Package ‘CreditMetrics’

February 19, 2015

Version 0.0-2
Date 2007-01-02
Title Functions for calculating the CreditMetrics risk model
Author Andreas Wittmann <andreas_wittmann@gmx.de>
Maintainer Andreas Wittmann <andreas_wittmann@gmx.de>
Depends R (>= 2.2.0)
Description A set of functions for computing the CreditMetrics risk model
License Unlimited
NeedsCompilation no
Repository CRAN
Date/Publication 2009-02-01 13:46:28

R topics documented:

  cm.cs ................................................................. 2
  cm.CVaR ............................................................ 3
  cm.gain .............................................................. 5
  cm.hist ............................................................. 6
  cm.matrix ........................................................... 8
  cm.portfolio ......................................................... 9
  cm.quantile ........................................................ 10
  cm.ref ............................................................... 12
  cm.rnorm ........................................................... 13
  cm.rnorm.cor ....................................................... 14
  cm.state ........................................................... 15
  cm.val .............................................................. 17

Index 19
Description

`cm.cs` computes the credit spreads for each rating of a one year empirical migration matrix. The failure limit is the quantile of the failure probability.

Usage

```
cm.cs(M, lgd)
```

Arguments

- `M`: one year empirical migration matrix, where the last row gives the default class.
- `lgd`: loss given default

Details

This function computes the credit spreads for each rating of a given one year empirical migration matrix with a default class in the last row. The credit spread is the risk premium demanded by the market.

According migration the nominal is differently calculated

\[ V_0 = V_t e^{-(r_t + CS_t)t} \]

where \( t \) is the time. Under a riskless probability measure the value of a credit position at time \( t \) is computed as

\[ V_0 = E[V_t] e^{-r_t t} \]

The default event is bernoulli distributed, so the expected value is

\[ E[V_t] = V_t (1 - PD_t) + V_t (1 - LGD) PD_t \]

By using the above equations and following transformation, we get the formula for the credit spread

\[ CS_t = \frac{-\ln(1 - LGD PD_t)}{t} \]

This function computes the credit spread for \( t = 1 \), this is the credit spread for one year is calculated.

Value

Return value is the credit spread for time \( t = 1 \) of each rating in the migration matrix.

Author(s)

Andreas Wittmann <andreas\_wittmann@gmx.de>
cm.CVaR

References

See Also

cm.matrix

Examples

lgd <- 0.45

# one year empirical migration matrix from standard&poors website
M <- matrix(c(90.81, 0.33, 0.68, 0.06, 0.08, 0.02, 0.01, 0.01,
              0.70, 90.65, 7.79, 0.64, 0.06, 0.13, 0.02, 0.01,
              0.09, 2.27, 91.05, 5.52, 0.74, 0.26, 0.01, 0.06,
              0.02, 0.33, 5.95, 85.93, 5.30, 1.17, 1.12, 0.18,
              0.03, 0.14, 0.67, 7.73, 80.53, 8.84, 1.00, 1.06,
              0.01, 0.11, 0.24, 0.43, 6.48, 83.46, 4.07, 5.20,
              0.21, 0, 0.22, 1.30, 2.38, 11.24, 64.86, 19.79,
              0, 0, 0, 0, 0, 0, 0, 100
           )/100, 8, 8, dimnames = list(rc, rc), byrow = TRUE)

cm.cs(M, lgd)

cm.CVaR

Computation of the Credit Value at Risk (CVaR)

Description
cm.CVaR computes the credit value at risk for the simulated profits and losses.

Usage

cm.CVaR(M, lgd, ead, N, n, r, rho, alpha, rating)

Arguments

M
  one year empirical migration matrix, where the last row gives the default class.
lgd
  loss given default
ead
  exposure at default
N
  number of companies
n
  number of simulated random numbers
r
  riskless interest rate
rho
  correlation matrix
alpha
  confidence level
rating
  rating of companies
Details

With function \texttt{cm.gain} one gets the profit and loss distribution of the credit positions. By building the quantile at confidence level $\alpha$ the credit value at risk can be reached.

Value

Return value is the credit value at risk at confidence level $\alpha$.

