

Package ‘wqrr’

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Type Package

Title Wavelet Quantile Regression Toolbox

Version 1.0.0

Description A comprehensive toolbox for wavelet-domain quantile analyses of bivariate and multivariate time series. Provides Wavelet Quantile Regression and Multivariate Wavelet Quantile Regression after Adebayo and Ozkan (2024) <[doi:10.1016/j.jclepro.2024.140832](https://doi.org/10.1016/j.jclepro.2024.140832)>, Wavelet Quantile-on-Quantile regression with bootstrap p-values extending Sim and Zhou (2015) <[doi:10.1016/j.jbankfin.2015.01.013](https://doi.org/10.1016/j.jbankfin.2015.01.013)>, the nonparametric Causality-in-Quantiles test of Balcilar, Gupta and Pierdzioch (2016) <[doi:10.1016/j.resourpol.2016.04.004](https://doi.org/10.1016/j.resourpol.2016.04.004)> together with its wavelet variant, Wavelet Quantile Mediation and Moderation, Wavelet Quantile Correlation, and a wavelet-based nonparametric Quantile Density estimator. The Maximal Overlap Discrete Wavelet Transform (MODWT) decomposition is performed via 'waveslim' and Short / Medium / Long band aggregation is supported throughout. For plain Quantile-on-Quantile regression see the companion CRAN package 'QuantileOnQuantile'. All interactive 3D surfaces, heatmaps and contour plots default to the 'MATLAB' 'Parula' colour map.

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VignetteBuilder knitr

URL <https://github.com/merwanroudane/wqrr>

BugReports <https://github.com/merwanroudane/wqrr/issues>

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wqrr-package	<i>wqrr: Wavelet Quantile Regression Toolbox</i>
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Description

Eight wavelet-quantile estimators in one consistent interface: Wavelet Quantile Regression, Multivariate WQR, Wavelet Quantile-on-Quantile Regression with p-values, nonparametric Causality-in-Quantiles and its wavelet variant, Wavelet Quantile Mediation and Moderation, Wavelet Quantile Correlation, and a wavelet nonparametric Quantile Density estimator.

Main functions

- [wavelet_qr](#) - Wavelet Quantile Regression.
- [multivariate_wqr](#) - Multivariate WQR.
- [wavelet_qqr](#) - Wavelet QQR with p-values.
- [np_quantile_causality](#) - Causality-in-Quantiles.
- [wavelet_np_causality](#) - Wavelet variant.

- [wavelet_mediation](#) - Mediation / moderation.
- [wavelet_quantile_correlation](#) - WQC.
- [wavelet_quantile_density](#) - Quantile density.
- [parula_colors](#), [wqrr_colorscapes](#) - MATLAB-style colour palettes.

See also

For plain Quantile-on-Quantile regression see the companion CRAN package `QuantileOnQuantile`.

Author(s)

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 GitHub: <https://github.com/merwanroudane/wqrr>

modwt_mra

MODWT decomposition and band aggregation

Description

Maximal Overlap Discrete Wavelet Transform (MODWT) MRA via `waveslim::mra`, plus a helper to combine details into Short / Medium / Long bands.

Usage

```
modwt_mra(x, wavelet = "la8", level = NULL, boundary = "periodic")
aggregate_bands(details, band_spec = NULL)
```

Arguments

<code>x</code>	Numeric vector.
<code>wavelet</code>	Wavelet filter (e.g. "la8", "la16", "d4", "haar").
<code>level</code>	Integer or NULL (auto).
<code>boundary</code>	"periodic" or "reflection".
<code>details</code>	List of detail series from <code>modwt_mra()</code> \$details.
<code>band_spec</code>	Named list of integer index vectors.

Value

For `modwt_mra`: a list with elements `details` and `smooth`. For `aggregate_bands`: a named list of aggregated band series.

Examples

```
set.seed(1); x <- cumsum(rnorm(128))
dec <- modwt_mra(x, "la8", level = 4)
bands <- aggregate_bands(dec$details)
sapply(bands, length)
```

multivariate_wqr	<i>Multivariate Wavelet Quantile Regression (MWQR)</i>
------------------	--

Description

MWQR aggregates MODWT details into Short / Medium / Long bands and runs a multiple quantile regression of y_b on all regressors at each quantile within each band.

