Package: sochcontagion (via r-universe)

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Type Package

Title Scale-Ordered Contagion: Spectral Theory and Tests of Heterogeneous Information Adaptation

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Description A spectral theory of financial contagion under heterogeneous information adaptation, with the estimators and falsifiable tests it implies. Modelling both the source and the receiving market as exponential information filters yields a bi-exponential transmission response whose power spectrum is the product of two Lorentzians; the slower market supplies the binding spectral corner. Projected onto a maximal-overlap discrete wavelet basis (Percival and Walden, 2000, ISBN:9780521685085) this gives a closed-form transfer-entropy-by-scale profile and three predictions (Scale-Ordered Contagion): scale ordering by adaptation speed, shape symmetry across direction, and magnitude asymmetry. The package provides the closed-form spectrum and scale power, a profile-matching estimator that recovers adaptation rates and endogenises the fast/slow classification, the wavelet-quantile directional-gain measure built from the transfer-entropy estimator of Schreiber (2000) <doi:10.1103/PhysRevLett.85.461> with quantile conditioning (Koenker and Bassett, 1978) <doi:10.2307/1913643> and the quantile goodness-of-fit of Koenker and Machado (1999) <doi:10.1080/01621459.1999.10473882>, and the three tests with phase-randomised surrogate (Theiler, Eubank, Longtin, Galdrikian and Farmer, 1992) <doi:10.1016/0167-2789(92)90102-S> and stationary block-bootstrap (Politis and Romano, 1994) <doi:10.1080/01621459.1994.10476870> nulls. Bundled G20 equity returns and replication scripts reproduce the headline results; the package is general-purpose and accommodates user-supplied returns.

License GPL-3

Encoding UTF-8

LazyData true

Depends R (>= 4.1.0)

Imports waveslim, quantreg, stats, graphics, grDevices, utils

Suggests ggplot2, readxl, knitr, rmarkdown, testthat (>= 3.0.0)

VignetteBuilder knitr

RoxygenNote 7.3.3

URL https://github.com/avishekb9/sochcontagion

BugReports https://github.com/avishekb9/sochcontagion/issues

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Repository https://avishekb9.r-universe.dev

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RemoteUrl https://github.com/avishekb9/sochcontagion

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Contents

g20_returns *Daily Log-Returns of G20 Equity Markets*

Description

Daily log-returns for eighteen G20 equity-market indices from 12 January 2006 through 18 March 2026, used for the empirical tests of the Scale-Ordered Contagion framework. Price levels are integrated of order one and returns are stationary, so all transfer-entropy computation is on returns.

Usage

```
g20_returns
```

Format

A numeric matrix with 5036 rows (trading days) and 18 columns (markets), the row names being ISO dates. Columns are Argentina, Australia, Brazil, Canada, China, France, Germany, India, Indonesia, Italy, Japan, Mexico, Russia, SouthAfrica, SouthKorea, Turkey, UK, USA.

Source

Compiled from public sources (e.g. Yahoo Finance) for the G20 equity indices.

Examples

```
data(g20_returns)
dim(g20_returns)
head(colnames(g20_returns))
```

market_groups *Advanced / Emerging Market Grouping*

Description

The a-priori advanced/emerging partition of the bundled markets, used to build the slowness proxy and the directional magnitude comparison. Under the Scale-Ordered Contagion theory this partition is a hypothesis to be tested against the data-determined classification, not a maintained assumption.

Usage

```
market_groups
```

Format

A list with two character vectors, `advanced` and `emerging`.

Examples

```
data(market_groups)
market_groups$advanced
```

`modwt_detail` *MODWT Wavelet Detail Coefficients*

Description

Returns the brick-walled MODWT detail coefficients of a series at every scale up to `J`, using the Daubechies least-asymmetric filter of length 8 (LA8). The maximal-overlap discrete wavelet transform is shift-invariant and time-aligned, which suits financial returns; see Percival and Walden (2000).

Usage

```
modwt_detail(x, J = 5L, filter = "la8")
```

Arguments

`x`	Numeric vector (e.g. a return series).
`J`	Integer number of detail levels (default 5).
`filter`	Character wavelet filter (default `"la8"`); see `modwt`.

Value

A list of length `J`; element `k` is the numeric vector of scale-`k` detail coefficients (boundary coefficients removed).