Author(s)

Andreas Wittmann \texttt{<andreas\_wittmann@gmx.de>}

References


See Also

\texttt{cm.matrix, cm.gain, quantile}

Examples

```r
N <- 3
n <- 50000
r <- 0.03
ead <- c(4000000, 1000000, 10000000)
lgd <- 0.45
rating <- c("BBB", "AA", "B")
firmnames <- c("firm 1", "firm 2", "firm 3")
alpha <- 0.99

# correlation matrix
rho <- matrix(c(1, 0.4, 0.6,
               0.4, 1, 0.5,
               0.6, 0.5, 1), 3, 3, dimnames = list(firmnames, firmnames),
             byrow = TRUE)

# one year empirical migration matrix from standard\&poors website
M <- matrix(c(90.81, 8.33, 0.68, 0.06, 0.08, 0.02, 0.01, 0.01,
              0.70, 90.65, 7.79, 0.64, 0.06, 0.13, 0.02, 0.01,
              0.09, 2.27, 91.05, 5.52, 0.74, 0.26, 0.01, 0.06,
              0.02, 0.33, 5.95, 85.93, 5.30, 1.17, 1.12, 0.18,
              0.03, 0.14, 0.67, 7.73, 80.53, 8.84, 1.00, 1.00,
              0.01, 0.11, 0.24, 0.43, 6.48, 83.46, 4.07, 5.20,
              0.21, 0, 0.22, 1.30, 2.38, 11.24, 64.86, 19.79,
              0, 0, 0, 0, 0, 0, 0, 0), 100, 8, 8, dimnames = list(rc, rc), byrow = TRUE)

cm.CVaR(M, lgd, ead, N, n, r, rho, alpha, rating)
```
**cm.gain**

*Computation of simulated profits and losses*

**Description**

`cm.gain` computes profits or losses, this is done by building the difference from the reference value and the simulated portfolio values of the credit positions.

**Usage**

```r
cm.gain(M, lgd, ead, N, n, r, rho, rating)
```

**Arguments**

- `M`: one year empirical migration matrix, where the last row gives the default class.
- `lgd`: loss given default
- `ead`: exposure at default
- `N`: number of companies
- `n`: number of simulated random numbers
- `r`: riskless interest rate
- `rho`: correlation matrix
- `rating`: rating of companies

**Details**

This function uses `cm.portfolio` and `cm.ref`. By building the difference of these functions, one gets the profits, if the difference is positive, or the losses, if the difference is negative.

**Value**

This functions returns simulated profits or losses.

**Author(s)**

Andreas Wittmann <andreas\_wittmann@gmx.de>

**References**


**See Also**

`cm.matrix`, `cm.ref`, `cm.portfolio`
Examples

```r
N <- 3
n <- 50000
r <- 0.03
ead <- c(4000000, 1000000, 10000000)
lgd <- 0.45
rating <- c("BBB", "AA", "B")
firmnames <- c("firm 1", "firm 2", "firm 3")

# correlation matrix
rho <- matrix(c(1, 0.4, 0.6,
               0.4, 1, 0.5,
               0.6, 0.5, 1), 3, 3, dimnames = list(firmnames, firmnames),
byrow = TRUE)

# one year empirical migration matrix from standard&poors website
M <- matrix(c(90.81, 8.33, 0.68, 0.06, 0.08, 0.02, 0.01, 0.01,
              0.70, 90.65, 7.79, 0.64, 0.06, 0.13, 0.02, 0.01,
              0.09, 2.27, 91.05, 5.52, 0.74, 0.26, 0.01, 0.06,
              0.02, 0.33, 5.95, 85.93, 5.30, 1.17, 1.12, 0.18,
              0.03, 0.14, 0.67, 7.73, 80.53, 0.84, 1.00, 1.06,
              0.01, 0.11, 0.24, 0.43, 6.48, 83.46, 4.07, 5.20,
              0.21, 0, 0.22, 1.30, 2.38, 11.24, 64.86, 19.79,
              0, 0, 0, 0, 0, 0, 0, 0), 8, 8, dimnames = list(rc, rc), byrow = TRUE)

cm.gain(M, lgd, ead, N, n, r, rho, rating)
```

---

### cm.hist

**Profit / Loss Distribution histogram**

**Description**

`cm.hist` plots a histogram for the simulated profit / loss distribution.