Usage

```
multivariate_wqr(y, X_list,
                 quantiles = c(0.05, 0.10, 0.25, 0.50,
                               0.75, 0.90, 0.95),
                 wavelet = "la8", J = 5, bands = TRUE,
                 dep_name = "Y", verbose = TRUE)
```

Arguments

y	Numeric response.
X_list	Named list of numeric regressors.
quantiles	Numeric vector of tau in (0, 1).
wavelet, J, bands, verbose	See wavelet_qr .
dep_name	Character label for the dependent variable.

Value

An object of class "mwqr_result".

Examples

```
set.seed(1); n <- 200
x1 <- cumsum(rnorm(n)); x2 <- cumsum(rnorm(n))
y <- 0.4 * x1 - 0.2 * x2 + rnorm(n, sd = 0.5)
fit <- multivariate_wqr(y, list(X1 = x1, X2 = x2),
                       quantiles = c(0.25, 0.5, 0.75),
                       wavelet = "la8", J = 4, verbose = FALSE)
```

np_quantile_causality *Nonparametric Causality-in-Quantiles (and Wavelet Variant)*

Description

Nonparametric quantile Granger-causality test. Standard critical values are 1.96 (5%) and 1.645 (10%).

Usage

```
np_quantile_causality(x, y,
                      test_type = c("mean", "variance"),
                      q = seq(0.05, 0.95, by = 0.05),
                      bandwidth = NULL)

wavelet_np_causality(x, y,
                    test_type = c("mean", "variance"),
                    q = seq(0.05, 0.95, by = 0.05),
                    wavelet = "la8", J = 5,
                    bands = TRUE, bandwidth = NULL,
                    verbose = TRUE)
```

Arguments

x, y	Numeric vectors of equal length.
test_type	"mean" (moment = 1) or "variance" (moment = 2).
q	Numeric vector of tau in (0, 1).
bandwidth	Numeric or NULL (Silverman plug-in).
wavelet, J, bands, verbose	See wavelet_qr .

Value

An object of class "causality_result" or "wavelet_causality_result".

References

Balcilar, M., Gupta, R., Pierdzioch, C. (2016). <doi:10.1016/j.resourpol.2016.04.004>.

Examples

```
set.seed(1); n <- 200
x <- rnorm(n); y <- 0.3 * c(0, x[-n]) + rnorm(n, sd = 0.5)
fit <- np_quantile_causality(x, y, q = c(0.25, 0.5, 0.75))
```

parula_colors *MATLAB-style colour palettes for wqrr*

Description

Colour palettes used by wqrr plots, with MATLAB Parula as the default. The Parula stops are reproduced exactly from MathWorks' 64 RGB values.

Usage

```
parula_colors(n = 256)
matlab_jet_colors(n = 256)
turbo_colors(n = 256)
bluered_colors(n = 256)
sinha_colors(n = 256)
green_orange_red_colors(n = 256)
green_yellow_red_colors(n = 256)
wqrr_palette(cols, n_breaks = 32)
resolve_colorscale(name = "Parula", n_breaks = 32)
wqrr_colorscales(show_preview = TRUE)
```

Arguments

n	Number of interpolated colours.
cols	Character vector of hex colours.
n_breaks	Stops for the plotly list.
name	Scale name (Parula by default).
show_preview	Print descriptions.

Value

Character vector or plotly colorscale list, depending on the function.

Examples

```
parula_colors(8)
wqrr_colorscales(show_preview = FALSE)
```

plot_wqr_heatmap	<i>Visualisations for wqrr Results</i>
------------------	--

Description

Interactive 3D surfaces, heatmaps and contour plots for all wqrr estimators. All default to the MATLAB 'Parula' colour map (see [parula_colors](#) and [wqrr_colorscale](#)).

Usage

```
plot_qq_3d(qq_result, value = "coefficient",
          colorscale = "Parula", show_contour = TRUE,
          x_label = "X Quantile (tau)",
          y_label = "Y Quantile (theta)", title = NULL)
```

```
plot_qq_heatmap(qq_result, value = "coefficient",
               colorscale = "Parula", show_stars = FALSE,
               x_label = "X Quantile (tau)",
               y_label = "Y Quantile (theta)", title = NULL)
```

```
plot_qq_contour(qq_result, value = "coefficient",
               colorscale = "Parula",
               x_label = "X Quantile (tau)",
               y_label = "Y Quantile (theta)", title = NULL)
```

```
plot_wqr_heatmap(wqr_result, value = "beta",
                colorscale = "GreenOrangeRed",
                title = "Wavelet Quantile Regression",
                x_label = "Quantiles",
                y_label = "Time Horizons")
```

```
plot_wqqr_surface(wqqr_result, colorscale = "Parula", title = NULL)
```

```
plot_wqqr_pvalue_heatmap(wqqr_result, alpha = 0.05,
                        colorscale = "Sinha", title = NULL)
```

```
plot_wqr_vs_wqqr(wqqr_result, ...)
```

```
plot_causality(causality_result, cv = 1.96, title = NULL)
```

```
plot_wavelet_causality(wcr, colorscale = "GreenOrangeRed", title = NULL)
```

```
plot_correlation_heatmap(x, y,
                        quantiles = seq(0.1, 0.9, by = 0.1),
                        colorscale = "RdBu",
                        title = "Quantile Correlation Heatmap")
```

```
plot_wqc_heatmap(wqc_result, colorscale = "Parula",
                 title = "Wavelet Quantile Correlation")

plot_quantile_density(qd_result, ...)

plot_mediation_panel(med_result, colorscale = "GreenYellowRed")
```

