

Package ‘exuber’

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Type Package

Title Econometric Analysis of Explosive Time Series

Version 0.4.1

Description Testing for and dating periods of explosive dynamics (exuberance) in time series using the univariate and panel recursive unit root tests proposed by Phillips et al. (2015) <doi:10.1111/iere.12132> and Pavlidis et al. (2016) <doi:10.1007/s11146-015-9531-2>. The recursive least-squares algorithm utilizes the matrix inversion lemma to avoid matrix inversion which results in significant speed improvements. Simulation of a variety of periodically-collapsing bubble processes.

License GPL-3

URL <https://github.com/kvasilopoulos/exuber>

BugReports <https://github.com/kvasilopoulos/exuber/issues>

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autoplot.ds_radf *Plotting a ds_radf object*

Description

Takes a ds_radf object and returns a ggplot2 object, with a [geom_segment\(\)](#) layer.

Usage

```
## S3 method for class 'ds_radf'  
autoplot(object, trunc = TRUE, ...)
```

Arguments

object	An object of class ds_radf. The output of datestamp()
trunc	Whether to remove the period of the minimum window from the plot (default = TRUE).
...	Further arguments passed to methods. Not used.

Value

A [ggplot2::ggplot\(\)](#)

Examples

```
sim_data_wdate %>%  
  radf() %>%  
  datestamp() %>%  
  autoplot()  
  
# Change the colour manually  
sim_data_wdate %>%  
  radf() %>%  
  datestamp() %>%  
  autoplot() +  
  ggplot2::scale_colour_manual(values = rep("black", 4))
```

autoplot.radf_distr *Plotting a radf_distr object*

Description

Takes a radf_distr object and returns a ggplot2 object.

Usage

```
## S3 method for class 'radf_distr'
autoplot(object, ...)
```

Arguments

object An object of class radf_distr.
 ... Further arguments passed to methods, used only in wb_distr facet options.

Value

A `ggplot2::ggplot()`

autoplot.radf_obj *Plotting radf models*

Description

autoplot.radf_obj takes radf_obj and radf_cv and returns a faceted ggplot object. shade is used as an input to shape_opt. shade modifies the geom_rect layer that demarcates the exuberance periods.

Usage

```
## S3 method for class 'radf_obj'
autoplot(
  object,
  cv = NULL,
  option = c("gsadf", "sadf"),
  min_duration = 0L,
  select_series = NULL,
  include_negative = FALSE,
  shade_opt = shade(),
  include = "DEPRECATED",
  select = "DEPRECATED",
  ...
)

shade(fill = "grey70", opacity = 0.5, ...)
```

Arguments

object	An object of class obj.
cv	An object of class cv.
option	Whether to apply the "gsadf" or "sadf" methodology (default = "gsadf").
min_duration	The minimum duration of an explosive period for it to be reported (default = 0).
select_series	A vector of column names or numbers specifying the series to be used in plotting. Note that the order of the series does not alter the order used in plotting.
include_negative	If TRUE, plot all variables regardless of rejecting the NULL at the 5 percent significance level.
shade_opt	Shading options, typically set using shade function.
include	Argument name is deprecated and substituted with include_negative.
select	Argument name is deprecated and substituted with select_series.
...	Further arguments passed to <code>ggplot2::facet_wrap</code> and <code>ggplot2::geom_rect</code> for shade.
fill	The shade color that indicates the exuberance periods.
opacity	The opacity of the shade color aka alpha.

Value

A `ggplot2::ggplot()`

Examples

```
rsim_data <- radf(sim_data_wdate)

autoplot(rsim_data)

# Modify facet_wrap options through ellipsis
autoplot(rsim_data, scales = "free_y", dir = "v")

autoplot(rsim_data, shade_opt = shade(fill = "pink", opacity = 0.5))

# We will need ggplot2 from here on out
library(ggplot2)

# Change (overwrite) color, size or linetype
autoplot(rsim_data) +
  scale_color_manual(values = c("black", "black")) +
  scale_size_manual(values = c(0.9, 1)) +
  scale_linetype_manual(values = c("solid", "solid"))

# Change names through labeller (first way)
custom_labels <- c("psy1" = "new_name_for_psy1", "psy2" = "new_name_for_psy2")
autoplot(rsim_data, labeller = labeller(.default = label_value, id = as_labeller(custom_labels)))
```

```
# Change names through labeller (second way)
custom_labels2 <- series_names(rsim_data)
names(custom_labels2) <- custom_labels2
custom_labels2[c(3,5)] <- c("Evans", "Blanchard")
autoplot(rsim_data, labeller = labeller(id = custom_labels2))

# Or change names before plotting
series_names(rsim_data) <- LETTERS[1:5]
autoplot(rsim_data)

# Change Theme options
autoplot(rsim_data) +
  theme(legend.position = "right")
```

calc_pvalue

Calculate p-values from distr object

Description

Calculate p-values from distr object

Usage

```
calc_pvalue(x, distr = NULL)
```

Arguments

x A radf_obj object.
distr A radf_distr object.