**Usage**

```r
cm.hist(M, lgd, ead, N, n, r, rho, rating,
col = "steelblue4", main = "Profit / Loss Distribution",
xlab = "profit / loss", ylab = "frequency")
```

**Arguments**

- `M` one year empirical migration matrix, where the last row gives the default class.
- `lgd` loss given default
- `ead` exposure at default
- `N` number of companies
cm.hist

- `n`: number of simulated random numbers
- `r`: riskless interest rate
- `rho`: correlation matrix
- `rating`: rating of companies
- `col`: a colour to be used to fill the bars, the default is 'steelblue4'.
- `main`: an overall title for the plot, the default is 'Profit / Loss Distribution'.
- `xlab`: a title for the x axis, the default is 'profit / loss'.
- `ylab`: a title for the y axis, the default is 'frequency'.

**Details**

This function gives a histogram of the simulated profits and losses. The 'breaks' of the histogram are obtained through the minimum and the maximum of the simulated values and the number of simulated random numbers. This is

\[
\text{breaks} = (\text{max}(\text{SimGV}) - \text{min}(\text{SimGV}))/2n
\]

**Value**

A histogram of the the simulated profit and loss distribution.

**Author(s)**

Andreas Wittmann <andreas\_wittmann@gmx.de>

**References**


**See Also**

`cm.matrix, cm.gain, hist`

**Examples**

```r
N <- 3
n <- 50000
r <- 0.03
ead <- c(4000000, 1000000, 10000000)
lgd <- 0.45
ingrating <- c("BBB", "AA", "B")
firmnames <- c("firm 1", "firm 2", "firm 3")

# correlation matrix
rho <- matrix(c(1, 0.4, 0.6,
                0.4, 1, 0.5,
                0.6, 0.5, 1), 3, 3, dimnames = list(firmnames, firmnames),
                byrow = TRUE)
```
# one year empirical migration matrix from standard&poors website
M <- matrix(c(90.81, 8.33, 0.68, 0.06, 0.08, 0.02, 0.01, 0.01,
              0.70, 90.65, 7.79, 0.64, 0.06, 0.13, 0.02, 0.01,
              0.09, 2.27, 91.05, 5.52, 0.74, 0.26, 0.01, 0.06,
              0.02, 0.33, 5.95, 85.93, 5.30, 1.17, 1.12, 0.18,
              0.03, 0.14, 0.67, 7.73, 80.53, 8.84, 1.00, 1.06,
              0.01, 0.11, 0.24, 0.43, 6.48, 83.46, 4.07, 5.20,
              0.21, 0, 0.22, 1.30, 2.38, 11.24, 64.86, 19.79,
              0, 0, 0, 0, 0, 0, 0, 100
) /100, 8, 8, dimnames = list(rc, rc), byrow = TRUE)

cm.hist(M, lgd, ead, N, n, r, rho, rating,
       col = "steelblue4", main = "Profit / Loss Distribution",
       xlab = "profit / loss", ylab = "frequency")

cm.matrix

## Testing for migration matrix

### Description

`cm.matrix` tests if the given matrix `M` is a migration matrix. So the dimensions of the migration matrix should be at least 2 times 2 and the row and column dimensions must be equal. Further the values in the migration matrix should be between 0 and 1. And the sum of each row should be 1.

### Usage

```r
cm.matrix(M)
```

### Arguments

- `M`  
  - one year empirical migration matrix, where the last row gives the default class.

### Value

There is no return value if the given migration matrix `M` fulfills the above attributes.

### Author(s)

Andreas Wittmann <andreas\_wittmann@gmx.de>

### References


### See Also

`is.matrix`
Examples

# one year empirical migration matrix from standard&poors website
M <- matrix(c(90.81, 8.33, 0.68, 0.06, 0.08, 0.02, 0.01, 0.01, 0.70, 90.65, 7.79, 0.64, 0.06, 0.13, 0.02, 0.01, 0.09, 2.27, 91.05, 5.52, 0.74, 0.26, 0.01, 0.06, 0.02, 0.33, 5.95, 85.93, 5.30, 1.17, 1.12, 0.18, 0.03, 0.14, 0.67, 7.73, 80.53, 8.84, 1.00, 1.06, 0.01, 0.11, 0.24, 0.43, 6.48, 83.46, 4.07, 5.20, 0.21, 0, 0.22, 1.30, 2.38, 11.24, 64.86, 19.79, 0, 0, 0, 0, 0, 0, 100)/100, 8, 8, dimnames = list(rc, rc), byrow = TRUE)

cm.matrix(M)

cm.portfolio

Computation of simulated portfolio values

Description

cm.portfolio computes simulated portfolio values by using function cm.val.

