Package ‘caustests’

May 8, 2026

Type Package

Title Multiple Granger Causality Tests for Time Series and Panel Data

Version 1.1.1

Description Comprehensive suite of Granger causality tests for time series and panel data. For time series: Toda-Yamamoto (1995) <doi:10.1016/0304-4076(94)01616-8>, Fourier-based tests with single frequency (Enders and Jones, 2016) <doi:10.1515/snde-2014-0101> and cumulative frequencies (Nazlioglu et al., 2019) <doi:10.1080/1540496X.2018.1434072>, quantile causality tests (Cai et al., 2023) <doi:10.1016/j.frl.2023.104327>, and Bootstrap Fourier Granger Causality in Quantiles (Cheng et al., 2021) <doi:10.1007/s12076-020-00263-0>. For panel data: Panel Fourier Toda-Yamamoto (Yilanci and Gorus, 2020) <doi:10.1007/s11356-020-10092-9> and Panel Quantile Causality tests (Wang and Nguyen, 2022) <doi:10.1080/1331677X.2021.1952089>, as well as Group-Mean and Pooled Fully Modified OLS estimators for panel cointegrating polynomial regressions (Wagner and Reichold, 2023) <doi:10.1080/07474938.2023.2178141>. All tests include bootstrap inference for robust p-values.

License GPL-3

URL `https://github.com/muhammedalkhalaf/caustests`

BugReports `https://github.com/muhammedalkhalaf/caustests/issues`

Encoding UTF-8

LazyData true

Depends R (>= 3.5.0)

Imports stats, quantreg

Suggests testthat (>= 3.0.0)

Config/testthat/edition 3

RoxygenNote 7.3.3

NeedsCompilation no

Author Muhammad Alkhalaf [aut, cre, cph] (ORCID: <https://orcid.org/0009-0002-2677-9246>)

Maintainer Muhammad Alkhalaf <muhammedalkhalaf@gmail.com>

Repository CRAN

Date/Publication 2026-04-05 06:50:06 UTC

Contents

`caustests` *Multiple Granger Causality Tests*

Description

Performs various Granger causality tests including Toda-Yamamoto, Fourier-based tests (single and cumulative frequency), and quantile causality tests with bootstrap inference.

Usage

```
caustests(
  data,
  test,
  pmax = 8,
  ic = 1,
  nboot = 1000,
  kmax = 3,
  dmax = NULL,
  quantiles = seq(0.1, 0.9, 0.1),
  verbose = TRUE
)
```

Arguments

`data`	A data frame or matrix with time series variables (columns).
`test`	Integer 1-7 specifying the test type: • 1: Toda-Yamamoto (1995) • 2: Single Fourier Granger (Enders & Jones, 2016) • 3: Single Fourier Toda-Yamamoto (Nazlioglu et al., 2016) • 4: Cumulative Fourier Granger (Enders & Jones, 2019) • 5: Cumulative Fourier Toda-Yamamoto (Nazlioglu et al., 2019) • 6: Quantile Toda-Yamamoto (Cai et al., 2023) • 7: Bootstrap Fourier Granger Causality in Quantiles (Cheng et al., 2021)
`pmax`	Maximum lag order for model selection (default: 8).
`ic`	Information criterion: 1 for AIC, 2 for SBC/BIC (default: 1).
`nboot`	Number of bootstrap replications (default: 1000).
`kmax`	Maximum Fourier frequency (default: 3, used for tests 2-5, 7).
`dmax`	Extra lags for Toda-Yamamoto augmentation. If NULL, automatically set to 0 for tests 2, 4 (differences) and 1 for tests 1, 3, 5, 6, 7 (levels).
`quantiles`	Numeric vector of quantiles for tests 6-7 (default: seq(0.1, 0.9, 0.1)).
`verbose`	Logical; print progress messages (default: TRUE).

Details

The package implements seven Granger causality tests:

Test 1: Toda-Yamamoto (1995) Standard Granger causality in levels using VAR with extra lags equal to the maximum integration order (dmax). This approach is robust to unknown integration and cointegration properties.

