

# Package ‘decisionSupport’

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**Type** Package

**Title** Quantitative Support of Decision Making under Uncertainty

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**Description** Supporting the quantitative analysis of binary welfare based decision making processes using Monte Carlo simulations. Decision support is given on two levels: (i) The actual decision level is to choose between two alternatives under probabilistic uncertainty. This package calculates the optimal decision based on maximizing expected welfare. (ii) The meta decision level is to allocate resources to reduce the uncertainty in the underlying decision problem, i.e to increase the current information to improve the actual decision making process. This problem is dealt with using the Value of Information Analysis (VIA). The Expected Value of Information (EVI) for arbitrary prospective estimates can be calculated as well as Individual and Clustered Expected Value of Perfect Information (EVPI). The probabilistic calculations are done via Monte Carlo simulations. This Monte Carlo functionality can be used on its own.

**License** GPL-3

**Depends** R (>= 3.1.3)

**Imports** msm (>= 1.5),  
mvtnorm (>= 1.0.2),  
nleqslv (>= 2.6),  
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 'paramposnorm90ci.R'  
 'rposnorm90ci\_numeric.R'  
 'rdistq\_fit.R'  
 'rdist90ci\_exact.R'  
 'paramtnormci.R'  
 'r0\_1norm90ci\_numeric.R'  
 'random\_estimate\_1d.R'  
 'random.R'  
 'estimate.R'  
 'mcSimulation.R'  
 'welfareDecisionAnalysis.R'  
 'eviSimulation.R'  
 'individualEvpiSimulation.R'  
 'estimate\_read\_csv\_old.R'  
 'uncertaintyAnalysis.R'  
 'decisionSupport-package.R'  
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<code>as.data.frame.mcSimulation</code>	<i>Coerce to a Data Frame.</i>
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### Description

Functions to check if an object is a data frame, or coerce it if possible.

### Usage

```
## S3 method for class 'mcSimulation'
as.data.frame(x, row.names = NULL, optional = FALSE,
  ..., stringsAsFactors = default.stringsAsFactors())
```

### Arguments

<code>x</code>	An object of class <code>mcSimulation</code> .
<code>row.names</code>	NULL or a character vector giving the row names for the data frame. Missing values are not allowed.
<code>optional</code>	logical. If TRUE, setting row names and converting column names (to syntactic names: see <a href="#">make.names</a> ) is optional.
<code>...</code>	additional arguments to be passed to or from methods.
<code>stringsAsFactors</code>	logical: should the character vector be converted to a factor?

### See Also

[as.data.frame](#)

---

corMat	<i>Return the Correlation Matrix of x.</i>
--------	--

---

**Description**

Return the correlation matrix of x.

**Usage**

```
corMat(rho)
```

**Arguments**

rho                    a distribution.

---

corMat.estimate	<i>Return the correlation matrix of an estimate object.</i>
-----------------	---

---

**Description**

This function returns the full correlation matrix of an [estimate](#) object.

**Usage**

```
## S3 method for class 'estimate'  
corMat(rho)
```

**Arguments**

rho                    an [estimate](#) object.

**See Also**

[estimate](#), [row.names.estimate](#), [names.estimate](#)

## Description

The **decisionSupport** package supports the quantitative analysis of welfare based decision making processes using Monte Carlo simulations. This is an important part of the Applied Information Economics (AIE) approach developed in Hubbard (2014). These decision making processes can be categorized into two levels of decision making:

1. The actual problem of interest of a policy maker which we call the *underlying welfare based decision* on how to influence an ecological-economic system based on a particular information on the system available to the decision maker and
2. the *meta decision* on how to allocate resources to reduce the uncertainty in the underlying decision problem, i.e to increase the current information to improve the underlying decision making process.

The first problem, i.e. the underlying problem, is the problem of choosing the decision which maximizes expected welfare. The welfare function can be interpreted as a von Neumann-Morgenstern utility function. Whereas, the second problem, i.e. the meta decision problem, is dealt with using the *Value of Information Analysis (VIA)*. Value of Information Analysis seeks to assign a value to a certain reduction in uncertainty or, equivalently, increase in information. Uncertainty is dealt with in a probabilistic manner. Probabilities are transformed via Monte Carlo simulations.

## Details

The functionality of this package is subdivided into three main parts: (i) the welfare based analysis of the underlying decision, (ii) the meta decision of reducing uncertainty and (iii) the Monte Carlo simulation for the transformation of probabilities and calculation of expectation values. Furthermore, there is a wrapper function around these three parts which aims at providing an easy-to-use interface.

