Package ‘ESGtoolkit’

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Type Package

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Description A toolkit for Monte Carlo Simulations in Finance, Economics, Insurance, Physics. Multiple simulation models can be created by combining building blocks provided in the package.

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Depends CDVine, ggplot2, gridExtra, reshape2, ycinterextra

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`esgcortest` *Correlation tests for the shocks*

Description

This function performs correlation tests for the shocks generated by `simshocks`.

Usage

```
esgcortest(
  x,
  alternative = c("two.sided", "less", "greater"),
  method = c("pearson", "kendall", "spearman"),
  conf.level = 0.95
)
```

Arguments

`x`	gaussian (bivariate) shocks, with correlation, generated by `simshocks`.
`alternative`	indicates the alternative hypothesis and must be one of "two.sided", "greater" or "less".
`method`	which correlation coefficient is to be used for the test : "pearson", "kendall", or "spearman".
`conf.level`	confidence level.

Value

a list with 2 components : estimated correlation coefficients, and confidence intervals for the estimated correlations.

Author(s)

Thierry Moudiki + stats package

References

D. J. Best & D. E. Roberts (1975), Algorithm AS 89: The Upper Tail Probabilities of Spearman's rho. Applied Statistics, 24, 377-379.

Myles Hollander & Douglas A. Wolfe (1973), Nonparametric Statistical Methods. New York: John Wiley & Sons. Pages 185-194 (Kendall and Spearman tests).

See Also

esgplotbands

Examples

```
nb <- 500

s0.par1 <- simshocks(n = nb, horizon = 3, frequency = "semi",
family = 1, par = 0.2)

s0.par2 <- simshocks(n = nb, horizon = 3, frequency = "semi",
family = 1, par = 0.8)

(test1 <- esgcortest(s0.par1))
(test2 <- esgcortest(s0.par2))
par(mfrow=c(2, 1))
esgplotbands(test1)
esgplotbands(test2)
```

---

esgdiscountfactor *Stochastic discount factors or discounted values*

Description

This function provides calculation of stochastic discount factors or discounted values

Usage

```
esgdiscountfactor(r, X)
```

Arguments

r	the short rate, a numeric (constant rate) or a time series object
X	the asset's price, a numeric (constant payoff or asset price) or a time series object

Details

The function result is :

$$X_t exp(-\int_0^t r_s ds)$$

where X_t is an asset value at a given maturity t, and $(r_s)_s$ is the risk-free rate.

Author(s)

Thierry Moudiki

See Also

esgmcprices, esgmccv

Examples

```
kappa <- 1.5
V0 <- theta <- 0.04
sigma_v <- 0.2
theta1 <- kappa*theta
theta2 <- kappa
theta3 <- sigma_v

# OU
r <- simdiff(n = 10, horizon = 5,
               frequency = "quart",
               model = "OU",
               x0 = V0, theta1 = theta1, theta2 = theta2, theta3 = theta3)

# Stochastic discount factors
esgdiscountfactor(r, 1)
```

---

esgfwdrates *Instantaneous forward rates*

Description

This function provides instantaneous forward rates. They can be used in no-arbitrage short rate models, to fit the yield curve exactly.

Usage

```
esgfwdrates(
  in.maturities,
  in.zerorates,
  n,
  horizon,
 out.frequency = c("annual", "semi-annual", "quarterly", "monthly", "weekly", "daily"),
  ...
)
```

Arguments

`in.maturities`	input maturities
`in.zerorates`	input zero rates
`n`	number of independent observations
`horizon`	horizon of projection
`out.frequency`	either "annual", "semi-annual", "quarterly", "monthly", "weekly", or "daily" (1, 1/2, 1/4, 1/12, 1/52, 1/252)
`...`	additional parameters provided to `ycinter`

Author(s)

Thierry Moudiki

References

Thierry Moudiki (2013). ycinterextra: Yield curve or zero-coupon prices interpolation and extrapolation. R package version 0.1. URL https://CRAN.R-project.org/package=ycinterextra