Usage

``` R
cm.portfolio(M, lgd, ead, N, n, r, rho, rating)
```

Arguments

- `M` one year empirical migration matrix, where the last row gives the default class.
- `lgd` loss given default
- `ead` exposure at default
- `N` number of companies
- `n` number of simulated random numbers
- `r` riskless interest rate
- `rho` correlation matrix
- `rating` rating of companies

Details

The simulated portfolio values are computed by using the function cm.val and summing up each column.

Value

This functions returns the simulated portfolio values for each scenario.
cm.quantile

Computation of migration quantils

Description

cm.quantile computes the empirical migration quantiles for each rating of a one year empirical migration matrix. The failure limit is the quantile of the failure probability.
Usage

cm.quantile(M)

Arguments

M

one year empirical migration matrix, where the last row gives the default class.

Details

This function computes the empirical migration threshold value of a given one year empirical migration matrix with a default class in the last row. So the migration threshold can be computed with the migration probabilities. Migration quantiles have to be computed for each output rating.

The default threshold value $S$ of the standard normal distribution with expectation 0 and standard deviation 1 gives

$$S = N^{-1}(PD)$$

where $N^{-1}$ is the inverse function of the standard normal distribution and PD is the probability of default.

Thus an example for an BBB rated company is

$$S = N^{-1}(PD_{BBB})$$

So for each rating class thresholds can be computed.

Value

Return value is the quantile of each rating in the migration matrix.

Author(s)

Andreas Wittmann <andreas\_wittmann@gmx.de>

References


See Also

cm.matrix, qnorm

Examples

# one year empirical migration matrix from standard&poors website
M <- matrix(c(90.81, 8.33, 0.68, 0.06, 0.08, 0.02, 0.01, 0.01,
    0.70, 90.65, 7.79, 0.64, 0.06, 0.13, 0.02, 0.01,
    0.09, 2.27, 91.05, 5.52, 0.74, 0.26, 0.01, 0.06,
    0.02, 0.33, 5.95, 85.93, 5.30, 1.17, 1.12, 0.18,
    0.03, 0.14, 0.67, 7.73, 80.53, 8.84, 1.00, 1.06,
    0.01, 0.11, 0.24, 0.43, 6.48, 83.46, 4.07, 5.20,
    0.21, 0, 0.22, 1.30, 2.38, 11.24, 64.86, 19.79),
11, 11, byrow = TRUE)
Computation of reference value

Description

`cm.ref` computes the value of a credit in one year for each rating. This is the return value `constVal`. Further the portfolio value at time $t = 1$ is computed, this is `constPV`.

Usage

```r
cm.ref(M, lgd, ead, r, rating)
```

Arguments

- `M`: one year empirical migration matrix, where the last row gives the default class.
- `lgd`: loss given default
- `ead`: exposure at default
- `r`: riskless interest rate
- `rating`: rating of companies

Details

This function computes the value of the credit in one year, this is

$$V_t = EAD_t e^{-(r_t + CS_t) t}$$

where $t = 1$.

Value

A list containing following components:

- `constVal`: credit value in one year
- `constPV`: portfolio of all credit values in one year

Author(s)

Andreas Wittmann <andreas\_wittmann@gmx.de>

References

cm.rnorm

See Also

cm_matrix, cm.cs

Examples

r <- 0.03
ead <- c(4000000, 1000000, 1000000)
rating <- c("BBB", "AA", "B")
lgd <- 0.45

# one year empirical migration matrix from standard&poors website
M <- matrix(c(90.01, 0.33, 0.68, 0.06, 0.08, 0.02, 0.01, 0.01,
              0.90, 90.65, 7.79, 0.64, 0.06, 0.13, 0.02, 0.01,
              0.09, 2.27, 91.05, 5.52, 0.74, 0.26, 0.01, 0.06,
              0.02, 0.33, 5.95, 85.93, 5.30, 1.17, 1.12, 0.18,
              0.03, 0.14, 0.67, 7.73, 80.53, 8.84, 1.00, 1.06,
              0.01, 0.11, 0.24, 0.43, 6.48, 83.46, 4.07, 5.20,
              0.21, 0, 0.22, 1.30, 2.38, 11.24, 64.86, 19.79,
              0, 0, 0, 0, 0, 0, 0, 100 )/100, byrow = TRUE)

cm.ref(M, lgd, ead, r, rating)

---

cm.rnorm

Computation of standard normal distributed random numbers

Description

cm.rnorm simulates standard normal distributed random numbers while using antithetic sampling.