Arguments

qq_result, wqr_result, wqqr_result, causality_result, wcr, wqc_result, qd_result, med_result

Result objects from the respective estimators.

x, y, quantiles Inputs for plot_correlation_heatmap.
value, colorscale, title, x_label, y_label, alpha, cv, show_contour, show_stars, ...

Plot options.

Value

A plotly object (or a named list of plotly objects for plot_mediation_panel).

Examples

```
set.seed(1); n <- 128
x <- cumsum(rnorm(n)); y <- 0.5 * x + rnorm(n, sd = 0.5)
fit <- wavelet_qr(y, x, quantiles = c(0.25, 0.5, 0.75),
                 wavelet = "la8", J = 4, verbose = FALSE)
p <- plot_wqr_heatmap(fit, colorscale = "Parula")
```

results_table	<i>Formatted coefficient table with significance stars</i>
---------------	--

Description

Convenience formatter to insert WQR / MWQR / mediation slope coefficients into a paper-style table.

Usage

```
results_table(x, value = "beta", digits = 3,
             row = "level", variable = NULL)
```

Arguments

x A data frame, or a wqr_result, mwqr_result, mediation_result.
value Column to format. Default "beta".
digits Rounding digits.
row Pivot row column name ("level" or "band").
variable Optional filter for MWQR results.

Value

Character data frame with rows = bands and columns = quantiles. Entries look like "0.345**" (stars for 1% / 5% / 10%).

Examples

```
set.seed(1); n <- 128
x <- cumsum(rnorm(n)); y <- 0.5 * x + rnorm(n, sd = 0.5)
fit <- wavelet_qr(y, x, quantiles = c(0.25, 0.5, 0.75),
                 wavelet = "la8", J = 4, verbose = FALSE)
results_table(fit)
```

wavelet_mediation	<i>Wavelet Quantile Mediation and Moderation</i>
-------------------	--

Description

Five wavelet-band quantile regressions for the triplet (y, x, z): direct effect, x*z moderation (interaction), path a (x -> z), path b (z -> y | x), indirect (a * b).

Usage

```
wavelet_mediation(y, x, z,
                 quantiles = c(0.05, 0.10, 0.25, 0.50,
                               0.75, 0.90, 0.95),
                 wavelet = "la8", J = NULL,
                 dep_name = "Y", main_name = "X",
                 mod_name = "Z", verbose = TRUE)
```

Arguments

y, x, z	Numeric vectors of equal length.
quantiles	Numeric vector of tau in (0, 1).
wavelet	Wavelet filter.
J	Decomposition depth or NULL (auto).
dep_name, main_name, mod_name	Character labels for printing.
verbose	Logical.

Value

An object of class "mediation_result" containing five data frames: direct, interaction, path_a, path_b, indirect.

Examples

```
set.seed(1); n <- 200
x <- rnorm(n); z <- 0.4 * x + rnorm(n, sd = 0.5)
y <- 0.3 * x + 0.4 * z + rnorm(n, sd = 0.5)
fit <- wavelet_mediation(y, x, z,
                        quantiles = c(0.25, 0.5, 0.75),
                        wavelet = "la8", J = 4, verbose = FALSE)
```

wavelet_qqr

Wavelet Quantile-on-Quantile Regression with p-values (WQQR)

Description

For a selected MODWT frequency band, builds the (theta, tau) coefficient and p-value surface of a kernel-weighted local linear quantile regression of y_b on x_b . Also returns the standard band-level WQR slopes for comparison.