Examples

```
# Yield to maturities
txZC <- c(0.01422,0.01309,0.01380,0.01549,0.01747,0.01940,0.02104,0.02236,0.02348,
         0.02446,0.02535,0.02614,0.02679,0.02727,0.02760,0.02779,0.02787,0.02786,0.02776
      ,0.02762,0.02745,0.02727,0.02707,0.02686,0.02663,0.02640,0.02618,0.02597,0.02578,0.02563)

# Observed maturities
u <- 1:30

## Not run:
par(mfrow=c(2,2))
fwdNS <- esgfwdrates(in.maturities = u, in.zerorates = txZC,
                    n = 10, horizon = 20,
                    out.frequency = "semi-annual", method = "NS")
matplot(time(fwdNS), fwdNS, type = 'l')

fwdSV <- esgfwdrates(in.maturities = u, in.zerorates = txZC,
                    n = 10, horizon = 20,
                    out.frequency = "semi-annual", method = "SV")
matplot(time(fwdSV), fwdSV, type = 'l')

fwdSW <- esgfwdrates(in.maturities = u, in.zerorates = txZC,
                    n = 10, horizon = 20,
                    out.frequency = "semi-annual", method = "SW")
matplot(time(fwdSW), fwdSW, type = 'l')

fwdHCSPL <- esgfwdrates(in.maturities = u, in.zerorates = txZC,
                       n = 10, horizon = 20,
                       out.frequency = "semi-annual", method = "HCSPL")
matplot(time(fwdHCSPL), fwdHCSPL, type = 'l')
```

```
## End(Not run)
```

`esgmartingaletest` *Martingale and market consistency tests*

Description

This function performs martingale and market consistency (t-)tests.

Usage

```
esgmartingaletest(r, X, p0, alpha = 0.05)
```

Arguments

`r`	a `numeric` or a time series object, the risk-free rate(s).
`X`	a time series object, containing payoffs or projected asset values.
`p0`	a `numeric` or a vector or a univariate time series containing initial price(s) of an asset.
`alpha`	1 - confidence level for the test. Default value is 0.05.

Value

The function result can be just displayed. Otherwise, you can get a list by an assignation, containing (for each maturity) :

- the Student t values
- the p-values
- the estimated mean of the martingale difference
- Monte Carlo prices

Author(s)

Thierry Moudiki

See Also

`esgplotbands`

Examples

```
r0 <- 0.03
S0 <- 100

set.seed(10)
eps0 <- simshocks(n = 100, horizon = 3, frequency = "quart")
sim.GBM <- simdiff(n = 100, horizon = 3, frequency = "quart",
               model = "GBM",
               x0 = S0, theta1 = r0, theta2 = 0.1,
               eps = eps0)

mc.test <- esgmartingaletest(r = r0, X = sim.GBM, p0 = S0,
alpha = 0.05)
esgplotbands(mc.test)
```

---

esgmccv *Convergence of Monte Carlo prices*

Description

This function computes and plots confidence intervals around the estimated average price, as functions of the number of simulations.

Usage

```
esgmccv(r, X, maturity, plot = TRUE, ...)
```

Arguments

`r`	a `numeric` or a time series object, the risk-free rate(s).
`X`	asset prices obtained with `simdiff`
`maturity`	the corresponding maturity (optional). If missing, all the maturities available in `X` are used.
`plot`	if `TRUE` (default), a plot of the convergence is displayed.
`...`	additional parameters provided to `matplot`

Details

Studying the convergence of the sample mean of :

$$E[X_T exp(-\int_0^T r_s ds)]$$

towards its true value.

Value

a list with estimated average prices and the confidence intervals around them.

Author(s)

Thierry Moudiki

Examples

```
r <- 0.03

set.seed(1)
eps0 <- simshocks(n = 100, horizon = 5, frequency = "quart")
sim.GBM <- simdiff(n = 100, horizon = 5, frequency = "quart",
               model = "GBM",
               x0 = 100, theta1 = 0.03, theta2 = 0.1,
               eps = eps0)

# monte carlo prices
esgmcprices(r, sim.GBM)

# convergence to a specific price
(esgmccv(r, sim.GBM, 2))
```

---

esgmcprices *Estimation of discounted asset prices*

Description

This function computes estimators (sample mean) of

$$E[X_T exp(-\int_0^T r_s ds)]$$

where X_T is an asset value at given maturities T, and $(r_s)_s$ is the risk-free rate.

Usage

```
esgmcprices(r, X, maturity = NULL)
```

Arguments

r	a `numeric` or a time series object, the risk-free rate(s).
X	asset prices obtained with `simdiff`
maturity	the corresponding maturity (optional). If missing, all the maturities available in `X` are used.

