

Package ‘temStaR’

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Title Tempered Stable Distribution

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Description This package provides useful tools to use the multivariate normal tempered stable distribution and process

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Imports functional,
nloptr,
pracma,
spatstat,
Matrix,
mvtnorm

Suggests functional,
nloptr,
pracma,
spatstat,
Matrix,
mvtnorm

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chf_NTS

chf_NTS

Description

chf_NTS calculates Ch.F of the NTS distribution with parameters $(\alpha, \theta, \beta, \gamma, \mu)$. If a time parameter value is given, it calculates Ch.F of the NTS process $\phi(u) = E[\exp(iu(X(t+s) - X(s)))] = \exp(t \log(E[\exp(iuX(1))]))$, where X is the NTS process generated by the NTS distribution with parameters $(\alpha, \theta, \beta, \gamma, \mu)$.

Usage

```
chf_NTS(u, param)
```

Arguments

u	An array of u
ntsparam	A vector of the NTS parameters $(\alpha, \theta, \beta, \gamma, \mu)$. For NTS process case it is a vector of parameters $(\alpha, \theta, \beta, \gamma, \mu, t)$.

Value

Characteristic function of the NTS distribution

Examples

```
alpha <- 1.2
theta <- 1
beta <- -0.2
gamma <- 0.3
mu <- 0.1
ntsparm <- c(alpha, theta, beta, gamma, mu)
u <- seq(from = -2*pi, to = 2*pi, length.out = 101)
phi <- chf_NTS(u, ntsparm)
```

```
#Annual based parameters
alpha <- 1.2
theta <- 1
beta <- -0.2
gamma <- 0.3
mu <- 0.1
#scaling annual parameters to one day
dt <- 1/250 #one day
ntsparm <- c(alpha, theta, beta, gamma, mu, dt)
u <- seq(from = -2*pi, to = 2*pi, length.out = 101)
phi <- chf_NTS(u, ntsparm)
```

chf_stdNTS

chf_stdNTS

Description

chf_stdNTS calculates Ch.F of the standard NTS distribution with parameters (α, θ, β) . If a time parameter value is given, it calculates Ch.F of the standard NTS process $\phi(u) = E[\exp(iu(X(t+s) - X(s))) = \exp(t \log(E[\exp(iuX(1))]))$, where X is the standard NTS process generated by the standard NTS distribution with parameters (α, θ, β) .

Usage

```
chf_stdNTS(u, param)
```

Arguments

u	An array of u
ntsparm	A vector of the standard NTS parameters (α, θ, β) . For the standard NTS process case it is a vector of parameters $(\alpha, \theta, \beta, t)$.

Value

Characteristic function of the standard NTS distribution

Examples

```
alpha <- 1.2
theta <- 1
beta <- -0.2
ntsparam <- c(alpha, theta, beta)
u <- seq(from = -2*pi, to = 2*pi, length.out = 101)
phi <- chf_stdNTS(u, ntsparam)

#Annual based parameters
alpha <- 1.2
theta <- 1
beta <- -0.2
#scaling annual parameters to one day
dt <- 1/250 #one day
ntsparam <- c(alpha, theta, beta, gamma, mu, dt)
u <- seq(from = -2*pi, to = 2*pi, length.out = 101)
phi <- chf_stdNTS(u, ntsparam)
```

copulaStdNTS

copulaStdNTS

Description

copulaStdNTS calculates the stdNTS copula values

Usage

```
copulaStdNTS(u, st, subTS = NULL)
```

cvarGauss

cvarGauss

Description

Calculate the CVaR for the normal distributed market model. Developer's version.

Usage

```
cvarGauss(eta, mu = 0, sigma = 1)
```

cvarmarginalmnts	<i>cvarmarginalmnts</i>
------------------	-------------------------

Description

cvarmarginalmnts calculates the CVaR of the n -th element of the multivariate NTS distributed random variable.

Usage

```
cvarmarginalmnts(eta, n, st)
```

Arguments

eta	the significant level for CVaR. Real value between 0 and 1.
st	Structure of parameters for the n -dimensional NTS distribution.

cvarnts	<i>cvarnts</i>
---------	----------------

Description

cvarnts calculates Conditional Value at Risk (CVaR, or expected shortfall ES) of the NTS market model with parameters $(\alpha, \theta, \beta, \gamma, \mu)$. If only three parameters are given, it calculates CVaR of the standard NTS distribution with parameter (α, θ, β)

Usage

```
cvarnts(eps, ntsparam)
```

Arguments

eps	the significant level for CVaR. Real value between 0 and 1.
ntsparam	A vector of the NTS parameters $(\alpha, \theta, \beta, \gamma, \mu)$. A vector of the standard NTS parameters (α, θ, β) .

Value

CVaR of the NTS distribution.

References

Y. S. Kim, S. T. Rachev, M. L. Bianchi, and F. J. Fabozzi (2010), Computing VaR and AVaR in infinitely divisible distributions, *Probability and Mathematical Statistics*, 30 (2), 223-245.

S. T. Rachev, Y. S. Kim, M. L. Bianchi, and F. J. Fabozzi (2011), *Financial Models with Levy Processes and Volatility Clustering*, John Wiley & Sons

Examples

```

alpha <- 1.2
theta <- 1
beta <- -0.2
ntsparm <- c(alpha, theta, beta)
u <- c(0.01, 0.05)
q <- cvarnts(u, ntsparm)

alpha <- 1.2
theta <- 1
beta <- -0.2
gamma <- 0.3
mu <- 0.1
ntsparm <- c(alpha, theta, beta, gamma, mu)
u <- c(0.01, 0.05)
q <- cvarnts(u, ntsparm)

#Annual based parameters
alpha <- 1.2
theta <- 1
beta <- -0.2
gamma <- 0.3
mu <- 0.1
#scaling annual parameters to one day
dt <- 1/250 #one day
ntsparm <- c(alpha, theta, beta, gamma, mu, dt)
u <- c(0.01, 0.05)
q <- cvarnts(u, ntsparm)

```

dBeta

*dBeta***Description**

The first derivative of the beta. Developer's version.

Usage

```
dBeta(n, w, betaArray, covMtx)
```

dcopulaStdNTS

*dcopulaStdNTS***Description**

dcopulaStdNTS calculates density of the stdNTS copula.