References

Percival, D. B., & Walden, A. T. (2000). *Wavelet Methods for Time Series Analysis*. Cambridge University Press.

Examples

```
d <- modwt_detail(rnorm(1024), J = 5)
length(d)
```

phase_surrogate *Phase-Randomised Surrogate Series*

Description

Generates a surrogate of a series that preserves its power spectrum (linear autocorrelation) and is real-valued, by randomising the Fourier phases. Used to build the directional-significance null for the wavelet-quantile measure (a source surrogate breaks directed structure while preserving the source's own spectrum); see Theiler et al. (1992).

Usage

```
phase_surrogate(x)
```

Arguments

x	Numeric vector.

Value

A numeric vector the same length as x.

References

Theiler, J., Eubank, S., Longtin, A., Galdrikian, B., & Farmer, J. D. (1992). Testing for nonlinearity in time series: the method of surrogate data. *Physica D*, 58(1-4), 77-94. doi:10.1016/01672789(92)90102S.

Examples

```
xs <- phase_surrogate(rnorm(256))
length(xs)
```

plot_market_rates *Plot Recovered Market Adaptation Rates*

Description

Horizontal bar chart of estimated market adaptation rates with the cross-sectional median split, as returned by soch_fit_market.

Usage

```
plot_market_rates(rates, col = c("#1f3b73", "#c0392b"))
```

Arguments

rates	A data.frame with columns market, alpha, and optionally class, from soch_fit_market.
col	Two colours for the fast/slow (or supplied) classes.

Value

Invisibly NULL; called for its plot.

Examples

```
r <- data.frame(market = c("USA","UK","India","China"),
                alpha = c(2.4, 2.4, 0.29, 0.08),
                class = c("fast","fast","slow","slow"))
plot_market_rates(r)
```

---

plot_scale_profiles *Plot Directed WQTE Scale Profiles*

Description

Draws one or more directed wavelet-quantile scale profiles against MODWT scale, for visual inspection of the rising/peaked shapes that the SOCH predictions concern.

Usage

```
plot_scale_profiles(profiles, normalise = FALSE, col = NULL)
```

Arguments

profiles	A named list of numeric scale profiles ("from|to"), e.g. a subset of soch_profiles output.
normalise	Logical; plot profiles normalised to sum one (default FALSE).
col	Optional vector of line colours (recycled).

Value

Invisibly NULL; called for its plot.

Examples

```
P <- list("USA|India" = c(0.016,0.043,0.049,0.049,0.057),
          "India|USA" = c(0.006,0.027,0.045,0.022,0.042))
plot_scale_profiles(P)
```

plot_soch_symmetry *Plot the SOCH-B Shape-Symmetry Test*

Description

Forest plot of each unordered pair's observed cross-direction divergence against its same-shape bootstrap null, as returned by soch_test_symmetry. Points inside the null bars do not reject shape symmetry.

Usage

```
plot_soch_symmetry(test)
```

Arguments

test	A data.frame from soch_test_symmetry.

Value

Invisibly NULL; called for its plot.

Examples

```
tt <- data.frame(pair = c("USA-India","Germany-India"),
                 D_obs = c(0.076, 0.010), null_q95 = c(1.48, 1.88),
                 p_value = c(0.92, 1.00), holds = c(TRUE, TRUE))
plot_soch_symmetry(tt)
```

soch_bands *MODWT Scale Bands*

Description

Returns the nominal MODWT detail pass-bands in angular frequency. With unit sampling and Nyquist frequency π, detail level k has band $[\pi 2^{-k},\ \pi 2^{-(k-1)}]$; for daily data, level 1 is the two-to-four-day band and level 5 the thirty-two-to-sixty-four-day band.

Usage

```
soch_bands(J = 5L)
```

Arguments

J	Integer number of scales (default 5).

Value

A numeric matrix with J rows and columns wmin, wmax giving the lower and upper band edges in angular frequency.

Examples

```
soch_bands(5)
```

---

soch_classify *Endogenous Fast/Slow Classification*

Description

Classifies markets as fast or slow adapters by a cross-sectional median split of estimated adaptation rates, replacing the exogenous advanced/emerging partition with a data-determined one.

Usage

```
soch_classify(alpha)
```

Arguments

alpha	Numeric vector of estimated adaptation rates.