Author(s)

Thierry Moudiki

See Also

esgdiscountfactor, esgmccv

Examples

```
# GBM

r <- 0.03

eps0 <- simshocks(n = 100, horizon = 5, frequency = "quart")
sim.GBM <- simdiff(n = 100, horizon = 5, frequency = "quart",
               model = "GBM",
               x0 = 100, theta1 = 0.03, theta2 = 0.1,
               eps = eps0)

# monte carlo prices
esgmcprices(r, sim.GBM)

# monte carlo price for a given maturity
esgmcprices(r, sim.GBM, 2)
```

---

esgplotbands *Plot time series percentiles and confidence intervals*

Description

This function plots colored bands for time series percentiles and confidence intervals. You can use it for outputs from `link{simdiff}`, `link{esgmartingaletest}`, `link{esgcortest}`.

Usage

```
esgplotbands(x, ...)
```

Arguments

x	a times series object
...	additionnal (optional) parameters provided to `plot`

Author(s)

Thierry Moudiki

See Also

esgplotts

Examples

```
# Times series

kappa <- 1.5
V0 <- theta <- 0.04
sigma <- 0.2
theta1 <- kappa*theta
theta2 <- kappa
theta3 <- sigma
x <- simdiff(n = 100, horizon = 5,
frequency = "quart",
model = "OU",
x0 = V0, theta1 = theta1, theta2 = theta2, theta3 = theta3)

par(mfrow=c(2,1))
esgplotbands(x, xlab = "time", ylab = "values")
matplot(time(x), x, type = 'l', xlab = "time", ylab = "series values")

# Martingale test

r0 <- 0.03
S0 <- 100
sigma0 <- 0.1
nbScenarios <- 100
horizon0 <- 10
eps0 <- simshocks(n = nbScenarios, horizon = horizon0, frequency = "quart",
method = "anti")
sim.GBM <- simdiff(n = nbScenarios, horizon = horizon0, frequency = "quart",
                 model = "GBM",
                 x0 = S0, theta1 = r0, theta2 = sigma0,
                 eps = eps0)

mc.test <- esgmartingaletest(r = r0, X = sim.GBM, p0 = S0, alpha = 0.05)
esgplotbands(mc.test)

# Correlation test

nb <- 500

s0.par1 <- simshocks(n = nb, horizon = 3, frequency = "semi",
family = 1, par = 0.2)

s0.par2 <- simshocks(n = nb, horizon = 3, frequency = "semi",
family = 1, par = 0.8)

(test1 <- esgcortest(s0.par1))
(test2 <- esgcortest(s0.par2))
```

```
par(mfrow=c(2, 1))
esgplotbands(test1)
esgplotbands(test2)
```

---

esgplotshocks *Visualize the dependence between 2 gaussian shocks*

Description

This function helps you in visualizing the dependence between 2 gaussian shocks.

Usage

```
esgplotshocks(x, y = NULL)
```

Arguments

x	an output from simshocks, a list with 2 components.
y	an output from simshocks, a list with 2 components (Optional).

Author(s)

Thierry Moudiki + some nice blogs :)

References

H. Wickham (2009), ggplot2: elegant graphics for data analysis. Springer New York.

See Also

simshocks

Examples

```
# Number of risk factors
d <- 2

# Number of possible combinations of the risk factors
dd <- d*(d-1)/2

# Family : Gaussian copula
fam1 <- rep(1,dd)
# Correlation coefficients between the risk factors (d*(d-1)/2)
par0.1 <- 0.1
par0.2 <- -0.9

# Family : Rotated Clayton (180 degrees)
fam2 <- 13
```

```
par0.3 <- 2

# Family : Rotated Clayton (90 degrees)
fam3 <- 23
par0.4 <- -2

# number of simulations
nb <- 500

# Simulation of shocks for the d risk factors
s0.par1 <- simshocks(n = nb, horizon = 4,
family = fam1, par = par0.1)

s0.par2 <- simshocks(n = nb, horizon = 4,
family = fam1, par = par0.2)

s0.par3 <- simshocks(n = nb, horizon = 4,
family = fam2, par = par0.3)

s0.par4 <- simshocks(n = nb, horizon = 4,
family = fam3, par = par0.4)

## Not run:
esgplotshocks(s0.par1, s0.par2)
esgplotshocks(s0.par2, s0.par3)
esgplotshocks(s0.par2, s0.par4)
esgplotshocks(s0.par1, s0.par4)
## End(Not run)
```

---

esgplotts *Plot time series objects*

Description

This function plots outputs from simdiff.

Usage

```
esgplotts(x)
```

Arguments

x	a time series object, an output from simdiff.