Usage

```
dcopulaStdNTS(u, st, subTS = NULL)
```

dCVaR_numint	<i>dCVaR_numint</i>
--------------	---------------------

Description

The first derivative of CVaR for the beta parameter of the stdNTS. Developer's version.

Usage

```
dCVaR_numint(eta, alpha, theta, beta, N = 200, rho = 0.1)
```

dinvCdf_stdNTS	<i>dinvCdf_stdNTS</i>
----------------	-----------------------

Description

The first derivative of inverse CDF for the beta parameter of the stdNTS. Developer's version.

Usage

```
dinvCdf_stdNTS(eta, alpha, theta, beta)
```

dmarginalmnts	<i>dmarginalmnts</i>
---------------	----------------------

Description

dmarginalmnts calculates the marginal density of the n -th element of the multivariate NTS distributed random variable.

Usage

```
dmarginalmnts(x, n, st)
```

Arguments

st	Structure of parameters for the n-dimensional NTS distribution.
----	---

dmnts

dmnts

Description

dmnts calculates the density of the multivariate NTS distribution: $f(x_1, \dots, x_n) = \frac{d^n}{dx_1 \dots dx_n} P(x_n < R_1, \dots, x_n < R_n)$. The multivariate NTS random vector $R = (R_1, \dots, R_n)$ is defined

$$R = \mu + \text{diag}(\sigma)X,$$

where

X follows $\text{stdNTS}_n(\alpha, \theta, \beta, \Sigma)$

Usage

```
dmnts(x, st, subTS = NULL)
```

Arguments

x	array of the (x_1, \dots, x_n)
st	Structure of parameters for the n-dimensional NTS distribution. $\text{st}\$ndim$: dimension $\text{st}\$\mu$: μ mean vector (column vector) of the input data. $\text{st}\$\sigma$: σ standard deviation vector (column vector) of the input data. $\text{st}\$\alpha$: α of the std NTS distribution (X). $\text{st}\$\theta$: θ of the std NTS distribution (X). $\text{st}\$\beta$: β vector (column vector) of the std NTS distribution (X). $\text{st}\$Rho$: ρ matrix of the std NTS distribution (X).
numofsample	number of samples.

Value

Simulated NTS random vectors

References

Kim, Y. S. (2020) Portfolio Optimization on the Dispersion Risk and the Asymmetric Tail Risk
<https://arxiv.org/pdf/2007.13972.pdf>

Examples

```
library(mvtnorm)
strPMNTS <- list(ndim = 2,
  mu = c( 0.5, -1.5 ),
  sigma = c( 2, 3 ),
  alpha = 0.1,
  theta = 3,
  beta = c( 0.1, -0.3 ),
  Rho = matrix( data = c(1.0, 0.75, 0.75, 1.0),
    nrow = 2, ncol = 2)
)
dmnts(c(0.6, -1.0), st = strPMNTS)
```



```

strPMNTS <- list(ndim = 2,
                 mu = c( 0, 0, 0 ),
                 sigma = c( 1, 1, 1 ),
                 alpha = 0.1,
                 theta = 3,
                 beta = c( 0.1, -0.3, 0 ),
                 Rho = matrix(
                   data = c(1.0, 0.75, 0.1, 0.75, 1.0, 0.2, 0.1, 0.2, 1.0),
                   nrow = 3, ncol = 3)
                 )
pmnts(c(0,0,0), st = strPMNTS)
dmnts(c(0,0,0), st = strPMNTS)

```

dnts

dnts

Description

dnts calculates pdf of the NTS distribution with parameters $(\alpha, \theta, \beta, \gamma, \mu)$. If only three parameters are given, it calculates pdf of the standard NTS distribution with parameter (α, θ, β) . If a time parameter value is given, it calculates pdf of the NTS process $f(x)dx = d(P((X(t+s) - X(s)) < x))$, where X is the NTS process generated by the NTS distribution with parameters $(\alpha, \theta, \beta, \gamma, \mu)$.

Usage

```
dnts(xdata, ntsparm)
```

Arguments

xdata	An array of x
ntsparm	A vector of the NTS parameters $(\alpha, \theta, \beta, \gamma, \mu)$. For the NTS process case it is a vector of parameters $(\alpha, \theta, \beta, \gamma, \mu, t)$. A vector of the standard NTS parameters (α, θ, β) .

Value

Density of NTS distribution

References

Kim, Y. S. (2020) Portfolio Optimization on the Dispersion Risk and the Asymmetric Tail Risk
<https://arxiv.org/pdf/2007.13972.pdf>

Examples

```

alpha <- 1.2
theta <- 1
beta <- -0.2
ntsparm <- c(alpha, theta, beta)
x <- seq(from = -6, to = 6, length.out = 101)

```

```

d <- dnts(x, ntsparm)
plot(x,d,type = 'l')

alpha <- 1.2
theta <- 1
beta <- -0.2
gamma <- 0.3
mu <- 0.1
ntsparm <- c(alpha, theta, beta, gamma, mu)
x <- seq(from = -2, to = 2, by = 0.01)
d <- dnts(x, ntsparm)
plot(x,d,type = 'l')

#Annual based parameters
alpha <- 1.2
theta <- 1
beta <- -0.2
gamma <- 0.3
mu <- 0.1
#scaling annual parameters to one day
dt <- 1/250 #one day
ntsparm <- c(alpha, theta, beta, gamma, mu, dt)
x <- seq(from = -0.02, to = 0.02, length.out = 101)
d <- dnts(x, ntsparm)
plot(x,d,type = 'l')

```

fitmnts

fitmnts

Description

fitmnts fit parameters of the n-dimensional NTS distribution.

$$r = \mu + \text{diag}(\sigma)X$$

where

X follows $\text{stdNTS}_n(\alpha, \theta, \beta, \Sigma)$

Usage

```

\code{res <- fitmnts(returndata, n)}
\code{res <- fitmnts(returndata, n, alphaNtheta = c(alpha, theta))}
\code{res <- fitmnts(returndata, n, stdflag = TRUE ) }
\code{res <- fitmnts(returndata, n, alphaNtheta = c(alpha, theta), stdflag = TRUE)}

```

Arguments

returndata	Raw data to fit the parameters. The data must be given as a matrix form. Each column of the matrix contains a sequence of asset returns. The number of row of the matrix is the number of assets.
n	Dimension of the data. That is the number of assets.

alphaNtheta	If α and θ are given, then put those numbers in this parameter. The function fixes those parameters and fits other remaining parameters. If you set <code>alphaNtheta = NULL</code> , then the function fits all parameters including α and θ .
stdflag	If you want only standard NTS parameter fit, set this value be TRUE.