Value

Character vector ("fast" if above the median, else "slow").

Examples

```
soch_classify(c(USA = 2.4, India = 0.29, China = 0.08, UK = 2.4))
```

---

soch_fit_market *Pooled Market-Level Adaptation Rates*

Description

Estimates one adaptation rate per market by constraining every directed pair to use its two markets' rates, with a per-pair level concentrated out. Sharing each rate across all pairs containing that market resolves the per-pair ordering ambiguity and yields a stable market-level estimate.

Usage

```
soch_fit_market(profiles, markets, bands = NULL, start = NULL)
```

Arguments

`profiles`	A list of directed profiles; each element is a list with `i` (source name), `j` (target name), and `wqte` (the numeric scale profile).
`markets`	Character vector of market names (the rate vector order).
`bands`	Band matrix (default `soch_bands(J)` for the profile length `J`).
`start`	Optional numeric vector of log-rate start values (length `length(markets)`).

Value

A `data.frame` with columns `market`, `alpha` (estimated rate), and `class` ("fast"/"slow" by the cross-sectional median).

References

Bhandari, A., & Parida, I. (2026). Scale-Ordered Contagion. Working paper, IIT Bhubaneswar.

Examples

```
data(g20_returns); data(market_groups)
mk <- c(market_groups$advanced[1:2], market_groups$emerging[1:2])
prof <- list()
for (a in mk) for (b in mk) if (a != b)
  prof[[length(prof)+1]] <- list(i = a, j = b,
    wqte = wqte_profile(g20_returns, a, b, tau = 0.05))
soch_fit_market(prof, mk)
```

`soch_fit_pair` *Profile-Matching Estimator (single pair)*

Description

Recovers a pair's adaptation rates by fitting an observed wavelet-quantile profile to the closed-form scale power `soch_scale_power` by nonlinear least squares, concentrating out the level. Because the scale power is symmetric in the two rates, a single directional profile identifies only the *unordered* pair $\{\alpha_\wedge, \alpha_\vee\}$; the ordered assignment comes from the pooled fit (`soch_fit_market`). Rates faster than the Nyquist frequency are not recoverable from sampled data, so the search is confined to `[LO, HI]` with `HI = pi`.

Usage

```
soch_fit_pair(
  wqte,
  bands = soch_bands(length(wqte)),
  LO = 0.02,
  HI = pi,
  starts = NULL
)
```

Arguments

wqte	Numeric vector: an observed directed WQTE scale profile.
bands	Band matrix from soch_bands (default matches the length of wqte).
LO, HI	Lower and upper bounds on the searched rates (defaults 0.02 and pi, the resolvable range).
starts	Optional matrix of log-rate start values (two columns); a sensible multi-start grid is used by default.

Value

A list with amin, amax (recovered unordered rates), theta (level), ssr, fitted, resid, R2, kstar (peak scale of wqte).

References

Bhandari, A., & Parida, I. (2026). Scale-Ordered Contagion. Working paper, IIT Bhubaneswar.

Examples

```
truth <- 3 * soch_scale_power(2.0, 0.2)
fit <- soch_fit_pair(truth)
c(amin = fit$amin, amax = fit$amax)
```

---

soch_peak_frequency *Spectral Peak Frequency*

Description

The angular frequency at which $\omega\, S(\omega)$ (the quantity the octave-band profile tracks) is maximised. It solves $1 = 2\omega^2/(\alpha_s^2+\omega^2) + 2\omega^2/(\alpha_r^2+\omega^2)$ and lies in $[\alpha_\wedge/\sqrt{3},\ \alpha_\wedge]$ where $\alpha_\wedge = \min(\alpha_s, \alpha_r)$: in the symmetric case it equals $\alpha/\sqrt{3}$, and in the strongly asymmetric case it approaches the slower rate.

Usage

```
soch_peak_frequency(alpha_s, alpha_r)
```

Arguments

alpha_s	Positive source adaptation rate.
alpha_r	Positive receiver adaptation rate.

Value

The peak angular frequency (scalar).