Examples

```
## Not run:
radf_psy1 <- radf(sim_psy1(100))

calc_pvalue(radf_psy1)

# Using the Wild-Bootstrapped
wb_psy1 <- wb_distr(sim_psy1(100))

calc_pvalue(radf_psy1, wb_psy1)

## End(Not run)
```

datestamp *Date-stamping periods of mildly explosive behavior*

Description

Computes the origination, termination and duration of episodes during which the time series display explosive dynamics.

Usage

```
datestamp(object, cv = NULL, min_duration = 0L, ...)
```

```
## S3 method for class 'radf_obj'
datestamp(
  object,
  cv = NULL,
  min_duration = 0L,
  option = c("gsadf", "sadf"),
  ...
)
```

Arguments

object	An object of class obj.
cv	An object of class cv.
min_duration	The minimum duration of an explosive period for it to be reported (default = 0).
...	further arguments passed to methods.
option	Whether to apply the "gsadf" or "sadf" methodology (default = "gsadf").

Details

Datestamp also stores a vector whose elements take the value of 1 when there is a period of explosive behaviour and 0 otherwise. This output can serve as a dummy variable for the occurrence of exuberance.

Value

Returns a list containing the estimated origination and termination dates of episodes of explosive behaviour and the corresponding duration.

References

Phillips, P. C. B., Shi, S., & Yu, J. (2015). Testing for Multiple Bubbles: Historical Episodes of Exuberance and Collapse in the S&P 500. *International Economic Review*, 56(4), 1043-1078.

Examples

```
rsim_data <- radf(sim_data)

ds_data <- datestamp(rsim_data)
ds_data

# Choose minimum window
datestamp(rsim_data, min_duration = psy_ds(nrow(sim_data)))

autoplot(ds_data)
```

diagnostics

Diagnostics on hypothesis testing

Description

Provides information on whether the null hypothesis of a unit root is rejected against the alternative of explosive behaviour for each series in a dataset.

Usage

```
diagnostics(object, cv = NULL, ...)

## S3 method for class 'radf_obj'
diagnostics(object, cv = NULL, option = c("gsadf", "sadf"), ...)
```

Arguments

object	An object of class obj.
cv	An object of class cv.
...	Further arguments passed to methods.
option	Whether to apply the "gsadf" or "sadf" methodology (default = "gsadf").

Details

Diagnostics also stores a vector whose elements take the value of 1 when there is a period of explosive behaviour and 0 otherwise.

Value

Returns a list with the series that reject (positive) and the series that do not reject (negative) the null hypothesis, and at what significance level.

Examples

```
rsim_data <- radf(sim_data)
diagnostics(rsim_data)

diagnostics(rsim_data, option = "sadf")
```

index-rd	<i>Retrieve/Replace the index</i>
----------	-----------------------------------

Description

Retrieve or replace the index of an object.

Usage

```
index(x, ...)
```

```
index(x) <- value
```

Arguments

x	An object.
...	Further arguments passed to methods.
value	An ordered vector of the same length as the 'index' attribute of x.

Details

If the user does not specify an index for the estimation a pseudo-index is generated which is a sequential numeric series. After the estimation, the user can use `index` to retrieve or ``index<-`` to replace the index. The index can be either numeric or Date.

install_exuberdata	<i>Install exuberdata Package</i>
--------------------	-----------------------------------

Description

This function wraps the `install.packages` function and offers a faster and more convenient way to install exuberdata.

Usage

```
install_exuberdata()
```

Examples

```
if("exuberdata" %in% loadedNamespaces()) {
  exuberdata::radf_crit2
}
```

 psy_minw

Helper functions in accordance to PSY(2015)

Description

psy_minw and psy_ds use the rules-of-thumb proposed by Phillips et al. (reference) to compute the minimum window size and the minimum duration of an episode of exuberance, respectively.

Usage

```
psy_minw(n)
```

```
psy_ds(n, rule = 1, delta = 1)
```

Arguments

n	A positive integer. The sample size.
rule	Rule 1 corresponds to $\log(T)$, while rule 2 $\log(T)/T$
delta	Frequency-dependent parameter. See details.

Details

For the minimum duration period, psy_ds allows the user to choose from two rules:

$$rule_1 = \delta \log(n) \quad \& \quad rule_2 = \delta \log(n)/n$$

delta depends on the frequency of the data and the minimal duration condition.

References

Phillips, P. C. B., Shi, S., & Yu, J. (2015). Testing for Multiple Bubbles: Historical Episodes of Exuberance and Collapse in the S&P 500. *International Economic Review*, 56(4), 1043-1078.

Examples

```
psy_minw(100)
psy_ds(100)
```

radf	<i>Recursive Augmented Dickey-Fuller Test</i>
------	---

Description

radf returns the recursive univariate and panel Augmented Dickey-Fuller test statistics.

Usage

```
radf(data, minw = NULL, lag = 0L)
```

Arguments

data	A univariate or multivariate numeric time series object, a numeric vector or matrix, or a data.frame. The object should not have any NA values.
minw	A positive integer. The minimum window size (default = $(0.01 + 1.8/\sqrt{T})T$, where T denotes the sample size).
lag	A non-negative integer. The lag length of the Augmented Dickey-Fuller regression (default = 0L).