Usage

cm.rnorm(N, n)

Arguments

N number of simulations

n number of simulated random numbers

Details

This function computes standard normal distributed random numbers with antithetic sampling. Here one has a sequence of standard normal distributed random numbers \((X_1, \ldots, X_{n/2})\). Reflected random numbers are computed with

\[ X'_i = (-1)X_i \]

So the sequence \(X'_1, \ldots, X'_{n/2}\) is also standard normal distributed.
Value

The function returns N simulations with n simulated random numbers each.

Author(s)

Andreas Wittmann <andreas\_wittmann@gmx.de>

References


See Also

matrix, rnorm

Examples

```r
N <- 3
n <- 50000
cm.rnorm(N, n)
```

Description

`cm.rnorm.cor` computes correlated standard normal distributed random numbers. This function uses a correlation matrix \( \rho \) and later the cholesky decomposition in order to get correlated random numbers.

Usage

```r
cm.rnorm.cor(N, n, rho)
```

Arguments

- `N` number of simulations
- `n` number of simulated random numbers
- `rho` correlation matrix

Details

This function computes standard normal distributed random numbers, which include the correlation matrix \( \rho \). One has a random matrix \( Y \) which is \( N(0, 1) \) distributed. With the linear transformation \( X = \mu + AY \) one gets \( X \), which is \( N(\mu, AA^T) \) distributed. If \( X \) should have the correlation matrix \( \Sigma \). By using the cholesky decomposition the matrix \( A \) can be computed from \( \Sigma \).
Value

The function returns \( N \) simulations with \( n \) simulated random numbers each, which include the correlation matrix \( \rho \).

Author(s)

Andreas Wittmann <andreas\_wittmann@gmx.de>

References


See Also

eigen, chol, cm.rnorm

Examples

```r
N <- 3
n <- 50000
firmnames <- c("firm 1", "firm 2", "firm 3")

# correlation matrix
rho <- matrix(c( 1L, 0.4, 0.6,
               0.4,  1L, 0.5,
               0.6, 0.5,  1L), 3, 3, dimnames = list(firmnames, firmnames),
             byrow = TRUE)

cm.rnorm.cor(N, n, rho)
```

---

**cm.state**

*Computation of state space*

Description

*cm.state* computes a state space, this is at time \( t = 1 \) the credit positions of all companies for all migrations is calculated. This state space is needed for the later valuation for the credit positions of each scenario.

Usage

```r
cm.state(M, lgd, ead, N, r)
```
Arguments

- \( M \) one year empirical migration matrix, where the last row gives the default class.
- \( \text{lgd} \) loss given default
- \( \text{ead} \) exposure at default
- \( N \) number of companies
- \( r \) riskless interest rate

Details

This function computes the value of the credits of each firm in one year, this is

\[
V_t = EAD_t e^{-(r_t + CS_t)t}
\]

where \( t = 1 \). Also the value for the default class is calculated, that is

\[
V_t = EAD(1 - LGD)
\]

Value

Return value is the matrix \( V \) for time \( t = 1 \) of each rating in the migration matrix including the credit values for all companies. The last column in the matrix \( V \) is the value for the default event of each company.

Author(s)

Andreas Wittmann <andreas\_wittmann@gmx.de>

References


See Also

cm.state, cm.matrix

Examples

```r
N <- 3
r <- 0.03
ead <- c(4000000, 1000000, 10000000)
lgd <- 0.45

# one year empirical migration matrix from standard&poors website
M <- matrix(c(90.81, 8.33, 0.68, 0.06, 0.08, 0.02, 0.01, 0.01,
              0.70, 90.65, 7.79, 0.64, 0.06, 0.13, 0.02, 0.01,
              0.09, 2.27, 91.05, 5.52, 0.74, 0.26, 0.01, 0.06,
              0.02, 0.33, 5.95, 85.93, 5.30, 1.17, 1.12, 0.18,
              0.03, 0.14, 0.67, 7.73, 80.53, 8.84, 1.00, 1.06,
              0.01, 0.11, 0.24, 0.43, 6.48, 83.46, 4.07, 5.20,
              0.01, 0.05, 0.45, 1.23, 12.34, 0.09, 5.67, 3.21), nrow = 5, ncol = 5, byrow = TRUE)
```
cm.val