Value

Structure of parameters for the n-dimensional NTS distribution.

`res$mu` : μ mean vector (column vector) of the input data.

`res$sigma` : σ standard deviation vector (column vector) of the input data.

`res$alpha` : α of the std NTS distribution (X).

`res$theta` : θ of the std NTS distribution (X).

`res$beta` : β vector (column vector) of the std NTS distribution (X).

`res$Rho` : ρ matrix of the std NTS distribution (X), which is correlation matrix of epsilon.

`res$CovMtx` : Covariance matrix of return data r .

References

Kim, Y. S. (2020) Portfolio Optimization on the Dispersion Risk and the Asymmetric Tail Risk
<https://arxiv.org/pdf/2007.13972.pdf>

Examples

```
library(functional)
library(nloptr)
library(pracma)
library(spatstat)
library(Matrix)
library(quantmod)

getSymbols("^GSPC", src="yahoo", from = "2016-1-1", to = "2020-08-31")
pr1 <- as.numeric(GSPC$GSPC.Adjusted)
getSymbols("^DJI", src="yahoo", from = "2016-1-1", to = "2020-08-31")
pr2 <- as.numeric(DJI$DJI.Adjusted)

returndata <- matrix(data = c(diff(log(pr1)),diff(log(pr2))),
                     ncol = 2, nrow = (length(pr1)-1))
res <- fitmnts( returndata = returndata, n=2 )

#Fix alpha and theta.
#Estimate alpha and theta from DJIA and use those parameter for IBM, INTL parameter fit.
getSymbols("^DJI", src="yahoo", from = "2020-8-25", to = "2020-08-31")
prDJ <- as.numeric(DJI$DJI.Adjusted)
ret <- diff(log(prDJ))
ntsparm <- fitmnts(ret)
getSymbols("IBM", src="yahoo", from = "2016-1-1", to = "2020-08-31")
pr1 <- as.numeric(IBM$IBM.Adjusted)
getSymbols("INTL", src="yahoo", from = "2016-1-1", to = "2020-08-31")
pr2 <- as.numeric(INTL$INTL.Adjusted)

returndata <- matrix(data = c(diff(log(pr1)),diff(log(pr2))),
```

```

      ncol = 2, nrow = (length(pr1)-1))
res <- fitmnts( returndata = returndata,
               n = 2,
               alphaNtheta = c(ntsparam["alpha"], ntsparam["theta"]) )

```

fitnts	<i>fitnts</i>
--------	---------------

Description

fitnts fit parameters $(\alpha, \theta, \beta, \gamma, \mu)$ of the NTS distribution. This function using the curvefit method between the empirical cdf and the NTS cdf.

Usage

```

\code{fitnts(rawdat)}
\code{fitnts(rawdat), ksdensityflag = 1}
\code{fitnts(rawdat, initialparam = c(alpha, theta, beta, gamma, mu))}
\code{fitnts(rawdat, initialparam = c(alpha, theta, beta, gamma, mu)), ksdensityflag = 1}
\code{fitnts(rawdat, initialparam = c(alpha, theta, beta, gamma, mu)), maxeval = 100, ksdensityflag

```

Arguments

rawdat	Raw data to fit the parameters.
initialparam	A vector of initial NTS parameters. This function uses the nloptr package. If it has a good initial parameter then estimation performs better. If users do not know a good initial parameters, then just set it as initialparam=NaN, that is default. The function cffitnts() may be helpful to find the initial parameters.
maxeval	Maximum evaluation number for nloptr. The iteration stops on this many function evaluations.
ksdensityflag	This function fit the parameters using the curvefit method between the empirical cdf and the NTS cdf. If ksdensityflag = 1 (default), then the empirical cdf is calculated by the kernel density estimation. If ksdensityflag = 0, then the empirical cdf is calculated by the empirical cdf.

Value

Estimated parameters

References

Kim, Y. S. (2020) Portfolio Optimization on the Dispersion Risk and the Asymmetric Tail Risk
<https://arxiv.org/pdf/2007.13972.pdf>

Examples

```
library("quantmod")
getSymbols("^GSPC", src="yahoo", from = "2010-1-1", to = "2020-12-31")
pr <- as.numeric(GSPC$GSPC.Adjusted)
ret <- diff(log(pr))
ntsparm <- fitnts(ret)

Femp = ecdf(ret)
x = seq(from=min(ret), to = max(ret), length.out = 100)
cemp = Femp(x)
ncdf = pnts(x, c(ntsparm))
plot(x,ncdf,type = 'l', col = "red")
points(x,cemp, type = 'l', col = "blue")
a = density(ret)
p = dnts(x,ntsparm)
plot(x,p,type = 'l', col = "red")
lines(a,type = 'l', col = "blue")
```

fitstdnts

fitstdnts

Description

fitstdnts fit parameters (α, θ, β) of the standard NTS distribution. This function using the curvefit method between the empirical cdf and the standard NTS cdf.

Usage

```
\code{fitstdnts(rawdat)}
\code{fitstdnts(rawdat), ksdensityflag = 1}
\code{fitstdnts(rawdat, initialparam = c(alpha, theta, beta))}
\code{fitstdnts(rawdat, initialparam = c(alpha, theta, beta)), ksdensityflag = 1}
\code{fitstdnts(rawdat, initialparam = c(alpha, theta, beta)), maxeval = 100, ksdensityflag = 1}
```

Arguments

rawdat	Raw data to fit the parameters.
initialparam	A vector of initial standard NTS parameters. This function uses the nloptr package. If it has a good initial parameter then estimation performs better. If users do not know a good initial parameters, then just set it as initialparam=NaN, that is default.
maxeval	Maximum evaluation number for nloptr. The iteration stops on this many function evaluations.
ksdensityflag	This function fit the parameters using the curvefit method between the empirical cdf and the standard NTS cdf. If ksdensityflag = 1 (default), then the empirical cdf is calculated by the kernel density estimation. If ksdensityflag = 0, then the empirical cdf is calculated by the empirical cdf.