Details

The radf() function is vectorized, i.e., it can handle multiple series at once, to improve efficiency. This property also enables the computation of panel statistics internally as a by-product of the univariate estimations with minimal additional cost incurred.

Value

A list that contains the unit root test statistics (sequence):

adf	Augmented Dickey-Fuller
badf	Backward Augmented Dickey-Fuller
sadf	Supremum Augmented Dickey-Fuller
bsadf	Backward Supremum Augmented Dickey-Fuller
gsadf	Generalized Supremum Augmented Dickey-Fuller
bsadf_panel	Panel Backward Supremum Augmented Dickey-Fuller
gsadf_panel	Panel Generalized Supremum Augmented Dickey-Fuller

References

Phillips, P. C. B., Wu, Y., & Yu, J. (2011). Explosive Behavior in The 1990s Nasdaq: When Did Exuberance Escalate Asset Values? *International Economic Review*, 52(1), 201-226.

Phillips, P. C. B., Shi, S., & Yu, J. (2015). Testing for Multiple Bubbles: Historical Episodes of Exuberance and Collapse in the S&P 500. *International Economic Review*, 56(4), 1043-1078.

Pavlidis, E., Yusupova, A., Paya, I., Peel, D., Martínez-García, E., Mack, A., & Grossman, V. (2016). Episodes of exuberance in housing markets: in search of the smoking gun. *The Journal of Real Estate Finance and Economics*, 53(4), 419-449.

Examples

```
# We will use simulated data that are stored as data
sim_data

rsim <- radf(sim_data)

str(rsim)

# We would also use data that contain a Date column
sim_data_wdate

rsim_wdate <- radf(sim_data_wdate)

tidy(rsim_wdate)

augment(rsim_wdate)

tidy(rsim_wdate, panel = TRUE)

head(index(rsim_wdate))

# For lag = 1 and minimum window = 20
rsim_20 <- radf(sim_data, minw = 20, lag = 1)
```

radf_crit

Stored Monte Carlo Critical Values

Description

A dataset containing Monte Carlo critical values for up to 600 observations generated using the default minimum window. The critical values have been simulated and stored as data to save computation time for the user. The stored critical values can be obtained with the `radf_mc_cv()` function, using `nrep = 2000` and the `seed = 123`.

Usage

```
radf_crit
```

Format

A list with lower level lists that contain

adf_cv: Augmented Dickey-Fuller

badf_cv: Backward Augmented Dickey-Fuller

sadf_cv: Supremum Augmented Dickey-Fuller

bsadf_cv: Backward Supremum Augmented Dickey-Fuller

gsadf_cv: Generalized Supremum Augmented Dickey Fuller

Source

Simulated from exuber package function [radf_mc_cv\(\)](#).

Examples

```
## Not run:
all.equal(radf_crit[[50]], radf_mc_cv(50, nrep = 2000, seed = 123))

## End(Not run)
```

radf_mc_cv

Monte Carlo Critical Values

Description

radf_mc_cv computes Monte Carlo critical values for the recursive unit root tests. radf_mc_distr computes the distribution.

Usage

```
radf_mc_cv(n, minw = NULL, nrep = 1000L, seed = NULL)
```

```
radf_mc_distr(n, minw = NULL, nrep = 1000L, seed = NULL)
```

Arguments

n	A positive integer. The sample size.
minw	A positive integer. The minimum window size (default = $(0.01 + 1.8/\sqrt{T})T$, where T denotes the sample size).
nrep	A positive integer. The number of Monte Carlo simulations.
seed	An object specifying if and how the random number generator (rng) should be initialized. Either NULL or an integer will be used in a call to <code>set.seed</code> before simulation. If set, the value is saved as "seed" attribute of the returned value. The default, NULL, will not change rng state, and return <code>.Random.seed</code> as the "seed" attribute. Results are different between the parallel and non-parallel option, even if they have the same seed.

Value

For `radf_mc_cv` a list that contains the critical values for ADF, BADF, BSADF and GSADF test statistics. For `radf_mc_distr` a list that contains the ADF, SADF and GSADF distributions.

See Also

[radf_wb_cv](#) for wild bootstrap critical values and [radf_sb_cv](#) for sieve bootstrap critical values

Examples

```
# Default minimum window
mc <- radf_mc_cv(n = 100)

tidy(mc)

# Change the minimum window and the number of simulations
mc2 <- radf_mc_cv(n = 100, nrep = 600, minw = 20)

tidy(mc2)

mdist <- radf_mc_distr(n = 100, nrep = 1000)

autoplot(mdist)
```

radf_sb_cv

Panel Sieve Bootstrap Critical Values

Description

radf_sb_cv computes critical values for the panel recursive unit root test using the sieve bootstrap procedure outlined in Pavlidis et al. (2016). radf_sb_distr computes the distribution.