0.21, 0, 0.22, 1.30, 2.38, 11.24, 64.86, 19.79,
0, 0, 0, 0, 0, 0, 0, 100
) / 100, 8, 8, dimnames = list(rc, rc), byrow = TRUE)

cm.state(M, lgd, ead, N, r)

cm.val Valuation for the credit positions of each scenario

Description

cm.val performs a valuation for the credit positions of each scenario. This is an allocation in rating
classes identification of the credit position values.

Usage

cm.val(M, lgd, ead, N, n, r, rho, rating)

Arguments

- **M**: one year empirical migration matrix, where the last row gives the default class.
- **lgd**: loss given default
- **ead**: exposure at default
- **N**: number of companies
- **n**: number of simulated random numbers
- **r**: riskless interest rate
- **rho**: correlation matrix
- **rating**: rating of companies

Details

According to the value $V_i$, the company is located in an other rating class. This location is performed
with the migration matrix by determining the thresholds. In order to implement a valuation at time
t, the credit spreads must be computed. With these the nominal is risk adjusted calculated. For
a portfolio with many credits correlations are included by simulating correlated company yield
returns. So the simulated ratings for each firm at time $t = 1$ can be computed.

Value

Simulated values of the firms for each rating of each scenario.

Author(s)

Andreas Wittmann <andreas\_wittmann@gmx.de>
References

See Also
   cm.matrix, eigen, cm.state, cm.quantile, cm.rnorm.cor

Examples
   N <- 3
   n <- 50000
   r <- 0.03
   ead <- c(4000000, 1000000, 10000000)
   lgd <- 0.45
   rating <- c("BBB", "AA", "B")
   firmnames <- c("firm 1", "firm 2", "firm 3")
   # correlation matrix
   rho <- matrix(c( 1, 0.4, 0.6,
                   0.4, 1, 0.5,
                   0.6, 0.5, 1), 3, 3, dimnames = list(firmnames, firmnames),
               byrow = TRUE)
   # one year empirical migration matrix from standard&poors website
   M <- matrix(c(90.81, 8.33, 0.68, 0.06, 0.08, 0.02, 0.01, 0.01,
                 0.70, 90.65, 7.79, 0.64, 0.06, 0.13, 0.02, 0.01,
                 0.09, 2.27, 91.05, 5.52, 0.74, 0.26, 0.01, 0.06,
                 0.02, 0.33, 5.95, 85.93, 5.30, 1.17, 1.12, 0.18,
                 0.03, 0.14, 0.67, 7.73, 80.53, 8.84, 1.00, 1.06,
                 0.01, 0.11, 0.24, 0.43, 6.48, 83.46, 4.07, 5.20,
                 0.21, 0, 0.22, 1.30, 2.38, 11.24, 64.86, 19.79,
                 0, 0, 0, 0, 0, 0, 0, 100
               )/100, 8, 8, dimnames = list(rc, rc), byrow = TRUE)
   cm.val(M, lgd, ead, N, n, r, rho, rating)
Index

*Topic models
  cm.cs, 2
  cm.CVaR, 3
  cm.gain, 5
  cm.hist, 6
  cm.matrix, 8
  cm.portfolio, 9
  cm.quantile, 10
  cm.ref, 12
  cm.rnorm, 13
  cm.rnorm.cor, 14
  cm.state, 15
  cm.val, 17

chol, 15
  cm.cs, 2, 13, 16
  cm.CVaR, 3
  cm.gain, 4, 5, 7
  cm.hist, 6
  cm.matrix, 3–5, 7, 8, 10, 11, 13, 16, 18
  cm.portfolio, 5, 9
  cm.quantile, 10, 18
  cm.ref, 5, 12
  cm.rnorm, 13, 15
  cm.rnorm.cor, 14, 18
  cm.state, 15, 18
  cm.val, 10, 17
  colSums, 10

eigen, 15, 18

hist, 7

is.matrix, 8

matrix, 14, 16

qnorm, 11
quantile, 4
rnorm, 14