title of the plot and labels for x- and y-axis.
lty	Line type for point estimates, only effective if type is "line" or "both". 1 for solid line, 2 for dashed line, 3 for dotted line. For other options, see the instructions for ggplot2 or par. If more than one is provided, they will be applied to data series accordingly.
lwd	Line width for point estimates, only effective if type is "line" or "both". Should be strictly positive. For other options, see the instructions for ggplot2 or par. If more than one is provided, they will be applied to data series accordingly.
lcol	Line color for point estimates, only effective if type is "line" or "both". 1 for black, 2 for red, 3 for green, 4 for blue. For other options, see the instructions for ggplot2 or par. If more than one is provided, they will be applied to data series accordingly.

pty	Scatter plot type for point estimates, only effective if type is "points" or "both". For options, see the instructions for ggplot2 or par. If more than one is provided, they will be applied to data series accordingly.
pwd	Scatter plot size for point estimates, only effective if type is "points" or "both". Should be strictly positive. If more than one is provided, they will be applied to data series accordingly.
pcol	Scatter plot color for point estimates, only effective if type is "points" or "both". 1 for black, 2 for red, 3 for green, 4 for blue. For other options, see the instructions for ggplot2 or par. If more than one is provided, they will be applied to data series accordingly.
CIshade	Numeric, opaqueness of the confidence region, should be between 0 (transparent) and 1. Default is 0.2. If more than one is provided, they will be applied to data series accordingly.
CIcol	color for confidence region. 1 for black, 2 for red, 3 for green, 4 for blue. For other options, see the instructions for ggplot2 or par. If more than one is provided, they will be applied to data series accordingly.
legendTitle	String, title of legend.
legendGroups	String Vector, group names used in legend.

Details

Companion command: lprobust for local polynomial-based regression functions and derivatives estimation.

Value

A standard ggplot2 object is returned, hence can be used for further customization.

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See Also

lprobust, kdrobust, ggplot2

Examples

```
x   <- runif(500)
y   <- sin(4*x) + rnorm(500)
est <- lprobust(y,x)
nprobust.plot(est)
```

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