Usage

```
wavelet_qqr(y, x, quantile_step = 0.05,
            wavelet = "la8", J = 5,
            band = "long", bandwidth = 1.0,
            verbose = TRUE)
```

Arguments

y, x	Numeric vectors of equal length.
quantile_step	Step of the tau-grid.
wavelet, J, verbose	See wavelet_qr .
band	One of "short", "medium", "long", "all" or "D1", "D2", ...
bandwidth	Gaussian-kernel bandwidth for the local linear QR.

Value

An object of class "wqqr_result" with coefficient matrix, p-value matrix, the standard WQR slopes (qr_coef) and their p-values.

Examples

```
set.seed(1); n <- 128
x <- cumsum(rnorm(n)); y <- 0.4 * x + rnorm(n, sd = 0.5)
fit <- wavelet_qqr(y, x, quantile_step = 0.25,
                  wavelet = "la8", J = 4, band = "long",
                  verbose = FALSE)
```

wavelet_qr

Wavelet Quantile Regression (WQR)

Description

Decompose y and x by MODWT, then run quantile regression of y_b on x_b at each quantile in each band b .

Usage

```
wavelet_qr(y, x,
           quantiles = seq(0.05, 0.95, by = 0.05),
           wavelet = "la8", J = 5,
           bands = TRUE, verbose = TRUE)
```

```
wqr_to_matrix(wqr, value = "beta")
```

Arguments

<code>y, x</code>	Numeric vectors of equal length.
<code>quantiles</code>	Numeric vector of tau in (0, 1).
<code>wavelet</code>	Wavelet filter; e.g. "la8" (sym4), "la16" (sym8), "d4" (db2), "haar".
<code>J</code>	Decomposition depth.
<code>bands</code>	Logical. TRUE aggregates details to Short / Medium / Long.
<code>verbose</code>	Logical.
<code>wqr</code>	A <code>wqr_result</code> object.
<code>value</code>	Column to pivot: "beta" (default), "se", "p_value".

Value

An object of class "wqr_result" (or numeric matrix).

References

Adebayo, T.S., Ozkan, O. (2024) <doi:10.1016/j.jclepro.2024.140832>.

Examples

```
set.seed(1); n <- 128
x <- cumsum(rnorm(n)); y <- 0.5 * x + rnorm(n, sd = 0.5)
fit <- wavelet_qr(y, x, quantiles = c(0.25, 0.5, 0.75),
                 wavelet = "la8", J = 4, verbose = FALSE)
wqr_to_matrix(fit)
```

wavelet_quantile_correlation

Wavelet Quantile Correlation (WQC)

Description

Quantile correlation between MODWT detail series of two time series, with parametric-bootstrap 95% confidence intervals.

Usage

```
wavelet_quantile_correlation(x, y,
                             quantiles = c(0.05, 0.25, 0.50,
                                             0.75, 0.95),
                             wavelet = "la8", J = 8,
                             n_sim = 200, verbose = TRUE)
```

Arguments

x, y	Numeric vectors of equal length.
quantiles	Numeric vector of tau in (0, 1).
wavelet, J, verbose	See wavelet_qr .
n_sim	Bootstrap replicates for the 95% confidence intervals.

Value

An object of class "wqc_result".

Examples

```
set.seed(1); n <- 256
x <- cumsum(rnorm(n)); y <- 0.4 * x + rnorm(n, sd = 0.5)
fit <- wavelet_quantile_correlation(
  x, y, quantiles = c(0.25, 0.5, 0.75),
  J = 4, n_sim = 20, verbose = FALSE)
```

`wavelet_quantile_density`*Wavelet Quantile Density Estimation*

Description

Three nonparametric estimators of the quantile density $q(p) = 1 / f(F^{-1}(p))$: linear wavelet, hard-thresholded, and local-linear smoothed.

Usage

```
wavelet_quantile_density(y, j0 = 5, bandwidth = 0.15,  
                          wavelet = "haar",  
                          gld_params = NULL)
```

Arguments

<code>y</code>	Numeric sample.
<code>j0</code>	Coarsest decomposition level. Default 5.
<code>bandwidth</code>	Gaussian-kernel bandwidth for local linear smoothing.
<code>wavelet</code>	Wavelet filter for the thresholding step.
<code>gld_params</code>	Length-4 <code>c(11, 12, 13, 14)</code> of the GLD or NULL; when provided the true quantile density is computed for ISE diagnostics.

Value

An object of class "quantile_density_result".

Examples

```
set.seed(1); y <- rnorm(256)  
qd <- wavelet_quantile_density(y, j0 = 4)
```

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