Details

For a large number of simulations, it's preferable to use esgplotbands for a synthetic view by percentiles.

Author(s)

Thierry Moudiki

References

H. Wickham (2009), ggplot2: elegant graphics for data analysis. Springer New York.

See Also

simdiff, esgplotbands

Examples

```
kappa <- 1.5
V0 <- theta <- 0.04
sigma <- 0.2
theta1 <- kappa*theta
theta2 <- kappa
theta3 <- sigma
x <- simdiff(n = 10, horizon = 5, frequency = "quart",
model = "OU",
x0 = V0, theta1 = theta1, theta2 = theta2, theta3 = theta3)

esgplotts(x)
```

`simdiff` *Simulation of diffusion processes.*

Description

This function makes simulations of diffusion processes, that are building blocks for various risk factors' models.

Usage

```
simdiff(
  n,
  horizon,
 frequency = c("annual", "semi-annual", "quarterly", "monthly", "weekly", "daily"),
  model = c("GBM", "CIR", "OU"),
  x0,
  theta1 = NULL,
  theta2 = NULL,
  theta3 = NULL,
  lambda = NULL,
  mu_z = NULL,
  sigma_z = NULL,
```

```
  p = NULL,
  eta_up = NULL,
  eta_down = NULL,
  eps = NULL,
  seed = 123
)
```

Arguments

- `n` — number of independent observations.
- `horizon` — horizon of projection.
- `frequency` — either "annual", "semi-annual", "quarterly", "monthly", "weekly", or "daily" (1, 1/2, 1/4, 1/12, 1/52, 1/252).
- `model` — either Geometric Brownian motion-like ("GBM"), Cox-Ingersoll-Ross ("CIR"), or Ornstein-Uhlenbeck ("OU").

  GBM-like (GBM, Merton, Kou, Heston, Bates)

  $$dX_t = \theta_1(t)X_t dt + \theta_2(t)X_t dW_t + X_t J dN_t$$

  CIR

  $$dX_t = (\theta_1 - \theta_2 X_t)dt + \theta_3\sqrt(X_t)dW_t$$

  Ornstein-Uhlenbeck

  $$dX_t = (\theta_1 - \theta_2 X_t)dt + \theta_3 dW_t$$

  Where $(W_t)_t$ is a standard brownian motion :

  $$dW_t \ \ \epsilon\sqrt(dt)$$

  and

  $$\epsilon \ \ N(0,1)$$

  The ϵ is a gaussian increment that can be an output from simshocks.

  For 'GBM-like', θ_1 and θ_2 can be held constant, and the jumps part JdN_t is optional. In case the jumps are used, they arise following a Poisson process (N_t), with intensities J drawn either from lognormal or asymmetric double-exponential distribution.
- `x0` — starting value of the process.
- `theta1` — a numeric for model = "GBM", model = "CIR", model = "OU". Can also be a time series object (an output from simdiff with the same number of scenarios, horizon and frequency) for model = "GBM", and time-varying parameters.
- `theta2` — a numeric for model = "GBM", model = "CIR", model = "OU". Can also be a time series object (an output from simdiff with the same number of scenarios, horizon and frequency) for model = "GBM", and time-varying parameters.
- `theta3` — a numeric, volatility for model = "CIR" and model = "OU".

`lambda`	intensity of the Poisson process counting the jumps. Optional.
`mu_z`	mean parameter for the lognormal jumps size. Optional.
`sigma_z`	standard deviation parameter for the lognormal jumps size. Optional.
`p`	probability of positive jumps. Must belong to]0, 1[. Optional.
`eta_up`	mean of positive jumps in Kou's model. Must belong to]0, 1[. Optional.
`eta_down`	mean of negative jumps. Must belong to]0, 1[. Optional.
`eps`	gaussian shocks. If not provided, independent shocks are generated internally by the function. Otherwise, for custom shocks, must be an output from `simshocks`.
`seed`	reproducibility seed

Value

a time series object.

Author(s)

Thierry Moudiki

References

Black, F., Scholes, M.S. (1973) The pricing of options and corporate liabilities, Journal of Political Economy, 81, 637-654.

Cox, J.C., Ingersoll, J.E., Ross, S.A. (1985) A theory of the term structure of interest rates, Econometrica, 53, 385-408.

Iacus, S. M. (2009). Simulation and inference for stochastic differential equations: with R examples (Vol. 1). Springer.

Glasserman, P. (2004). Monte Carlo methods in financial engineering (Vol. 53). Springer.