Usage

```
radf_sb_cv(data, minw = NULL, lag = 0L, nboot = 500L, seed = NULL)

radf_sb_distr(data, minw = NULL, lag = 0L, nboot = 500L, seed = NULL)
```

Arguments

data	A univariate or multivariate numeric time series object, a numeric vector or matrix, or a data.frame. The object should not have any NA values.
minw	A positive integer. The minimum window size (default = $(0.01 + 1.8/\sqrt{T})T$, where T denotes the sample size).
lag	A non-negative integer. The lag length of the Augmented Dickey-Fuller regression (default = 0L).
nboot	A positive integer. Number of bootstraps (default = 500L).
seed	An object specifying if and how the random number generator (rng) should be initialized. Either NULL or an integer will be used in a call to set.seed before simulation. If set, the value is saved as "seed" attribute of the returned value. The default, NULL, will not change rng state, and return .Random.seed as the "seed" attribute. Results are different between the parallel and non-parallel option, even if they have the same seed.

Value

For `radf_sb_cv` A list A list that contains the critical values for the panel BSADF and panel GSADF test statistics. For `radf_wb_dist` a numeric vector that contains the distribution of the panel GSADF statistic.

References

Pavlidis, E., Yusupova, A., Paya, I., Peel, D., Martínez-García, E., Mack, A., & Grossman, V. (2016). Episodes of exuberance in housing markets: In search of the smoking gun. *The Journal of Real Estate Finance and Economics*, 53(4), 419-449.

See Also

`radf_mc_cv` for Monte Carlo critical values and `radf_wb_cv` for wild Bootstrap critical values

Examples

```
rsim_data <- radf(sim_data, lag = 1)

# Critical vales should have the same lag length with \code{radf()}
sb <- radf_sb_cv(sim_data, lag = 1)

tidy(sb)

summary(rsim_data, cv = sb)

autoplot(rsim_data, cv = sb)

# Simulate distribution
sdist <- radf_sb_distr(sim_data, lag = 1, nboot = 1000)

autoplot(sdist)
```

radf_wb_cv

Wild Bootstrap Critical Values

Description

`radf_wb_cv` performs the Harvey et al. (2016) wild bootstrap re-sampling scheme, which is asymptotically robust to non-stationary volatility, to generate critical values for the recursive unit root tests. `radf_wb_distr` computes the distribution.

Usage

```
radf_wb_cv(data, minw = NULL, nboot = 500L, dist_rad = FALSE, seed = NULL)
```

```
radf_wb_distr(data, minw = NULL, nboot = 500L, dist_rad = FALSE, seed = NULL)
```

Arguments

<code>data</code>	A univariate or multivariate numeric time series object, a numeric vector or matrix, or a data.frame. The object should not have any NA values.
<code>minw</code>	A positive integer. The minimum window size (default = $(0.01 + 1.8/\sqrt{T})T$, where T denotes the sample size).
<code>nboot</code>	A positive integer. Number of bootstraps (default = 500L).
<code>dist_rad</code>	Logical. If TRUE then the Rademacher distribution will be used.
<code>seed</code>	An object specifying if and how the random number generator (rng) should be initialized. Either NULL or an integer will be used in a call to <code>set.seed</code> before simulation. If set, the value is saved as "seed" attribute of the returned value. The default, NULL, will not change rng state, and return <code>.Random.seed</code> as the "seed" attribute. Results are different between the parallel and non-parallel option, even if they have the same seed.

Details

This approach involves applying a wild bootstrap re-sampling scheme to construct the bootstrap analogue of the Phillips et al. (2015) test which is asymptotically robust to non-stationary volatility.

Value

For `radf_wb_cv` a list that contains the critical values for the ADF, BADF, BSADF and GSADF tests. For `radf_wb_distr` a list that contains the ADF, SADF and GSADF distributions.

References

Harvey, D. I., Leybourne, S. J., Sollis, R., & Taylor, A. M. R. (2016). Tests for explosive financial bubbles in the presence of non-stationary volatility. *Journal of Empirical Finance*, 38(Part B), 548-574.

Phillips, P. C. B., Shi, S., & Yu, J. (2015). Testing for Multiple Bubbles: Historical Episodes of Exuberance and Collapse in the S&P 500. *International Economic Review*, 56(4), 1043-1078.

See Also

[radf_mc_cv](#) for Monte Carlo critical values and [radf_sb_cv](#) for sieve bootstrap critical values.

Examples

```
# Default minimum window
wb <- radf_wb_cv(sim_data)

tidy(wb)

# Change the minimum window and the number of bootstraps
wb2 <- radf_wb_cv(sim_data, nboot = 600, minw = 20)

tidy(wb2)
```



```
# Simulate distribution
wdist <- radf_wb_distr(sim_data)

autoplot(wdist)
```

scale_exuber_manual *Exuber scale and theme functions*

Description

scale_exuber_manual allows specifying the color, size and linetype in autoplot.radf_obj mappings. theme_exuber is a complete theme which control all non-data display.

Usage

```
scale_exuber_manual(
  color_values = c("red", "blue"),
  linetype_values = c(2, 1),
  size_values = c(0.8, 0.7)
)

theme_exuber(
  base_size = 11,
  base_family = "",
  base_line_size = base_size/22,
  base_rect_size = base_size/22
)
```

Arguments

color_values a set of color values to map data values to.
linetype_values a set of linetype values to map data values to.
size_values a set of size values to map data values to.
base_size base font size
base_family base font family
base_line_size base size for line elements
base_rect_size base size for rect elements

series_names	<i>Retrieve/Replace series names</i>
--------------	--------------------------------------

Description

Retrieve or replace the series names of an object.