Value

Estimated parameters

References

Kim, Y. S. (2020) Portfolio Optimization on the Dispersion Risk and the Asymmetric Tail Risk
<https://arxiv.org/pdf/2007.13972.pdf>

Examples

```
library("quantmod")
getSymbols("^GSPC", src="yahoo", from = "2010-1-1", to = "2020-12-31")
pr <- as.numeric(GSPC$GSPC.Adjusted)
ret <- diff(log(pr))
stdret <- (ret-mean(ret))/sd(ret)
stdntsparam <- fitstdnts(stdret)

Femp = ecdf(stdret)
x = seq(from=min(stdret), to = max(stdret), length.out = 100)
cemp = Femp(x)
ncdf = pnts(x, c(stdntsparam))
plot(x,ncdf,type = 'l', col = "red")
lines(x,cemp, type = 'l', col = "blue")
a = density(stdret)
p = dnts(x,stdntsparam)
plot(x,p,type = 'l', col = "red", ylim = c(0, max(a$y, p)))
lines(a,type = 'l', col = "blue")
```

gensamplepathnts

gensamplepathnts

Description

gensamplepathnts generate sample paths of the NTS process with parameters $(\alpha, \theta, \beta, \gamma, \mu)$. If only three parameters are given, it generate sample paths of the standard NTS process with parameters (α, θ, β) .

Usage

```
gensamplepathnts(npath, nimestep, ntsparm, dt)
```

Arguments

npath	Number of sample paths
nimestep	number of time step
ntsparm	A vector of the NTS parameters $(\alpha, \theta, \beta, \gamma, \mu)$. A vector of the standard NTS parameters (α, θ, β) .
dt	the time length of one time step by the year fraction. "dt=1" means 1-year.

Value

Structure of the sample path. Matrix of sample path. Column index is time.

Examples

```
#standard NTS process sample path
alpha <- 1.2
theta <- 1
beta <- -0.2
ntsparam <- c(alpha, theta, beta)
npath <- 5
ntimestep <- 250
dt <- 1/250
simulation <- gensamplepathnts(npath, ntimestep, ntsparam, dt)
matplot(colnames(simulation), t(simulation), type = 'l')

#NTS process sample path
alpha <- 1.2
theta <- 1
beta <- -0.2
gamma <- 0.3
mu <- 0.1
ntsparam <- c(alpha, theta, beta, gamma, mu)
npath <- 5
ntimestep <- 250
dt <- 1/250
simulation <- gensamplepathnts(npath, ntimestep, ntsparam, dt)
matplot(colnames(simulation), t(simulation), type = 'l')
```

getPortNTSParm

getPortNTSParm

Description

Portfolio return with capital allocation weight is $R_p = \langle w, r \rangle$, which is a weighted sum of elements in the N-dimensional NTS random vector. R_p becomes an 1-dimensional NTS random variable. getPortNTSParm find the parameters of R_p .

Usage

```
\code{res <- setPortfolioParam(strPMNTS,w)}
\code{res <- setPortfolioParam(strPMNTS,w, FALSE)}
```

Arguments

strPMNTS	Structure of parameters for the n-dimensional NTS distribution. strPMNTS\$ndim : dimension strPMNTS\$mu : μ mean vector (column vector) of the input data. strPMNTS\$sigma : σ standard deviation vector (column vector) of the input data. strPMNTS\$alpha : α of the std NTS distribution (X). strPMNTS\$theta : θ of the std NTS distribution (X). strPMNTS\$beta : β vector (column vector) of the std NTS distribution (X). res\$Rho : ρ matrix (Correlation) of the std NTS distribution (X). res\$Sigma : Covariance Σ matrix of return data r .
----------	--

w Capital allocation weight vector.

stdform If **stdform** is FALSE, then the return parameter has the following representation
 $R_p = \langle w, r \rangle = \mu + \text{diag}(\sigma)X$,
 where
 X follows $\text{stdNTS}_1(\alpha, \theta, \beta, 1)$.
 If **stdform** is TRUE, then the return parameter has the following representation
 $R_p = \langle w, r \rangle$ follows $\text{stdNTS}_1(\alpha, \theta, \beta, \gamma, \mu)$

Value

The weighted sum follows 1-dimensional NTS.

$$R_p = \langle w, r \rangle = \mu + \text{diag}(\sigma)X,$$

where

X follows $\text{stdNTS}_1(\alpha, \theta, \beta, 1)$.

Hence we obtain

res\$mu : μ mean of R_p .

res\$sigma : σ standard deviation of R_p .

res\$alpha : α of X .

res\$theta : θ of X .

res\$beta : β of X .

References

Proposition 2.1 of Kim, Y. S. (2020) Portfolio Optimization on the Dispersion Risk and the Asymmetric Tail Risk <https://arxiv.org/pdf/2007.13972.pdf>

Examples

```
strPMNTS <- list(ndim = 2,
  mu = c( 9.876552e-05, 4.747343e-04 ),
  sigma = c( 0.01620588, 0.02309643 ),
  alpha = 0.1888129 ,
  theta = 0.523042,
  beta = c( -0.04632938, 0.04063555 ),
  Rho = matrix( data = c(1.0, 0.469883,
    0.469883, 1.0),
    nrow = 2, ncol = 2)
  CovMtx = matrix( data = c(0.0002626304, 0.0001740779,
    0.0001740779, 0.0005334452),
    nrow = 2, ncol = 2)
)
w <- c(0.3, 0.7)
res <- getPortNTSPParam(strPMNTS,w)
```

importantSampling	<i>importantSampling</i>
-------------------	--------------------------

Description

importantSampling do the important sampling for the TS Subordinator.

Usage

```
importantSampling(alpha, theta)
```

ipnts	<i>ipnts</i>
-------	--------------

Description

ipnts calculates inverse cdf of the NTS distribution with parameters $(\alpha, \theta, \beta, \gamma, \mu)$. If only three parameters are given, it calculates inverse cdf of the standard NTS distribution with parameter (α, θ, β) .