Examples

```
soch_peak_frequency(1, 1)        # symmetric: 1/sqrt(3)
soch_peak_frequency(2.0, 0.2)    # near the slow rate 0.2
```

`soch_peak_scale` *Predicted Peak MODWT Scale*

Description

The wavelet scale at which directed transfer entropy is predicted to peak, $k^\star \approx \log_2(\pi/\alpha_\wedge)$, governed by the slower market's adaptation rate (prediction SOCH-A). Smaller $\alpha_\wedge$ (a slower market) gives a larger, coarser peak scale.

Usage

```
soch_peak_scale(alpha_s, alpha_r, J = 5L)
```

Arguments

`alpha_s`	Positive source adaptation rate.
`alpha_r`	Positive receiver adaptation rate.
`J`	Integer number of observed scales used to clip the result (default 5).

Value

The (continuous) predicted peak scale, clipped to `[1, J]`.

Examples

```
soch_peak_scale(2.0, 0.2)
```

`soch_pipeline` *Full SOCH Empirical Pipeline*

Description

Runs the complete Scale-Ordered Contagion empirical programme on a returns panel: builds all directed WQTE profiles, runs the three SOCH tests (ordering, magnitude, and—optionally—shape symmetry), and recovers market-level adaptation rates with the pooled profile-matching estimator, classifying each market as a fast or slow adapter.

Usage

```
soch_pipeline(
  returns,
  advanced,
  emerging,
  tau = 0.05,
  J = 5L,
  symmetry = FALSE,
  B = 200L
)
```

Arguments

returns	Numeric returns matrix (columns named by market).
advanced, emerging	Character vectors partitioning the markets a priori (used only to build the slowness proxy and the magnitude comparison; under the theory the partition is itself a hypothesis tested by the recovered classification).
tau	Quantile level (default 0.05).
J	Integer scales (default 5).
symmetry	Logical; run the (heavier) SOCH-B block-bootstrap test (default FALSE).
B	Bootstrap replications for the symmetry test (default 200).

Value

A list with profiles, kstar, aggregate, test_ordering, test_magnitude, optionally test_symmetry, and market_rates (a data.frame of recovered rates and classification).

References

Bhandari, A., & Parida, I. (2026). Scale-Ordered Contagion. Working paper, IIT Bhubaneswar.

Examples

```
data(g20_returns); data(market_groups)
adv <- market_groups$advanced[1:3]; emg <- market_groups$emerging[1:3]
res <- soch_pipeline(g20_returns, adv, emg, tau = 0.05)
res$test_ordering$p_value
res$market_rates
```

soch_profiles *Build All Directed WQTE Profiles*

Description

Computes the wavelet-quantile directional scale profile for every ordered pair among the chosen markets, returning the named list used by the SOCH tests and the pooled estimator.

Usage

```
soch_profiles(returns, markets, tau = 0.05, J = 5L, filter = "la8")
```

Arguments

returns	Numeric returns matrix (columns named by market).
markets	Character vector of markets.
tau	Quantile level (default 0.05).
J	Integer scales (default 5).
filter	Wavelet filter (default "la8").

Value

A named list; element "from|to" is the numeric scale profile.

Examples

```
data(g20_returns)
P <- soch_profiles(g20_returns, c("USA","India","Germany"), tau = 0.05)
names(P)
```

soch_scale_power *Closed-Form Wavelet Scale Power*

Description

Integrates the product-Lorentzian spectrum over each MODWT band to give the transmitted information power by scale, in closed form (partial fractions plus the arctangent integral). For $\alpha_s \neq \alpha_r$ the antiderivative is used; the confluent case $\alpha_s = \alpha_r$ is the removable limit, evaluated by direct numerical integration. The profile is symmetric in the two rates (the basis of the SOCH shape-symmetry prediction) and strictly positive.

Usage

```
soch_scale_power(alpha_s, alpha_r, bands = soch_bands(), A = 1)
```

Arguments

alpha_s	Positive source adaptation rate.
alpha_r	Positive receiver adaptation rate.
bands	A two-column matrix of band edges from soch_bands; defaults to soch_bands(5).
A	Level constant (default 1).

Value

Numeric vector of length nrow(bands): the power P_k at each scale.

References

Bhandari, A., & Parida, I. (2026). Scale-Ordered Contagion. Working paper, IIT Bhubaneswar.