### Welfare based Analysis of the Underlying Decision Problem:

*Welfare Decision Analysis:* Implementation: [welfareDecisionAnalysis](#)

*Utility Functions:* Implementation: `ToDo`

**The Meta Decision of Reducing Uncertainty:** The meta decision of how to allocate resources for uncertainty reduction can be analyzed with this package in two different ways: via (i) Expected Value of Information Analysis or (ii) via Partial Least Squares (PLS) analysis and Variable Importance in Projection (VIP).

*Expected Value of Information (EVI):* Implementation: [eviSimulation](#), [individualEvpSimulation](#)

*Partial Least Squares (PLS) analysis and Variable Importance in Projection (VIP):* Implementation: `ToDo`

**Solving the Practical Problem of Calculating Expectation Values by Monte Carlo Simulation:**

*Estimates:* Implementation: [estimate](#)

*Multivariate Random Number Generation:* Implementation: [random.estimate](#)

*Monte Carlo Simulation:* Implementation: [mcSimulation](#)

**Uncertainty Analysis: A wrapper function:** Implementation: [uncertaintyAnalysis](#)

## Package Options

ToDo

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## References

Hubbard, Douglas W., *How to Measure Anything? - Finding the Value of "Intangibles" in Business*, John Wiley & Sons, Hoboken, New Jersey, 2014, 3rd Ed, <http://www.howtomeasureanything.com/>.

Hugh Gravelle and Ray Rees, *Microeconomics*, Pearson Education Limited, 3rd edition, 2004.

## See Also

[welfareDecisionAnalysis](#), [eviSimulation](#), [mcSimulation](#)

---

estimate	Create an Estimate Object
----------	---------------------------

---

**Description**

This function creates an object of class estimate. #ToDo: detailed description #ToDo: Implement characterization of distribution by mean and sd. Eventually, also by other quantiles.

**Usage**

```
estimate(..., correlation_matrix = NULL)
```

**Arguments**

- ... arguments that can be coerced to a data frame comprising the base of the estimate.
- correlation\_matrix numeric matrix containing the correlations of the variables.

**Details**

The parameters in ... provide the base information of an estimate.

**The structure of the estimate base information (mandatory):** Mandatory columns:

Column name	R-type	Explanation
distribution	character	Distribution types
variable	character	Variable names

**Value**

An object of type estimate which is a list whith components base and correlation\_matrix. base is a data.frame with mandatory column distribution. The row.names are the names of the variables. correlation\_matrix is a symmetric matrix with row and column names being the subset of the variables supplied in base which are correlated. Its elements are the corresponding correlations.

**See Also**

row.names.estimate, names.estimate, corMat, estimate\_read\_csv, estimate\_write\_csv, random.estimate

---

estimate_read_csv	Read an Estimate from CSV - File.
-------------------	-----------------------------------

---

## Description

This function reads an [estimate](#) from the specified csv files. In this context, an estimate of a variable is defined by its distribution type, its 90%-confidence interval [lower, upper] and its correlation to other variables. #ToDo: Implement characterization of distribution by mean and sd. Eventually, also by other quantiles.

## Usage

```
estimate_read_csv(fileName, strip.white = TRUE, ...)
```

## Arguments

fileName	Name of the file containing the base information of the estimate that should be read.
strip.white	logical. Allows the stripping of leading and trailing white space from unquoted character fields (numeric fields are always stripped). See <a href="#">scan</a> for further details (including the exact meaning of 'white space'), remembering that the columns may include the row names.
...	Further parameters to be passed to <a href="#">read.csv</a> .

## Details

An estimate might consists of uncorrelated and correlated variables. This is reflected in the input file structure, which is described in the following.

## Value

An object of type [estimate](#).

## CSV input file structures

The estimate is read from one or two csv files: the basic csv file which is mandatory and the correlation csv file which is optional. The basic csv file contains the definition of the distribution of all variables ignoring potential correlations. The correlation csv file only defines correlations.

**The structure of the basic input file (mandatory):** File name structure: <basic-filename>.csv  
Mandatory columns:

Column name	R-type	Explanation
lower	numeric	ToDo
upper	numeric	ToDo
distribution	character	ToDo
variable	character	ToDo

Optional columns:

Column name	R-type	Explanation
description	character	ToDo
median	numeric	ToDo



start	integer	ToDo
end	integer	ToDo
indicator	logical	ToDo

Columns without names are ignored. Rows where the variable field is empty are also dropped.

**The structure of the correlation file (optional):** File name structure: <basic-filename>\_cor.csv  
Columns and rows are named by the corresponding variables. Only those variables need to be present which are correlated with others. The element ["rowname", "columnname"] contains the correlation between the variables rowname and columnname. Uncorrelated elements can be left empty, i.e. as NA, or defined as 0. The element ["name", "name"] has to be set to 1. The matrix must be given in symmetric form.