Usage

```
ipnts(u, ntsparam, maxmin = c(-10, 10), du = 0.01)
```

Arguments

u	Real value between 0 and 1
ntsparam	A vector of the NTS parameters $(\alpha, \theta, \beta, \gamma, \mu)$. A vector of the standard NTS parameters (α, θ, β) .

Value

Inverse cdf of the NTS distribution. It is the same as qnts function.

References

Kim, Y. S. (2020) Portfolio Optimization on the Dispersion Risk and the Asymmetric Tail Risk
<https://arxiv.org/pdf/2007.13972.pdf>

Examples

```
alpha <- 1.2
theta <- 1
beta <- -0.2
ntsparam <- c(alpha, theta, beta)
u <- seq(from = 0.01, to = 0.99, length.out = 99)
q <- ipnts(u, ntsparam)
plot(u, q, type = 'l')

alpha <- 1.2
theta <- 1
```

```

beta <- -0.2
gamma <- 0.3
mu <- 0.1
ntsparam <- c(alpha, theta, beta, gamma, mu)
u <- seq(from = 0.01, to = 0.99, length.out = 99)
q <- ipnts(u, ntsparam)
plot(x,q,type = 'l')

#Annual based parameters
alpha <- 1.2
theta <- 1
beta <- -0.2
gamma <- 0.3
mu <- 0.1
#scaling annual parameters to one day
dt <- 1/250 #one day
ntsparam <- c(alpha, theta, beta, gamma, mu, dt)
u <- seq(from = 0.01, to = 0.99, length.out = 99)
q <- ipnts(u, ntsparam)
plot(x,q,type = 'l')

```

mctCVaRmnts

mctCVaRmnts

Description

Calculate the marginal contribution to CVaR for the multivariate NTS market model: the random vector r is

$$r = \mu + \text{diag}(\sigma)X$$

where

X follows $\text{stdNTS}_N(\alpha, \theta, \beta, \Sigma)$

Usage

```
\code{mctCVaRmnts(eta, n, w, st)}
```

Arguments

eta	Significant level of CVaR.
n	The target stock to calculate the mctCVaR
w	The capital allocation rate vector for the current portfolio
st	Structure of parameters for the N-dimensional NTS distribution. $\text{st}\$ndim$: Dimension of the model. Here $\text{st}\$ndim=N$. $\text{st}\$\mu$: μ mean vector (column vector) of the input data. $\text{st}\$\sigma$: σ standard deviation vector (column vector) of the input data. $\text{st}\$\alpha$: α of the std NTS distribution (X). $\text{st}\$\theta$: θ of the std NTS distribution (X). $\text{st}\$\beta$: β vector (column vector) of the std NTS distribution (X).

st\$Rho : ρ matrix of the std NTS distribution (X), which is correlation matrix of epsilon.

st\$CovMtx : Covariance matrix of return data r .

References

Kim, Y. S. (2020) Portfolio Optimization on the Dispersion Risk and the Asymmetric Tail Risk
<https://arxiv.org/pdf/2007.13972.pdf>

Examples

```
library(functional)
library(nloptr)
library(pracma)
library(spatstat)
library(Matrix)
library(quantmod)
library(mvtnorm)

#Fix alpha and theta.
#Estimate alpha and theta from DJIA and use those parameter for IBM, INTL parameter fit.
getSymbols("^DJIA", src="yahoo", from = "2020-8-25", to = "2020-08-31")
prDJ <- as.numeric(DJIA$DJIA.Adjusted)
ret <- diff(log(prDJ))
ntsparam <- fitnts(ret)
getSymbols("IBM", src="yahoo", from = "2016-1-1", to = "2020-08-31")
pr1 <- as.numeric(IBM$IBM.Adjusted)
getSymbols("INTL", src="yahoo", from = "2016-1-1", to = "2020-08-31")
pr2 <- as.numeric(INTL$INTL.Adjusted)

returndata <- matrix(data = c(diff(log(pr1)), diff(log(pr2))),
                     ncol = 2, nrow = (length(pr1)-1))
st <- fitmnts( returndata = returndata,
              n = 2,
              alphaNtheta = c(ntsparam["alpha"], ntsparam["theta"]) )
w <- c(0.3, 0.7)
eta <- 0.01

mctVaRmnts(eta, 1, w, st) #MCT-VaR for IBM
mctVaRmnts(eta, 2, w, st) #MCT-VaR for INTL

mctCVaRmnts(eta, 1, w, st) #MCT-CVaR for IBM
mctCVaRmnts(eta, 2, w, st) #MCT-CVaR for INTL
```

mctCVaRnts

mctCVaRnts

Description

Calculate the marginal contribution to CVaR for the multivariate NTS market model. Developer's version.

Usage

```
mctCVaRnts(
  eta,
  n,
  w,
  covMtx,
  alpha,
  theta,
  betaArray,
  muArray,
  CVaR = NULL,
  dCVaR = NULL
)
```

mctStdDev	<i>mctStdDev</i>
-----------	------------------

Description

Morginal contribution to Risk for Standard Deviation.

Usage

```
mctStdDev(n, w, covMtx)
```

Arguments

n	The targer stock to calculate the mctCVaR
w	The capital allocation rate vector for the current portfolio
CovMtx	Covariance matrix of return data.

mctVaRmnts	<i>mctVaRmnts</i>
------------	-------------------

Description

Calculate the marginal contribution to VaR for the multivariate NTS market model: the random vector r is

$$r = \mu + \text{diag}(\sigma)X$$

where

X follows $\text{stdNTS}_N(\alpha, \theta, \beta, \Sigma)$

Usage

```
\code{mctVaRmnts(eta, n, w, st)}
```

Arguments

eta	Significant level of CVaR.
n	The target stock to calculate the mctCVaR
w	The capital allocation rate vector for the current portfolio
st	Structure of parameters for the N-dimensional NTS distribution. $st\$ndim$: Dimension of the model. Here $st\$ndim=N$. $st\$mu$: μ mean vector (column vector) of the input data. $st\$sigma$: σ standard deviation vector (column vector) of the input data. $st\$alpha$: α of the std NTS distribution (X). $st\$theta$: θ of the std NTS distribution (X). $st\$beta$: β vector (column vector) of the std NTS distribution (X). $st\$Rho$: ρ matrix of the std NTS distribution (X), which is correlation matrix of epsilon. $st\$CovMtx$: Covariance matrix of return data r .