Tests 2-3: Single Fourier Frequency Incorporate a single Fourier frequency to capture smooth structural breaks. Test 2 uses first differences, Test 3 uses levels (Toda-Yamamoto style).

Tests 4-5: Cumulative Fourier Frequency Use cumulative Fourier frequencies (1 to k) for more flexible break patterns. Test 4 uses first differences, Test 5 uses levels.

Test 6: Quantile Toda-Yamamoto Extends Toda-Yamamoto to quantile regression, allowing causality analysis across different quantiles of the conditional distribution.

Test 7: Bootstrap Fourier Granger Causality in Quantiles (BFGC-Q) Combines Fourier flexibility with quantile regression for robust inference under structural breaks and across quantiles.

Value

An object of class `"caustests"` containing:

`results`	Data frame with test results for each direction
`test`	Test number used
`test_name`	Name of the test
`pmax`	Maximum lag considered

`ic`	Information criterion used
`nboot`	Number of bootstrap replications
`kmax`	Maximum Fourier frequency
`dmax`	Augmentation lags
`quantiles`	Quantiles used (for tests 6-7)
`quantile_results`	Detailed quantile results (for tests 6-7)

References

Toda, H. Y., & Yamamoto, T. (1995). Statistical inference in vector autoregressions with possibly integrated processes. *Journal of Econometrics*, 66(1-2), 225-250. doi:10.1016/03044076(94)016168

Enders, W., & Jones, P. (2016). Grain prices, oil prices, and multiple smooth breaks in a VAR. *Studies in Nonlinear Dynamics & Econometrics*, 20(4), 399-419. doi:10.1515/snde20140101

Nazlioglu, S., Gormus, N. A., & Soytas, U. (2016). Oil prices and real estate investment trusts (REITs): Gradual-shift causality and volatility transmission analysis. *Energy Economics*, 60, 168-175. doi:10.1016/j.eneco.2016.09.009

Nazlioglu, S., Soytas, U., & Gormus, N. A. (2019). Oil prices and monetary policy in emerging markets: Structural shifts in causal linkages. *Emerging Markets Finance and Trade*, 55(1), 105-117. doi:10.1080/1540496X.2018.1434072

Cai, Y., Chang, T., Xiang, Y., & Chang, H. L. (2023). Testing Granger causality in quantiles between the stock and the foreign exchange markets of Japan. *Finance Research Letters*, 58, 104327. doi:10.1016/j.frl.2023.104327

Cheng, S. C., Hsueh, H. P., Ranjbar, O., Wang, M. C., & Chang, T. (2021). Bootstrap Fourier Granger causality test in quantiles and the asymmetric causal relationship between CO2 emissions and economic growth. *Letters in Spatial and Resource Sciences*, 14, 31-49. doi:10.1007/s12076-020002630

Examples

```
# Load example data
data(caustests_data)


# Test 1: Toda-Yamamoto test
result1 <- caustests(caustests_data, test = 1, nboot = 199)
print(result1)
summary(result1)

# Test 3: Single Fourier Toda-Yamamoto
result3 <- caustests(caustests_data, test = 3, kmax = 2, nboot = 199)
print(result3)

# Test 6: Quantile causality (fewer quantiles for speed)
result6 <- caustests(caustests_data, test = 6,
                     quantiles = c(0.25, 0.50, 0.75), nboot = 199)
print(result6)
```

caustests_data *Example Time Series Dataset for Causality Tests*

Description

A simulated dataset containing three time series variables for demonstrating Granger causality tests. The data includes one dependent variable (Y) and two potential causal variables (X1, X2) with known causal relationships.

Usage

```
caustests_data
```

Format

A data frame with 200 observations and 3 variables:

Y Dependent variable, generated as AR(2) plus causal effects from X1

X1 First explanatory variable, AR(1) process

X2 Second explanatory variable, independent AR(1) process

Details

The data generating process is:

- X1 and X2 are independent AR(1) processes
- Y depends on its own lags plus lagged values of X1 (but not X2)
- This creates a true causal relationship from X1 to Y
- There is no true causality from X2 to Y or from Y to X1/X2

This allows users to verify that the causality tests correctly identify the causal direction X1 => Y while finding no significant causality in other directions (with appropriate sample sizes and test settings).