Kou S, (2002), A jump diffusion model for option pricing, Management Sci- ence Vol. 48, 1086-1101.

Merton, R. C. (1976). Option pricing when underlying stock returns are discontinuous. Journal of financial economics, 3(1), 125-144.

Uhlenbeck, G. E., Ornstein, L. S. (1930) On the theory of Brownian motion, Phys. Rev., 36, 823-841.

Vasicek, O. (1977) An Equilibrium Characterization of the Term Structure, Journal of Financial Economics, 5, 177-188.

See Also

`simshocks`, `esgplotts`

Examples

```
kappa <- 1.5
V0 <- theta <- 0.04
sigma_v <- 0.2
theta1 <- kappa*theta
theta2 <- kappa
theta3 <- sigma_v

# OU

sim.OU <- simdiff(n = 10, horizon = 5,
               frequency = "quart",
               model = "OU",
               x0 = V0, theta1 = theta1, theta2 = theta2, theta3 = theta3)
head(sim.OU)
par(mfrow=c(2,1))
esgplotbands(sim.OU, xlab = "time", ylab = "values", main = "with esgplotbands")
matplot(time(sim.OU), sim.OU, type = 'l', main = "with matplot")


# OU with simulated shocks (check the dimensions)

eps0 <- simshocks(n = 50, horizon = 5, frequency = "quart", method = "anti")
sim.OU <- simdiff(n = 50, horizon = 5, frequency = "quart",
               model = "OU",
               x0 = V0, theta1 = theta1, theta2 = theta2, theta3 = theta3,
               eps = eps0)
par(mfrow=c(2,1))
esgplotbands(sim.OU, xlab = "time", ylab = "values", main = "with esgplotbands")
matplot(time(sim.OU), sim.OU, type = 'l', main = "with matplot")
# a different plot
esgplotts(sim.OU)


# CIR

sim.CIR <- simdiff(n = 50, horizon = 5,
               frequency = "quart",
               model = "CIR",
               x0 = V0, theta1 = theta1, theta2 = theta2, theta3 = 0.05)
esgplotbands(sim.CIR, xlab = "time", ylab = "values", main = "with esgplotbands")
matplot(time(sim.CIR), sim.CIR, type = 'l', main = "with matplot")



# GBM

eps0 <- simshocks(n = 100, horizon = 5, frequency = "quart")
sim.GBM <- simdiff(n = 100, horizon = 5, frequency = "quart",
               model = "GBM",
               x0 = 100, theta1 = 0.03, theta2 = 0.1,
```

```
                 eps = eps0)
esgplotbands(sim.GBM, xlab = "time", ylab = "values", main = "with esgplotbands")
matplot(time(sim.GBM), sim.GBM, type = 'l', main = "with matplot")


eps0 <- simshocks(n = 100, horizon = 5, frequency = "quart")
sim.GBM <- simdiff(n = 100, horizon = 5, frequency = "quart",
                 model = "GBM",
                 x0 = 100, theta1 = 0.03, theta2 = 0.1,
                 eps = eps0)
esgplotbands(sim.GBM, xlab = "time", ylab = "values", main = "with esgplotbands")
matplot(time(sim.GBM), sim.GBM, type = 'l', main = "with matplot")
```

---

simshocks *Underlying gaussian shocks for risk factors' simulation.*

Description

This function makes simulations of correlated or dependent gaussian shocks for risk factors.

Usage

```
simshocks(
  n,
  horizon,
 frequency = c("annual", "semi-annual", "quarterly", "monthly", "weekly", "daily"),
  method = c("classic", "antithetic", "mm", "hybridantimm", "TAG"),
  family = NULL,
  par = NULL,
  par2 = NULL,
  type = c("CVine", "DVine"),
  seed = 123
)
```

Arguments

n	number of independent observations for each risk factor.
horizon	horizon of projection.
frequency	either "annual", "semi-annual", "quarterly", "monthly", "weekly", or "daily" (1, 1/2, 1/4, 1/12, 1/52, 1/252).
method	either classic monte carlo, antithetic variates, moment matching, hybrid antithetic variates + moment matching or "TAG" (see the 4th reference for the latter).
family	the same as CDVineSim from package CDVine. A d*(d-1)/2 integer vector of C-/D-vine pair-copula families with values 0 = independence copula, 1 = Gaussian copula, 2 = Student t copula (t-copula), 3 = Clayton copula, 4 = Gumbel copula, 5 = Frank copula, 6 = Joe copula, 7 = BB1 copula, 8 = BB6 copula, 9 = BB7