References

Kim, Y. S. (2020) Portfolio Optimization on the Dispersion Risk and the Asymmetric Tail Risk
<https://arxiv.org/pdf/2007.13972.pdf>

Examples

```
library(functional)
library(nloptr)
library(pracma)
library(spatstat)
library(Matrix)
library(quantmod)
library(mvtnorm)

#Fix alpha and theta.
#Estimate alpha and theta from DJIA and use those parameter for IBM, INTL parameter fit.
getSymbols("^DJI", src="yahoo", from = "2020-8-25", to = "2020-08-31")
prDJ <- as.numeric(DJI$DJI.Adjusted)
ret <- diff(log(prDJ))
ntsparm <- fitnts(ret)
getSymbols("IBM", src="yahoo", from = "2016-1-1", to = "2020-08-31")
pr1 <- as.numeric(IBM$IBM.Adjusted)
getSymbols("INTL", src="yahoo", from = "2016-1-1", to = "2020-08-31")
pr2 <- as.numeric(INTL$INTL.Adjusted)

returndata <- matrix(data = c(diff(log(pr1)),diff(log(pr2))),
                     ncol = 2, nrow = (length(pr1)-1))
st <- fitmnts( returndata = returndata,
              n = 2,
              alphaNtheta = c(ntsparm["alpha"], ntsparm["theta"]) )
w <- c(0.3, 0.7)
eta <- 0.01

mctVaRmnts(eta, 1, w, st) #MCT-VaR for IBM
mctVaRmnts(eta, 2, w, st) #MCT-VaR for INTL

mctCVaRmnts(eta, 1, w, st) #MCT-CVaR for IBM
```

```
mctCVaRmnts(eta, 2, w, st) #MCT-CVaR for INTL
```

mctVaRnts	<i>mctVaRnts</i>
-----------	------------------

Description

Calculate the marginal contribution to VaR for the multivariate NTS market model. Developer's version.

Usage

```
mctVaRnts(
  eta,
  n,
  w,
  covMtx,
  alpha,
  theta,
  betaArray,
  muArray,
  icdf = NULL,
  dicdf = NULL
)
```

moments_NTS	<i>moments_NTS</i>
-------------	--------------------

Description

moments_NTS calculates mean, variance, skewness, and excess kurtosis of the NTS distribution with parameters $(\alpha, \theta, \beta, \gamma, \mu)$.

Usage

```
moments_NTS(param)
```

Arguments

param A vector of the NTS parameters $(\alpha, \theta, \beta, \gamma, \mu)$.

Value

First 4 moments (Mean, Variance, Skewness, Excess Kurtosis) of NTS distribution. The mean is always the same as the parameter μ .

References

Kim, Y.S, K-H Roh, R. Douady (2020) Tempered Stable Processes with Time Varying Exponential Tails <https://arxiv.org/pdf/2006.07669.pdf>

Examples

```
alpha <- 1.2
theta <- 1
beta <- -0.2
gamma <- 0.3
mu <- 0.1
ntsparam <- c(alpha, theta, beta, gamma, mu)
moments_NTS(param = ntsparam)
```

moments_stdNTS	<i>moments_stdNTS</i>
----------------	-----------------------

Description

moments_stdNTS calculates mean, variance, skewness, and excess kurtosis of the standard NTS distribution with parameters (α, θ, β) .

Usage

```
moments_stdNTS(param)
```

Arguments

param A vector of the standard NTS parameters (α, θ, β) .

Value

First 4 moments (Mean, Variance, Skewness, Excess Kurtosis) of NTS distribution. Of course, the mean and variance are always 0 and 1, respectively.

References

Kim, Y.S, K-H Roh, R. Douady (2020) Tempered Stable Processes with Time Varying Exponential Tails <https://arxiv.org/pdf/2006.07669.pdf>

Examples

```
alpha <- 1.2
theta <- 1
beta <- -0.2
ntsparam <- c(alpha, theta, beta)
moments_stdNTS(param = ntsparam)
```

pmarginalmnts	<i>pmarginalmnts</i>
---------------	----------------------

Description

pmarginalmnts calculates the marginal cdf of the n -th element of the multivariate NTS distributed random variable.

Usage

```
pmarginalmnts(x, n, st)
```

Arguments

st	Structure of parameters for the n-dimensional NTS distribution.
----	---

pmnts	<i>pmnts</i>
-------	--------------

Description

pmnts calculates the cdf values of the multivariate NTS distribution: $F(x_1, \dots, x_n) = P(x_n < R_1, \dots, x_n < R_n)$. The multivariate NTS random vector $R = (R_1, \dots, R_n)$ is defined $R = \mu + \text{diag}(\sigma)X$, where X follows $\text{stdNTS}_n(\alpha, \theta, \beta, \Sigma)$

Usage

```
pmnts(x, st, subTS = NULL)
```

Arguments

x	array of the (x_1, \dots, x_n)
st	Structure of parameters for the n-dimensional NTS distribution. st\$ndim : dimension st\$mu : μ mean vector (column vector) of the input data. st\$sigma : σ standard deviation vector (column vector) of the input data. st\$alpha : α of the std NTS distribution (X). st\$theta : θ of the std NTS distribution (X). st\$beta : β vector (column vector) of the std NTS distribution (X). st\$Rho : ρ matrix of the std NTS distribution (X).
numofsample	number of samples.