Usage

```
series_names(x, ...)  
  
series_names(x) <- value  
  
## S3 replacement method for class 'radf_obj'  
series_names(x) <- value  
  
## S3 replacement method for class 'wb_cv'  
series_names(x) <- value  
  
## S3 replacement method for class 'sb_cv'  
series_names(x) <- value
```

Arguments

x	An object.
...	Further arguments passed to methods.
value	n ordered vector of the same length as the "index" attribute of x.

Examples

```
# Simulate bubble processes  
dta <- data.frame(psy1 = sim_psy1(n = 100), psy2 = sim_psy2(n = 100))  
  
rfd <- radf(dta)  
  
series_names(rfd) <- c("OneBubble", "TwoBubbles")
```

sim_blan	<i>Simulation of a Blanchard (1979) bubble process</i>
----------	--

Description

Simulation of a Blanchard (1979) rational bubble process.

Usage

```
sim_blan(n, pi = 0.7, sigma = 0.03, r = 0.05, b0 = 0.1, seed = NULL)
```

Arguments

n	A positive integer specifying the length of the simulated output series.
pi	A positive value in (0, 1) which governs the probability of the bubble continuing to grow.
sigma	A positive scalar indicating the standard deviation of the innovations.
r	A positive scalar that determines the growth rate of the bubble process.
b0	The initial value of the bubble.
seed	An object specifying if and how the random number generator (rng) should be initialized. Either NULL or an integer will be used in a call to set.seed before simulation. If set, the value is saved as "seed" attribute of the returned value. The default, NULL, will not change rng state, and return .Random.seed as the "seed" attribute. Results are different between the parallel and non-parallel option, even if they have the same seed.

Details

Blanchard's bubble process has two regimes, which occur with probability π and $1 - \pi$. In the first regime, the bubble grows exponentially, whereas in the second regime, the bubble collapses to a white noise.

With probability π :

$$B_{t+1} = \frac{1+r}{\pi} B_t + \epsilon_{t+1}$$

With probability $1 - \pi$:

$$B_{t+1} = \epsilon_{t+1}$$

where r is a positive constant and $\epsilon \sim iid(0, \sigma^2)$.

Value

A numeric vector of length n .

References

Blanchard, O. J. (1979). Speculative bubbles, crashes and rational expectations. *Economics letters*, 3(4), 387-389.

See Also

[sim_psy1](#), [sim_psy2](#), [sim_evans](#)

Examples

```
sim_blan(n = 100, seed = 123) %>%  
  autoplot()
```

sim_data

Simulated dataset

Description

An artificial dataset containing series simulated from data generating processes widely used in the literature on speculative bubbles.

Usage

sim_data

sim_data_wdate

Format

An object of class `tbl_df` (inherits from `tbl`, `data.frame`) with 100 rows and 5 columns.

An object of class `tbl_df` (inherits from `tbl`, `data.frame`) with 100 rows and 6 columns.

See Also

[sim_psy1](#) [sim_psy2](#) [sim_evans](#) [sim_div](#) [sim_blan](#)

Examples

```
## Not run:  
# The dataset can be easily replicated with the code below  
library(tibble)  
set.seed(1122)  
sim_data <- tibble(  
  sim_psy1 = sim_psy1(100),  
  sim_psy2 = sim_psy2(100),  
  sim_evans = sim_evans(100),  
  sim_div = sim_div(100),  
  sim_blan = sim_blan(100)  
)  
sim_data_wdate <- tibble(  
  psy1 = sim_psy1(100),  
  psy2 = sim_psy2(100),  
  evans = sim_evans(100),
```

```

div = sim_div(100),
blan = sim_blan(100),
date = seq(as.Date("2000-01-01"), by = "month", length.out = 100)
)

## End(Not run)

```

sim_div

Simulation of dividends

Description

Simulate (log) dividends from a random walk with drift.

Usage

```

sim_div(
  n,
  mu,
  sigma,
  r = 0.05,
  log = FALSE,
  output = c("pf", "d"),
  seed = NULL
)

```

Arguments

n	A positive integer specifying the length of the simulated output series.
mu	A scalar indicating the drift.
sigma	A positive scalar indicating the standard deviation of the innovations.
r	A positive value indicating the discount factor.
log	Logical. If true dividends follow a lognormal distribution.
output	A character string giving the fundamental price("pf") or dividend series("d"). Default is 'pf'.
seed	An object specifying if and how the random number generator (rng) should be initialized. Either NULL or an integer will be used in a call to <code>set.seed</code> before simulation. If set, the value is saved as "seed" attribute of the returned value. The default, NULL, will not change rng state, and return <code>.Random.seed</code> as the "seed" attribute. Results are different between the parallel and non-parallel option, even if they have the same seed.