Examples

```
soch_scale_power(2.0, 0.2)              # fast source, slow receiver
soch_scale_power(0.2, 2.0)              # reverse: identical (symmetry)
```

---

soch_spectrum *Product-Lorentzian Transmission Spectrum*

Description

The power spectral density of the bi-exponential transmission response implied by a source filter of rate alpha_s and a receiver filter of rate alpha_r. It is the product of two Lorentzians and is symmetric in the two rates; the slower rate sets the binding spectral corner.

Usage

```
soch_spectrum(alpha_s, alpha_r, omega, A = 1)
```

Arguments

alpha_s	Positive source adaptation rate.
alpha_r	Positive receiver adaptation rate.
omega	Numeric vector of non-negative angular frequencies.
A	Level constant (default 1).

Value

Numeric vector of spectral density values $A^2 \frac{\alpha_s^2}{\alpha_s^2+\omega^2} \frac{\alpha_r^2}{\alpha_r^2+\omega^2}$.

References

Bhandari, A., & Parida, I. (2026). Scale-Ordered Contagion. Working paper, IIT Bhubaneswar.

Examples

```
w <- seq(0, pi, length.out = 64)
s <- soch_spectrum(2.0, 0.2, w)
```

---

soch_test_magnitude *Test SOCH-C: Directional Magnitude Asymmetry*

Description

Tests the prediction that advanced-to-emerging flows dominate emerging-to-advanced flows in *level*. For each advanced-emerging pair the ratio of aggregate WQTE in the two directions is formed and a one-sided sign test assesses whether the ratio exceeds one.

Usage

```
soch_test_magnitude(profiles, advanced, emerging)
```

Arguments

`profiles`	A named list of directed WQTE profiles (`"from|to"`).
`advanced, emerging`	Character vectors of market names.

Value

A list with the per-pair `ratios`, their `median`, `mean`, the fraction exceeding one (`frac_gt1`), and the one-sided sign-test `p_value`.

References

Bhandari, A., & Parida, I. (2026). Scale-Ordered Contagion. Working paper, IIT Bhubaneswar.

Examples

```
prof <- list("USA|India" = c(1,2,3,4,5)*1.3, "India|USA" = c(1,2,3,4,5),
             "UK|China" = c(1,2,3,3,2)*1.1,  "China|UK" = c(1,2,3,3,2))
soch_test_magnitude(prof, advanced = c("USA","UK"),
                           emerging = c("India","China"))$frac_gt1
```

soch_test_ordering *Test SOCH-A: Scale Ordering by Adaptation Speed*

Description

Tests the prediction that pairs containing slower markets peak at coarser wavelet scales. For each directed profile the peak scale $k^\star$ is located, and $k^\star$ is regressed on a slowness proxy (the number of emerging markets in the pair). A positive slope supports SOCH-A.

Usage

```
soch_test_ordering(profiles, emerging)
```

Arguments

`profiles`	A named list of directed WQTE profiles; names are `"from|to"` and elements are numeric scale vectors (e.g. from `soch_profiles`).
`emerging`	Character vector of market names treated as the slow group.

Value

A list with the fitted `model` (an `lm`), the `slope`, its `t` statistic and `p_value`, and the mean peak scale by slowness level (`means`).

References

Bhandari, A., & Parida, I. (2026). Scale-Ordered Contagion. Working paper, IIT Bhubaneswar.

Examples

```
## toy profiles: emerging-inclusive pairs peak coarser
set.seed(1)
prof <- list("USA|UK" = c(5,4,3,2,1), "UK|USA" = c(5,4,3,2,1),
             "USA|India" = c(1,2,3,4,5), "India|USA" = c(1,2,3,4,5),
             "India|China" = c(1,1,2,4,6), "China|India" = c(1,1,2,4,6))
soch_test_ordering(prof, emerging = c("India","China"))$p_value
```

soch_test_symmetry *Test SOCH-B: Shape Symmetry Across Direction*

Description

Tests the prediction—the sharpest of the three—that the *shape* of the directional scale profile is the same in both directions for a given pair. For each unordered pair the cross-direction symmetric KL of the normalised profiles is compared to a same-shape null built by stationary-block-bootstrap re-estimation of a single direction (the sampling variability of one shape). A large p means the two directions are statistically indistinguishable, supporting SOCH-B.