Value

Simulated NTS random vectors

References

Kim, Y. S. (2020) Portfolio Optimization on the Dispersion Risk and the Asymmetric Tail Risk
<https://arxiv.org/pdf/2007.13972.pdf>

Examples

```
library(mvtnorm)
strPMNTS <- list(ndim = 2,
  mu = c( 0.5, -1.5 ),
  sigma = c( 2, 3 ),
  alpha = 0.1,
  theta = 3,
  beta = c( 0.1, -0.3 ),
  Rho = matrix( data = c(1.0, 0.75, 0.75, 1.0),
    nrow = 2, ncol = 2)
)
pmnts(c(0.6, -1.0), st = strPMNTS)

strPMNTS <- list(ndim = 2,
  mu = c( 0, 0, 0 ),
  sigma = c( 1, 1, 1 ),
  alpha = 0.1,
  theta = 3,
  beta = c( 0.1, -0.3, 0 ),
  Rho = matrix(
    data = c(1.0, 0.75, 0.1, 0.75, 1.0, 0.2, 0.1, 0.2, 1.0),
    nrow = 3, ncol = 3)
)
pmnts(c(0,0,0), st = strPMNTS)
dmnts(c(0,0,0), st = strPMNTS)
```

pnts	<i>pnts</i>
------	-------------

Description

pnts calculates cdf of the NTS distribution with parameters $(\alpha, \theta, \beta, \gamma, \mu)$. If only three parameters are given, it calculates cdf of the standard NTS distribution with parameter (α, θ, β) . If a time parameter value is given, it calculates cdf of the process $F(x) = P((X(t+s) - X(s)) < x)$, where X is the NTS process generated by the NTS distribution with parameters $(\alpha, \theta, \beta, \gamma, \mu)$.

Usage

```
pnts(xdata, ntsparm, dz = 2^-8, m = 2^12)
```

Arguments

xdata	An array of x
ntsparm	A vector of the NTS parameters $(\alpha, \theta, \beta, \gamma, \mu)$. For the NTS process case it is a vector of parameters $(\alpha, \theta, \beta, \gamma, \mu, t)$. A vector of the standard NTS parameters (α, θ, β) .

Value

Cumulative probability of the NTS distribution

References

Kim, Y. S. (2020) Portfolio Optimization on the Dispersion Risk and the Asymmetric Tail Risk
<https://arxiv.org/pdf/2007.13972.pdf>

Examples

```
alpha <- 1.2
theta <- 1
beta <- -0.2
ntsparam <- c(alpha, theta, beta)
x <- seq(from = -6, to = 6, length.out = 101)
p <- pnts(x, ntsparam)
plot(x,p,type = 'l')

alpha <- 1.2
theta <- 1
beta <- -0.2
gamma <- 0.3
mu <- 0.1
ntsparam <- c(alpha, theta, beta, gamma, mu)
x <- seq(from = -2, to = 2, by = 0.01)
p <- pnts(x, ntsparam)
plot(x,p,type = 'l')

#Annual based parameters
alpha <- 1.2
theta <- 1
beta <- -0.2
gamma <- 0.3
mu <- 0.1
#scaling annual parameters to one day
dt <- 1/250 #one day
ntsparam <- c(alpha, theta, beta, gamma, mu, dt)
x <- seq(from = -0.02, to = 0.02, length.out = 101)
p <- pnts(x, ntsparam)
plot(x,p,type = 'l')
```

portfolioCVaRmnts

portfolioCVaRmnts

Description

Calculate portfolio conditional value at risk (expected shortfall) on the NTS market model

Usage

```
portfolioCVaRmnts(strPMNTS, w, eta)
```

Arguments

strPMNTS	Structure of parameters for the n-dimensional NTS distribution. strPMNTS\$ndim : dimension strPMNTS\$mu : μ mean vector (column vector) of the input data. strPMNTS\$sigma : σ standard deviation vector (column vector) of the input data. strPMNTS\$alpha : α of the std NTS distribution (X). strPMNTS\$theta : θ of the std NTS distribution (X). strPMNTS\$beta : β vector (column vector) of the std NTS distribution (X). res\$Rho : ρ matrix (Correlation) of the std NTS distribution (X). res\$Sigma : Covariance Σ matrix of return data r .
w	Capital allocation weight vector.
eta	significantlt level

Value

portfolio value at risk on the NTS market model

portfolioVaRmnts

portfolioVaRmnts

Description

Calculate portfolio value at risk on the NTS market model

Usage

```
portfolioVaRmnts(strPMNTS, w, eta)
```

Arguments

strPMNTS	Structure of parameters for the n-dimensional NTS distribution. strPMNTS\$ndim : dimension strPMNTS\$mu : μ mean vector (column vector) of the input data. strPMNTS\$sigma : σ standard deviation vector (column vector) of the input data. strPMNTS\$alpha : α of the std NTS distribution (X). strPMNTS\$theta : θ of the std NTS distribution (X). strPMNTS\$beta : β vector (column vector) of the std NTS distribution (X). res\$Rho : ρ matrix (Correlation) of the std NTS distribution (X). res\$Sigma : Covariance Σ matrix of return data r .
w	Capital allocation weight vector.
eta	significantlt level

Value

portfolio value at risk on the NTS market model

qmarginalmnts	<i>qmarginalmnts</i>
---------------	----------------------

Description

qmarginalmnts calculates the quantile value of the n -th element of the multivariate NTS distributed random variable.

Usage

```
qmarginalmnts(u, n, st)
```

Arguments

st	Structure of parameters for the n-dimensional NTS distribution.
----	---

qnts	<i>qnts</i>
------	-------------

Description

qnts calculates quantile of the NTS distribution with parameters $(\alpha, \theta, \beta, \gamma, \mu)$. If only three parameters are given, it calculates quantile of the standard NTS distribution with parameter (α, θ, β) . If a time parameter value is given, it calculates quantile of NTS process. That is it finds x such that $u = P((X(t+s) - X(s)) < x)$, where X is the NTS process generated by the NTS distribution with parameters $(\alpha, \theta, \beta, \gamma, \mu)$.

Usage

```
qnts(u, ntsparm)
```

Arguments

u	vector of probabilities.
ntsparm	A vector of the NTS parameters $(\alpha, \theta, \beta, \gamma, \mu)$. For the NTS process case it is a vector of parameters $(\alpha, \theta, \beta, \gamma, \mu, t)$. A vector of standard NTS parameters (α, θ, β) .