Details

If log is set to FALSE (default value) dividends follow:

$$d_t = \mu + d_{t-1} + \epsilon_t$$

where $\epsilon \sim \mathcal{N}(0, \sigma^2)$. The default parameters are $\mu = 0.0373$, $\sigma^2 = 0.1574$ and $d[0] = 1.3$ (the initial value of the dividend sequence). The above equation can be solved to yield the fundamental price:

$$F_t = \mu(1+r)r^{-2} + r^{-1}d_t$$

If log is set to TRUE then dividends follow a lognormal distribution or log(dividends) follow:

$$\ln(d_t) = \mu + \ln(d_{t-1}) + \epsilon_t$$

where $\epsilon \sim \mathcal{N}(0, \sigma^2)$. Default parameters are $\mu = 0.013$, $\sigma^2 = 0.16$. The fundamental price in this case is:

$$F_t = \frac{1+g}{r-g} d_t$$

where $1+g = \exp(\mu + \sigma^2/2)$. All default parameter values are those suggested by West (1988).

Value

A numeric vector of length n.

References

West, K. D. (1988). Dividend innovations and stock price volatility. *Econometrica: Journal of the Econometric Society*, p. 37-61.

Examples

```
# Price is the sum of the bubble and fundamental components
# 20 is the scaling factor
pf <- sim_div(100, r = 0.05, output = "pf", seed = 123)
pb <- sim_evans(100, r = 0.05, seed = 123)
p <- pf + 20 * pb

autoplot(p)
```

sim_evans	<i>Simulation of an Evans (1991) bubble process</i>
-----------	---

Description

Simulation of an Evans (1991) rational periodically collapsing bubble process.

Usage

```
sim_evans(
  n,
  alpha = 1,
  delta = 0.5,
  tau = 0.05,
  pi = 0.7,
  r = 0.05,
  b1 = delta,
  seed = NULL
)
```

Arguments

n	A positive integer specifying the length of the simulated output series.
alpha	A positive scalar, with restrictions (see details).
delta	A positive scalar, with restrictions (see details).
tau	The standard deviation of the innovations.
pi	A positive value in (0, 1) which governs the probability of the bubble continuing to grow.
r	A positive scalar that determines the growth rate of the bubble process.
b1	A positive scalar, the initial value of the series. Defaults to delta.
seed	An object specifying if and how the random number generator (rng) should be initialized. Either NULL or an integer will be used in a call to set.seed before simulation. If set, the value is saved as "seed" attribute of the returned value. The default, NULL, will not change rng state, and return .Random.seed as the "seed" attribute. Results are different between the parallel and non-parallel option, even if they have the same seed.

Details

delta and alpha are positive parameters which satisfy $0 < \delta < (1 + r)\alpha$. delta represents the size of the bubble after collapse. The default value of r is 0.05. The function checks whether alpha and delta satisfy this condition and will return an error if not.

The Evans bubble has two regimes. If $B_t \leq \alpha$ the bubble grows at an average rate of $1 + r$:

$$B_{t+1} = (1 + r)B_t u_{t+1},$$

When $B_t > \alpha$ the bubble expands at the increased rate of $(1 + r)\pi^{-1}$:

$$B_{t+1} = [\delta + (1 + r)\pi^{-1}\theta_{t+1}(B_t - (1 + r)^{-1}\delta B_t)]u_{t+1},$$

where θ theta is a binary variable that takes the value 0 with probability $1 - \pi$ and 1 with probability π . In the second phase, there is a $(1 - \pi)$ probability of the bubble process collapsing to δ . By modifying the values of δ , α and π the user can change the frequency at which bubbles appear, the mean duration of a bubble before collapse and the scale of the bubble.

Value

A numeric vector of length n.

References

Evans, G. W. (1991). Pitfalls in testing for explosive bubbles in asset prices. The American Economic Review, 81(4), 922-930.

See Also

[sim_psy1](#), [sim_psy2](#), [sim_blan](#)

Examples

```
sim_evans(100, seed = 123) %>%
  autoplot()
```

sim_psy1

Simulation of a single-bubble process

Description

The following function generates a time series which switches from a martingale to a mildly explosive process and then back to a martingale.

Usage

```
sim_psy1(
  n,
  te = 0.4 * n,
  tf = 0.15 * n + te,
  c = 1,
  alpha = 0.6,
  sigma = 6.79,
  seed = NULL
)
```


Arguments

n	A positive integer specifying the length of the simulated output series.
te	A scalar in (0, tf) specifying the observation in which the bubble originates.
tf	A scalar in (te, n) specifying the observation in which the bubble collapses.
c	A positive scalar determining the autoregressive coefficient in the explosive regime.
alpha	A positive scalar in (0, 1) determining the value of the expansion rate in the autoregressive coefficient.
sigma	A positive scalar indicating the standard deviation of the innovations.
seed	An object specifying if and how the random number generator (rng) should be initialized. Either NULL or an integer will be used in a call to set.seed before simulation. If set, the value is saved as "seed" attribute of the returned value. The default, NULL, will not change rng state, and return .Random.seed as the "seed" attribute. Results are different between the parallel and non-parallel option, even if they have the same seed.