Source

Simulated data for package demonstration

Examples

```
data(caustests_data)
head(caustests_data)
summary(caustests_data)

# Check correlations
cor(caustests_data)
```

grunfeld_cmg — *Example Panel Data for xtpcmg*

Description

Returns the Grunfeld (1958) balanced panel dataset for examples.

Usage

```
grunfeld_cmg()
```

Value

A data frame with columns `firm`, `year`, `invest`, and `mvalue`.

Examples

```
dat <- grunfeld_cmg()
head(dat)
```

grunfeld_panel — *Example Panel Data for xtpcaus*

Description

Returns a small balanced panel dataset (subset of Grunfeld 1958) for use in examples and testing.

Usage

```
grunfeld_panel()
```

Value

A data frame with columns `firm`, `year`, `invest`, and `mvalue`.

Examples

```
dat <- grunfeld_panel()
head(dat)
```

plot.caustests *Plot Quantile Causality Results*

Description

Creates diagnostic plots for quantile causality tests (tests 6-7).

Usage

```
## S3 method for class 'caustests'
plot(x, which = 1, type = "both", ...)
```

Arguments

`x`	An object of class `"caustests"` from test 6 or 7.
`which`	Which direction to plot (default: 1, first direction).
`type`	Plot type: "wald" for Wald statistics, "pval" for p-values, or "both" (default).
`...`	Additional arguments passed to `plot`.

Value

Invisibly returns the plotted data.

Examples

```
data(caustests_data)
result <- caustests(caustests_data, test = 6,
                    quantiles = c(0.25, 0.50, 0.75), nboot = 199)
plot(result)
```

print.xtpcaus *Print Method for xtpcaus Objects*

Description

Print Method for xtpcaus Objects

Usage

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

Arguments

`x`	An object of class "`xtpcaus`".
`...`	Additional arguments (ignored).

Value

Invisibly returns `x`.

`print.xtpcmg` *Print Method for xtpcmg Objects*

Description

Print Method for xtpcmg Objects

Usage

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

Arguments

`x`	An object of class "`xtpcmg`".
`...`	Additional arguments (ignored).

Value

Invisibly returns `x`.

`summary.xtpcaus` *Summary Method for xtpcaus Objects*

Description

Summary Method for xtpcaus Objects

Usage

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

Arguments

`object`	An object of class "`xtpcaus`".
`...`	Additional arguments (ignored).

Value

Invisibly returns `object`.

`summary.xtpcmg` *Summary Method for xtpcmg Objects*

Description

Summary Method for xtpcmg Objects

Usage

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

Arguments

`object`	An object of class `"xtpcmg"`.
`...`	Additional arguments (ignored).

Value

Invisibly returns `object`.

`xtpcaus` *Panel Granger Causality Tests*

Description

Tests whether `x` Granger-causes `y` in a balanced panel using either the Panel Fourier Toda-Yamamoto (PFTY) test or the Panel Quantile Causality (PQC) test.

Usage

```
xtpcaus(
  data,
  y,
  x,
  panel_id,
  time_id,
  test = c("pfty", "pqc"),
  pmax = 4L,
  dmax = 1L,
  nboot = 499L,
  kmax = 3L,
```

```
  ic = c("aic", "bic"),
  quantiles = c(0.1, 0.25, 0.5, 0.75, 0.9),
  seed = -1L
)
```