Value

The quantile function of the NTS distribution

Examples

```
alpha <- 1.2
theta <- 1
beta <- -0.2
ntsparam <- c(alpha, theta, beta)
u <- c(0.01,0.05,0.25,0.5, 0.75, 0.95, 0.99)
q <- qnts(u, ntsparam)

alpha <- 1.2
theta <- 1
beta <- -0.2
gamma <- 0.3
mu <- 0.1
ntsparam <- c(alpha, theta, beta, gamma, mu)
u <- c(0.01,0.05,0.25,0.5, 0.75, 0.95, 0.99)
q <- qnts(u, ntsparam)

#Annual based parameters
alpha <- 1.2
theta <- 1
beta <- -0.2
gamma <- 0.3
mu <- 0.1
#scaling annual parameters to one day
dt <- 1/250 #one day
ntsparam <- c(alpha, theta, beta, gamma, mu, dt)
u <- c(0.01,0.05,0.25,0.5, 0.75, 0.95, 0.99)
q <- qnts(u, ntsparam)
```

rmnts

rmnts

Description

rmnts generates random vector following the n dimensional NTS distribution.

$$r = \mu + \text{diag}(\sigma)X,$$

where

X follows $\text{stdNTS}_n(\alpha, \theta, \beta, \Sigma)$

Usage

```
rmnts(strPMNTS, numofsample, rW = NaN, rTau = NaN)
```

Arguments

strPMNTS	Structure of parameters for the n-dimensional NTS distribution. strPMNTS\$ndim : dimension strPMNTS\$mu : μ mean vector (column vector) of the input data. strPMNTS\$sigma : σ standard deviation vector (column vector) of the input data. strPMNTS\$alpha : α of the std NTS distribution (X).
----------	--

`strPMNTS$theta` : θ of the std NTS distribution (X).
`strPMNTS$beta` : β vector (column vector) of the std NTS distribution (X).
`strPMNTS$Rho` : ρ matrix of the std NTS distribution (X).
`numofsample` number of samples.

Value

Simulated NTS random vectors

References

Kim, Y. S. (2020) Portfolio Optimization on the Dispersion Risk and the Asymmetric Tail Risk
<https://arxiv.org/pdf/2007.13972.pdf>

Examples

```

strPMNTS <- list(ndim = 2,
  mu = c( 0.00011, 0.00048 ),
  sigma = c( 0.0162, 0.0231 ),
  alpha = 1.23,
  theta = 3.607,
  beta = c( -0.1209, 0.0905 ),
  Rho = matrix( data = c(1.0, 0.55, 0.55, 1.0), nrow = 2, ncol = 2)
)
gensim <- rmnts( strPMNTS, 100 )
plot(gensim)

```

<code>rnts</code>	<i>rnts</i>
-------------------	-------------

Description

`rnts` generates random numbers following NTS distribution with parameters $(\alpha, \theta, \beta, \gamma, \mu)$. If only three parameters are given, it generates random numbers of standard NTS distribution with parameter (α, θ, β) . If a time parameter value is given, it generates random numbers of increments of NTS process for time interval t .

Usage

```
rnts(n, ntsparam)
```

Arguments

`n` number of random numbers to be generated.
`ntsparam` A vector of NTS parameters $(\alpha, \theta, \beta, \gamma, \mu)$. For NTS process case it is a vector of parameters $(\alpha, \theta, \beta, \gamma, \mu, t)$. A vector of standard NTS parameters (α, θ, β) .

Value

NTS random numbers

References

Kim, Y. S. (2020) Portfolio Optimization on the Dispersion Risk and the Asymmetric Tail Risk
<https://arxiv.org/pdf/2007.13972.pdf>

Examples

```
alpha <- 1.2
theta <- 1
beta <- -0.2
ntsparam <- c(alpha, theta, beta)
r <- rnts(100, ntsparam) #generate 100 NTS random numbers
plot(r)

alpha <- 1.2
theta <- 1
beta <- -0.2
gamma <- 0.3
mu <- 0.1
ntsparam <- c(alpha, theta, beta, gamma, mu)
r <- rnts(100, ntsparam) #generate 100 NTS random numbers
plot(r)

#Annual based parameters
alpha <- 1.2
theta <- 1
beta <- -0.2
gamma <- 0.3
mu <- 0.1
#scaling annual parameters to one day
dt <- 1/250 #one day
ntsparam <- c(alpha, theta, beta, gamma, mu, dt)
r <- rnts(100, ntsparam) #generate 100 NTS random numbers
plot(r)
```

setPortfolioParam	<i>setPortfolioParam</i>
-------------------	--------------------------

Description

Please use getPortNTSParam instead of setPortfolioParam.

Portfolio return with capital allocation weight is $R_p = \langle w, r \rangle$, which is a weighted sum of elements in the N-dimensional NTS random vector. R_p becomes an 1-dimensional NTS random variable. setPortfolioParam find the parameters of R_p .

Usage

```
\code{res <- setPortfolioParam(strPMNTS,w)}
```

Arguments

strPMNTS Structure of parameters for the n-dimensional NTS distribution.
 strPMNTS\$ndim : dimension
 strPMNTS\$mu : μ mean vector (column vector) of the input data.
 strPMNTS\$sigma : σ standard deviation vector (column vector) of the input data.
 strPMNTS\$alpha : α of the std NTS distribution (X).
 strPMNTS\$theta : θ of the std NTS distribution (X).
 strPMNTS\$beta : β vector (column vector) of the std NTS distribution (X).
 strPMNTS\$Rho : Σ matrix of the std NTS distribution (X).
 w Capital allocation weight vector.

Value

The weighted sum follows 1-dimensional NTS.

$$R_p = \langle w, r \rangle = \mu + \text{diag}(\sigma)X,$$

where

X follows $\text{stdNTS}_1(\alpha, \theta, \beta, 1)$.

Hence we obtain

res\$mu : μ mean of R_p .

res\$sigma : σ standard deviation of R_p .

res\$alpha : α of X .

res\$theta : θ of X .

res\$beta : β of X .

References

Kim, Y. S. (2020) Portfolio Optimization on the Dispersion Risk and the Asymmetric Tail Risk
<https://arxiv.org/pdf/2007.13972.pdf>

Examples

```
strPMNTS <- list(ndim = 2,
  mu = c( 9.876552e-05, 4.747343e-04 ),
  sigma = c( 0.01620588, 0.02309643 ),
  alpha = 0.1888129 ,
  theta = 0.523042,
  beta = c( -0.04632938, 0.04063555 ),
  Rho = matrix( data = c(1.0, 0.469883,
    0.469883, 1.0),
    nrow = 2, ncol = 2)
  CovMtx = matrix( data = c(0.0002626304, 0.0001740779,
    0.0001740779, 0.0005334452),
    nrow = 2, ncol = 2)
)
w <- c(0.3, 0.7)
res <- setPortfolioParam(strPMNTS,w)
```


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