Details

The data generating process is described by the following equation:

$$X_t = X_{t-1}1\{t < \tau_e\} + \delta_T X_{t-1}1\{\tau_e \leq t \leq \tau_f\} + \left(\sum_{k=\tau_f+1}^t \epsilon_k + X_{\tau_f} \right) 1\{t > \tau_f\} + \epsilon_t 1\{t \leq \tau_f\}$$

where the autoregressive coefficient δ_T is given by:

$$\delta_T = 1 + cT^{-\alpha}$$

with $c > 0$, $\alpha \in (0, 1)$, $\epsilon \sim iid(0, \sigma^2)$ and $X_{\tau_f} = X_{\tau_e} + X'$ with $X' = O_p(1)$, $\tau_e = [Tr_e]$ dates the origination of the bubble, and $\tau_f = [Tr_f]$ dates the collapse of the bubble. During the pre- and post- bubble periods, $[1, \tau_e)$, X_t is a pure random walk process. During the bubble expansion period $[\tau_e, \tau_f]$ becomes a mildly explosive process with expansion rate given by the autoregressive coefficient δ_T ; and, finally during the post-bubble period, $(\tau_f, \tau]$ X_t reverts to a martingale.

For further details see Phillips et al. (2015) p. 1054.

Value

A numeric vector of length n.

References

Phillips, P. C. B., Shi, S., & Yu, J. (2015). Testing for Multiple Bubbles: Historical Episodes of Exuberance and Collapse in the S&P 500. *International Economic Review*, 56(4), 1043-1078.

See Also

[sim_psy2](#), [sim_blan](#), [sim_evans](#)

Examples

```
# 100 periods with bubble origination date 40 and termination date 55
sim_psy1(n = 100, seed = 123) %>%
  autoplot()

# 200 periods with bubble origination date 80 and termination date 110
sim_psy1(n = 200, seed = 123) %>%
  autoplot()

# 200 periods with bubble origination date 100 and termination date 150
sim_psy1(n = 200, te = 100, tf = 150, seed = 123) %>%
  autoplot()
```

 sim_psy2

Simulation of a two-bubble process

Description

The following data generating process is similar to [sim_psy1](#), with the difference that there are two episodes of mildly explosive dynamics.

Usage

```
sim_psy2(
  n,
  te1 = 0.2 * n,
  tf1 = 0.2 * n + te1,
  te2 = 0.6 * n,
  tf2 = 0.1 * n + te2,
  c = 1,
  alpha = 0.6,
  sigma = 6.79,
  seed = NULL
)
```

Arguments

n	A positive integer specifying the length of the simulated output series.
te1	A scalar in (0, n) specifying the observation in which the first bubble originates.
tf1	A scalar in (te1, n) specifying the observation in which the first bubble collapses.
te2	A scalar in (tf1, n) specifying the observation in which the second bubble originates.
tf2	A scalar in (te2, n) specifying the observation in which the second bubble collapses.
c	A positive scalar determining the autoregressive coefficient in the explosive regime.

alpha	A positive scalar in (0, 1) determining the value of the expansion rate in the autoregressive coefficient.
sigma	A positive scalar indicating the standard deviation of the innovations.
seed	An object specifying if and how the random number generator (rng) should be initialized. Either NULL or an integer will be used in a call to <code>set.seed</code> before simulation. If set, the value is saved as "seed" attribute of the returned value. The default, NULL, will not change rng state, and return <code>.Random.seed</code> as the "seed" attribute. Results are different between the parallel and non-parallel option, even if they have the same seed.

Details

The two-bubble data generating process is given by (see also `sim_psy1`):

$$X_t = X_{t-1}1\{t \in N_0\} + \delta_T X_{t-1}1\{t \in B_1 \cup B_2\} + \left(\sum_{k=\tau_{1f}+1}^t \epsilon_k + X_{\tau_{1f}} \right) 1\{t \in N_1\} \\ + \left(\sum_{l=\tau_{2f}+1}^t \epsilon_l + X_{\tau_{2f}} \right) 1\{t \in N_2\} + \epsilon_t 1\{t \in N_0 \cup B_1 \cup B_2\}$$

where the autoregressive coefficient δ_T is:

$$\delta_T = 1 + cT^{-\alpha}$$

with $c > 0$, $\alpha \in (0, 1)$, $\epsilon \sim iid(0, \sigma^2)$, $N_0 = [1, \tau_{1e})$, $B_1 = [\tau_{1e}, \tau_{1f}]$, $N_1 = (\tau_{1f}, \tau_{2e})$, $B_2 = [\tau_{2e}, \tau_{2f}]$, $N_2 = (\tau_{2f}, \tau]$, where τ is the last observation of the sample. The observations $\tau_{1e} = [Tr_{1e}]$ and $\tau_{1f} = [Tr_{1f}]$ are the origination and termination dates of the first bubble; $\tau_{2e} = [Tr_{2e}]$ and $\tau_{2f} = [Tr_{2f}]$ are the origination and termination dates of the second bubble. After the collapse of the first bubble, X_t resumes a martingale path until time $\tau_{2e} - 1$, and a second episode of exuberance begins at τ_{2e} . Exuberance lasts until τ_{2f} at which point the process collapses to a value of $X_{\tau_{2f}}$. The process then continues on a martingale path until the end of the sample period τ . The duration of the first bubble is assumed to be longer than that of the second bubble, i.e. $\tau_{1f} - \tau_{1e} > \tau_{2f} - \tau_{2e}$.

For further details you can refer to Phillips et al., (2015) p. 1055.