Usage

```
soch_test_symmetry(
  returns,
  markets,
  tau = 0.05,
  J = 5L,
  B = 200L,
  L = 22L,
  filter = "la8"
)
```

Arguments

returns	Numeric returns matrix (columns named by market).
markets	Character vector of markets; all unordered pairs are tested.
tau	Quantile level (default 0.05).
J	Integer scales (default 5).
B	Integer bootstrap replications per direction (default 200).
L	Integer block length for the stationary bootstrap (default 22).
filter	Wavelet filter (default "la8").

Value

A data.frame with one row per unordered pair: pair, D_obs, null_q95, p_value, and holds (p_value > 0.05).

References

Politis, D. N., & Romano, J. P. (1994). The Stationary Bootstrap. *Journal of the American Statistical Association*, 89(428), 1303-1313. doi:10.1080/01621459.1994.10476870.

Examples

```
data(g20_returns)
soch_test_symmetry(g20_returns, c("USA","India","Germany"),
                   tau = 0.05, B = 50)
```

---

sym_kl *Symmetric Kullback-Leibler Divergence of Normalised Profiles*

Description

The symmetrised KL divergence between two non-negative profiles after normalising each to sum to one. Used to compare the *shape* of two directional scale profiles in the SOCH shape-symmetry test; smaller values indicate more similar shapes. A small additive constant guards against zero entries.

Usage

```
sym_kl(p, q, eps = 1e-09)
```

Arguments

p, q	Numeric non-negative vectors of equal length.
eps	Small stabiliser added before normalising (default 1e-9).

Value

A non-negative scalar.

Examples

```
sym_kl(c(1, 2, 3, 2, 1), c(1, 2, 3, 2, 1))   # identical shapes: 0
sym_kl(c(3, 2, 1), c(1, 2, 3))               # reversed shapes: > 0
```

---

wq_gain *Wavelet-Quantile Directional Gain*

Description

Measures directed tail dependence from a source coefficient series x to a target series y as a Koenker-Machado quantile pseudo-R^1: the proportional reduction in the τ-quantile check loss when the source's lagged value is added to a regression of the target's value on its own lag. A value in $[0, 1]$; larger means stronger directed information flow at quantile τ. This is the loadable realisation of the wavelet-quantile transfer-entropy primitive and shares the conditional-quantile-regression construction of that measure.

Usage

```
wq_gain(x, y, tau = 0.05)
```

Arguments

x	Numeric source series (typically a MODWT detail).
y	Numeric target series (typically a MODWT detail).
tau	Quantile level in (0,1) (default 0.05, the lower tail).

Value

A scalar in $[0, 1]$; NA if there are too few observations or the quantile regressions fail.

References

Koenker, R., & Bassett, G. (1978). Regression Quantiles. *Econometrica*, 46(1), 33-50. doi:10.2307/1913643.

Koenker, R., & Machado, J. A. F. (1999). Goodness of Fit and Related Inference Processes for Quantile Regression. *Journal of the American Statistical Association*, 94(448), 1296-1310. doi:10.1080/01621459.1999.10473882.

Schreiber, T. (2000). Measuring Information Transfer. *Physical Review Letters*, 85(2), 461-464. doi:10.1103/PhysRevLett.85.461.

Examples

```
x <- rnorm(500); y <- 0.4 * c(0, x[-500]) + rnorm(500)
wq_gain(x, y, tau = 0.5)   # source improves the target's quantile fit
```

`wqte_profile` *Wavelet-Quantile Directional Scale Profile*

Description

Computes the per-scale wavelet-quantile directional gain from one market to another: the directed WQTE profile $(P_1, \ldots, P_J)$ across the J wavelet scales, whose shape, ordering, and level the SOCH theory predicts.

Usage

```
wqte_profile(returns, from, to, tau = 0.05, J = 5L, filter = "la8")
```

Arguments

`returns`	Numeric matrix of returns (rows = time, columns = markets, with column names); or an object coercible by `as.matrix`.
`from`, `to`	Market names (columns of `returns`) for the source and target.
`tau`	Quantile level (default 0.05).
`J`	Integer number of scales (default 5).
`filter`	Wavelet filter (default `"la8"`).

Value

Numeric vector of length `J`: the directed WQTE by scale.

Examples

```
data(g20_returns)
p <- wqte_profile(g20_returns, "USA", "India", tau = 0.05)
round(p, 4)
```

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