copula, 10 = BB8 copula, 13 = rotated Clayton copula (180 degrees; "survival Clayton"), 14 = rotated Gumbel copula (180 degrees; "survival Gumbel"), 16 = rotated Joe copula (180 degrees; "survival Joe"), 17 = rotated BB1 copula (180 degrees; "survival BB1"), 18 = rotated BB6 copula (180 degrees; "survival BB6"), 19 = rotated BB7 copula (180 degrees; "survival BB7"), 20 = rotated BB8 copula (180 degrees; "survival BB8"), 23 = rotated Clayton copula (90 degrees), 24 = rotated Gumbel copula (90 degrees), 26 = rotated Joe copula (90 degrees), 27 = rotated BB1 copula (90 degrees), 28 = rotated BB6 copula (90 degrees), 29 = rotated BB7 copula (90 degrees), 30 = rotated BB8 copula (90 degrees), 33 = rotated Clayton copula (270 degrees), 34 = rotated Gumbel copula (270 degrees), 36 = rotated Joe copula (270 degrees), 37 = rotated BB1 copula (270 degrees), 38 = rotated BB6 copula (270 degrees), 39 = rotated BB7 copula (270 degrees), 40 = rotated BB8 copula (270 degrees)

`par` the same as `CDVineSim` from package `CDVine`. A d*(d-1)/2 vector of pair-copula parameters.

`par2` the same as `CDVineSim` from package `CDVine`. A d*(d-1)/2 vector of second parameters for pair-copula families with two parameters (t, BB1, BB6, BB7, BB8; no default).

`type` type of the vine model: 1 : C-vine 2 : D-vine

`seed` reproducibility seed

Details

The function shall be used along with `simdiff`, in order to embed correlated or dependent random gaussian shocks into simulated diffusions. `esgplotshocks` can help in visualizing the type of dependence between the shocks.

Value

If `family` and `par` are not provided, a univariate time series object with simulated gaussian shocks for one risk factor. Otherwise, a list of time series objects, containing gaussian shocks for each risk factor.

Author(s)

Thierry Moudiki

References

Brechmann, E., Schepsmeier, U. (2013). Modeling Dependence with C- and D-Vine Copulas: The R Package CDVine. Journal of Statistical Software, 52(3), 1-27. URL `http://www.jstatsoft.org/v52/i03/`.

Genz, A. Bretz, F., Miwa, T. Mi, X., Leisch, F., Scheipl, F., Hothorn, T. (2013). mvtnorm: Multivariate Normal and t Distributions. R package version 0.9-9996.

Genz, A. Bretz, F. (2009), Computation of Multivariate Normal and t Probabilities. Lecture Notes in Statistics, Vol. 195., Springer-Verlag, Heidelberg. ISBN 978-3-642-01688-2.

Nteukam T, O., & Planchet, F. (2012). Stochastic evaluation of life insurance contracts: Model point on asset trajectories and measurement of the error related to aggregation. Insurance: Mathematics and Economics, 51(3), 624-631. URL http://www.ressources-actuarielles.net/EXT/ISFA/1226.nsf/0/ab539dcebcc4e77ac12576c6004afa67/$FILE/Article_US_v1.5.pdf

See Also

simdiff, esgplotshocks

Examples

```
# Number of risk factors
d <- 6

# Number of possible combinations of the risk factors
dd <- d*(d-1)/2

# Family : Gaussian copula for all
fam1 <- rep(1,dd)

# Correlation coefficients between the risk factors (d*(d-1)/2)
par1 <- c(0.2,0.69,0.73,0.22,-0.09,0.51,0.32,0.01,0.82,0.01,
        -0.2,-0.32,-0.19,-0.17,-0.06)


# Simulation of shocks for the 6 risk factors
simshocks(n = 10, horizon = 5, family = fam1, par = par1)


# Simulation of shocks for the 6 risk factors
# on a quarterly basis
simshocks(n = 10, frequency = "quarterly", horizon = 2, family = fam1,
par = par1)


# Simulation of shocks for the 6 risk factors simulation
# on a quarterly basis, with antithetic variates and moment matching.
s0 <- simshocks(n = 10, method = "hyb", horizon = 4,
family = fam1, par = par1)


s0[[2]]
colMeans(s0[[1]])
colMeans(s0[[5]])
apply(s0[[3]], 2, sd)
apply(s0[[4]], 2, sd)
```

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