Value

A numeric vector of length n .

References

Phillips, P. C. B., Shi, S., & Yu, J. (2015). Testing for Multiple Bubbles: Historical Episodes of Exuberance and Collapse in the S&P 500. *International Economic Review*, 56(4), 1043-1078.

See Also

[sim_psy1](#), [sim_blan](#), [sim_evans](#)

Examples

```
# 100 periods with bubble origination dates 20/60 and termination dates 40/70
sim_psy2(n = 100, seed = 123) %>%
  autoplot()

# 200 periods with bubble origination dates 40/120 and termination dates 80/140
sim_psy2(n = 200, seed = 123) %>%
  autoplot()
```

summary.radf_obj	<i>Summarizing radf models</i>
------------------	--------------------------------

Description

summary method for radf models that consist of radf_obj and radf_cv.

Usage

```
## S3 method for class 'radf_obj'
summary(object, cv = NULL, ...)
```

Arguments

object	An object of class radf_obj. The output of radf() .
cv	An object of class radf_cv. The output of radf_mc_cv() , radf_wb_cv() or radf_sb_cv() .
...	Further arguments passed to methods. Not used.

Value

Returns a list of summary statistics, which include the estimated ADF, SADF, and GSADF test statistics and the corresponding critical values

Examples

```
# Simulate bubble processes, compute the test statistics and critical values
rsim_data <- radf(sim_data)

# Summary, diagnostics and datestamp (default)
summary(rsim_data)

#Summary, diagnostics and datestamp (wild bootstrap critical values)
```

```
wb <- radf_wb_cv(sim_data)
summary(rsim_data, cv = wb)
```

tidy.ds_radf	<i>Tidy a ds_radf object</i>
--------------	------------------------------

Description

Summarizes information about ds_radf object.

Usage

```
## S3 method for class 'ds_radf'
tidy(x, ...)
```

Arguments

x	An object of class ds_radf.
...	Further arguments passed to methods. Not used.

tidy.radf_cv	<i>Tidy a radf_cv object</i>
--------------	------------------------------

Description

Summarizes information about radf_cv object.

Usage

```
## S3 method for class 'radf_cv'
tidy(x, format = c("wide", "long"), ...)

## S3 method for class 'radf_cv'
augment(x, format = c("wide", "long"), ...)
```

Arguments

x	An object of class radf_cv.
format	Long or wide format (default = "wide").
...	Further arguments passed to methods. Not used.

Value

A `tibble::tibble()`

- id: The series names.
- sig: The significance level.
- name: The name of the series (when format is "long").
- crit: The critical value (when format is "long").

Examples

```
mc <- radf_mc_cv(100)

# Get the critical values
tidy(mc)

# Get the critical value sequences
augment(mc)
```

tidy.radf_distr	<i>Tidy a radf_distr object</i>
-----------------	---------------------------------

Description

Summarizes information about `radf_distr` object.

Usage

```
## S3 method for class 'radf_distr'
tidy(x, ...)
```

Arguments

x	An object of class <code>radf_distr</code> .
...	Further arguments passed to methods. Not used.

Value

A `tibble::tibble()`

Examples

```
## Not run:
mc <- mc_cv(n = 100)

tidy(mc)

## End(Not run)
```

tidy.radf_obj	<i>Tidy a radf_obj object</i>
---------------	-------------------------------

Description

Summarizes information about radf_obj object.

Usage

```
## S3 method for class 'radf_obj'
tidy(x, format = c("wide", "long"), panel = FALSE, ...)

## S3 method for class 'radf_obj'
augment(x, format = c("wide", "long"), panel = FALSE, ...)
```

Arguments

x	An object of class radf_obj.
format	Long or wide format (default = "wide").
panel	If TRUE then returns the panel statistics
...	Further arguments passed to methods. Not used.

Value

A `tibble::tibble()`

Examples

```
dta <- data.frame(psy1 = sim_psy1(n = 100), psy2 = sim_psy2(n = 100))

rfd <- radf(dta)

# Get the test statistic
tidy(rfd)

# Get the test statistic sequences
augment(rfd)

# Get the panel test statistic
```

```
tidy(rfd, panel = TRUE)
```

tidy_join	<i>Tidy into a joint model</i>
-----------	--------------------------------

Description

Tidy or augment and then join objects.

Usage

```
tidy_join(x, y, ...)
```

```
augment_join(x, y, ...)
```

Arguments

x	An object of class obj.
y	An object of class cv.
...	Further arguments passed to methods.

tidy_join.radf_obj	<i>Tidy into a joint model</i>
--------------------	--------------------------------

Description

Tidy or augment and then join objects of class radf_obj and radf_cv. The object of reference is the radf_cv. For example, if panel critical values are provided the function will return the panel test statistic.

Usage

```
## S3 method for class 'radf_obj'
tidy_join(x, y = NULL, ...)
```

```
## S3 method for class 'radf_obj'
augment_join(x, y = NULL, ...)
```

Arguments

x	An object of class radf_obj.
y	An object of class radf_cv. The output will depend on the type of critical value.
...	Further arguments passed to methods. Not used.

Details

tidy_join also calls augment_join when cv is of class sb_cv.

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