Arguments

`data`	A data frame in long format.
`y`	Character. Name of the dependent (caused) variable.
`x`	Character. Name of the independent (causing) variable.
`panel_id`	Character. Name of the panel identifier variable.
`time_id`	Character. Name of the time variable.
`test`	Character. Test type: `"pfty"` for Panel Fourier Toda-Yamamoto or `"pqc"` for Panel Quantile Causality.
`pmax`	Integer. Maximum lag order for selection. Default is `4`.
`dmax`	Integer. Maximum integration order for Toda-Yamamoto augmentation. Default is `1`.
`nboot`	Integer. Number of bootstrap replications. Minimum 99. Default is `499`.
`kmax`	Integer. Maximum Fourier frequency (PFTY only). Default is `3`.
`ic`	Character. Information criterion: `"aic"` or `"bic"`. Default is `"aic"`.
`quantiles`	Numeric vector. Quantile grid for PQC test (values strictly between 0 and 1). Default is `c(0.1, 0.25, 0.50, 0.75, 0.90)`.
`seed`	Integer. Random seed for bootstrap. `-1` means no seed. Default is `-1`.

Value

An object of class `"xtpcaus"` containing:

test Character. `"pfty"` or `"pqc"`.

N Integer. Number of panel units.

TT Integer. Number of time periods.

nboot Integer. Number of bootstrap replications.

y Character. Name of the y variable.

x Character. Name of the x variable. For PFTY:

fisher Numeric. Fisher panel statistic.

fisher_df Integer. Degrees of freedom (2*N).

fisher_pv Numeric. Fisher p-value.

wbar Numeric. Average individual Wald statistic.

zbar Numeric. Dumitrescu-Hurlin Z-bar statistic.

zbar_pv Numeric. Z-bar p-value.

ind_wald Numeric vector. Individual Wald statistics (length N).

ind_freq Integer vector. Optimal Fourier frequencies (length N).

ind_pval_b Numeric vector. Bootstrap p-values (length N).

ind_lags Integer vector. Selected lag orders (length N). For PQC:

quantiles Numeric vector. Quantiles tested.

wald_xy Numeric vector. Wald statistics per quantile (x => y).

pval_xy Numeric vector. Bootstrap p-values per quantile (x => y).

wald_yx Numeric vector. Wald statistics per quantile (y => x).

pval_yx Numeric vector. Bootstrap p-values per quantile (y => x).

supwald_xy Numeric. Sup-Wald statistic for x => y.

supwald_yx Numeric. Sup-Wald statistic for y => x.

p_opt Integer. Selected optimal lag.

References

Chuang, C.C., Kuan, C.M. and Lin, H.Y. (2009). Causality in quantiles and dynamic stock return-volume relations. *Journal of Banking and Finance*, 33(7), 1351–1360. doi:10.1016/j.jbankfin.2009.02.013

Emirmahmutoglu, F. and Kose, N. (2011). Testing for Granger causality in heterogeneous mixed panels. *Economic Modelling*, 28(3), 870–876. doi:10.1016/j.econmod.2010.10.018

Toda, H.Y. and Yamamoto, T. (1995). Statistical inference in vector autoregressions with possibly integrated processes. *Journal of Econometrics*, 66(1–2), 225–250. doi:10.1016/03044076(94)01616-8

Wang, K.M. and Nguyen, T.B. (2022). A quantile panel-type analysis of income inequality and healthcare expenditure. *Economic Research*, 35(1), 873–893. doi:10.1080/1331677X.2021.1952089

Yilanci, V. and Gorus, M.S. (2020). Does economic globalization have predictive power for ecological footprint. *Environmental Science and Pollution Research*, 27, 40552–40562. doi:10.1007/s11356020100929

Examples

```
dat <- grunfeld_panel()
# PFTY test (quick with few bootstrap reps)

res <- xtpcaus(dat, y = "invest", x = "mvalue",
               panel_id = "firm", time_id = "year",
               test = "pfty", pmax = 2L, dmax = 1L,
               nboot = 99L, kmax = 2L, seed = 42L)
print(res)


# PQC test

res2 <- xtpcaus(dat, y = "invest", x = "mvalue",
                panel_id = "firm", time_id = "year",
                test = "pqc", pmax = 2L, nboot = 99L,
                quantiles = c(0.25, 0.50, 0.75), seed = 42L)
print(res2)
```

xtpcmg *Panel Cointegrating Polynomial Regressions via FM-OLS*

Description

Estimates a polynomial cointegrating regression in a panel using either Group-Mean FM-OLS (Wagner & Reichold 2023) or Pooled FM-OLS (de Jong & Wagner 2022). Models the long-run relationship:

Usage

```
xtpcmg(
  data,
  y,
  x,
  panel_id,
  time_id,
  model = c("mg", "pmg"),
  q = 2L,
  controls = NULL,
  trend = 1L,
  kernel = "ba",
  bw = "And91",
  effects = "oneway",
  corr_rob = FALSE
)
```

Arguments

`data`	A data frame in long format.
`y`	Character. Name of the dependent variable.
`x`	Character. Name of the polynomial (I(1)) regressor.
`panel_id`	Character. Name of the panel identifier variable.
`time_id`	Character. Name of the time variable.
`model`	Character. Estimator: `"mg"` for Group-Mean FM-OLS (default) or `"pmg"` for Pooled FM-OLS.
`q`	Integer. Polynomial degree: `2` (quadratic, default) or `3` (cubic).
`controls`	Character vector. Names of additional I(1) control variables. Default is `NULL` (no controls).
`trend`	Integer. Deterministic trend type: `1` for demeaning only (default), `2` for demeaning and detrending.
`kernel`	Character. HAC kernel: `"ba"` (Bartlett, default), `"pa"` (Parzen), `"qs"` (Quadratic Spectral), `"tr"` (truncated), `"bo"` (Bohman).

bw
: Character or numeric. Bandwidth for HAC estimation. `"And91"` (default) uses Andrews (1991) automatic selection. A numeric value sets the bandwidth directly.

effects
: Character. For Pooled FM-OLS: `"oneway"` (default) for one-way demeaning or `"twoways"` for two-way demeaning.

corr_rob
: Logical. For Group-Mean FM-OLS: if `TRUE`, use cross-sectionally robust VCV. Default is `FALSE`.

Details

$$y_{it} = \alpha_i + \beta_1 x_{it} + \beta_2 x_{it}^2 [+\beta_3 x_{it}^3][+\gamma z_{it}] + u_{it}$$

where x_{it} and z_{it} are I(1) processes.

Value

An object of class `"xtpcmg"` with elements: `coefficients` (named numeric vector), `vcov` (variance-covariance matrix), `se` (standard errors), `tstat` (t-statistics), `pvalue` (two-sided p-values), `model` (estimator type: `mg` or `pmg`), `q` (polynomial degree), `N` (number of panel units), `TT` (number of time periods), `y` (dependent variable name), `x` (polynomial variable name), `tp` (turning point estimate, quadratic models only), `tp_se` (delta-method SE for turning point), `tp_lo` and `tp_hi` (95% CI bounds), `ind_coef` (individual FM-OLS estimates, MG model), `swamy_s` and `swamy_p` (Swamy slope homogeneity test).

References

Andrews, D.W.K. (1991). Heteroskedasticity and autocorrelation consistent covariance matrix estimation. *Econometrica*, 59(3), 817–858. doi:10.2307/2938229

de Jong, R.M. and Wagner, M. (2022). Panel cointegrating polynomial regressions. *Annals of Applied Statistics*, 16(1), 416–442. doi:10.1214/21AOAS1536

Wagner, M. and Reichold, K. (2023). Panel cointegrating polynomial regressions. *Econometric Reviews*, 42(9–10), 782–827. doi:10.1080/07474938.2023.2178141

Examples

```
dat <- grunfeld_cmg()

# Group-Mean FM-OLS (quadratic EKC-type model)
res <- xtpcmg(dat, y = "invest", x = "mvalue",
              panel_id = "firm", time_id = "year",
              model = "mg", q = 2L)
print(res)
summary(res)

# Pooled FM-OLS
res2 <- xtpcmg(dat, y = "invest", x = "mvalue",
               panel_id = "firm", time_id = "year",
               model = "pmg", q = 2L)
```

```
print(res2)
```

Index