### See Also

[estimate\\_write\\_csv](#), [read.csv](#), [estimate](#)

---

estimate\_read\_csv\_old *Read an Estimate from CSV - File (depreciated standard).*

---

### Description

This function reads an [estimate](#) from the specified csv files. In this context, an estimate of a variable is defined by its distribution type, its 90%-confidence interval [lower, upper] and its correlation to other variables. #ToDo: Implement characterization of distribution by mean and sd. Eventually, also by other quantiles.

### Usage

```
estimate_read_csv_old(fileName, strip.white = TRUE, ...)
```

### Arguments

fileName	Name of the file containing the base information of the estimate that should be read.
strip.white	logical. Allows the stripping of leading and trailing white space from unquoted character fields (numeric fields are always stripped). See <a href="#">scan</a> for further details (including the exact meaning of 'white space'), remembering that the columns may include the row names.
...	Further parameters to be passed to <a href="#">read.csv</a> .

### Details

An estimate might consists of uncorrelated and correlated variables. This is reflected in the input file structure, which is described in the following.

**Value**

An object of type `estimate`.

**CSV input file structures**

The estimate is read from one or two csv files: the basic csv file which is mandatory and the correlation csv file which is optional. The basic csv file contains the definition of the distribution of all variables ignoring potential correlations. The correlation csv file only defines correlations.

**The structure of the basic input file (mandatory):** File name structure: <basic-filename>.csv

Mandatory columns:

Column name	R-type	Explanation
lower	numeric	ToDo
upper	numeric	ToDo
distribution	character	ToDo
variable	character	ToDo

Optional columns:

Column name	R-type	Explanation
description	character	ToDo
median	numeric	ToDo
start	integer	ToDo
end	integer	ToDo
indicator	logical	ToDo

Columns without names are ignored. Rows where the variable field is empty are also dropped.

**The structure of the correlation file (optional):** File name structure: <basic-filename>.csv\_correlations.csv  
#ToDo

**See Also**

`estimate_read_csv`, `read.csv`, `estimate`

---

<code>estimate_write_csv</code>	<i>Write an Estimate to CSV - File.</i>
---------------------------------	---

---

**Description**

This function writes an `estimate` to the specified csv file(s).

**Usage**

```
estimate_write_csv(estimate, fileName, varNamesAsColumn = TRUE,
  quote = FALSE, ...)
```

**Arguments**

estimate	Estimate object to write to file fileName.
fileName	character. Output file name which must end with .csv.
varNamesAsColumn	logical; If TRUE the variable names will be written as a separate column, otherwise as row names.
quote	a logical value (TRUE or FALSE) or a numeric vector. If TRUE, any character or factor columns will be surrounded by double quotes. If a numeric vector, its elements are taken as the indices of columns to quote. In both cases, row and column names are quoted if they are written. If FALSE, nothing is quoted. Parameter is passed on to <a href="#">write.csv</a> .
...	Further parameters to be passed to <a href="#">write.csv</a> .

**Value**

An object of type [estimate](#).

**See Also**

[estimate\\_read\\_csv](#), [estimate](#), [write.csv](#)

---

 eviSimulation

*Expected Value of Information (EVI) Simulation.*

---

**Description**

The Expected Value of Information (EVI) is calculated based on a Monte Carlo simulation of the values of two different decision alternatives.

**Usage**

```
eviSimulation(model, currentEstimate, prospectiveEstimate, numberOfSimulations,
  functionSyntax = "data.frameNames")
```

**Arguments**

model	either a function or a list with two functions: <code>list(p1,p2)</code> . In the first case the function is the net benefit of project approval vs. the status quo. In the second case the element p1 is the function valuing the first project and the element p2 valuing the second project.
currentEstimate	<a href="#">estimate</a> object describing the distribution of the input variables as currently estimated.

**prospectiveEstimate** [estimate](#) object describing the prospective distribution of the input variables which could hypothetically achieved by collecting more information, viz. improving the measurement.

**numberOfSimulations** integer; number of simulations to be used in the underlying Monte Carlo analysis

**functionSyntax** function character; function syntax used in the model function(s).

## Details

This principle is along the line described in Hubbard (2014). The Expected Value of Information is the decrease in the EOL for an information improvement from the current estimate ( $I_{\text{current}}$ ) to a better prospective (or hypothetical) information ( $I_{\text{prospective}}$ ):  $\text{EVI} := \text{EOL}(I_{\text{current}}) - \text{EOL}(I_{\text{prospective}})$ . Thus, the EVI depends on the model for valueing a decision, the current information, i.e. the current estimate, and the specification of a hypothetical improvement in information, i.e. a prospective estimate.

## Value

An object of class `eviSimulation` with the following elements:

**current** [welfareDecisionAnalysis](#) object for `currentEstimate`  
**prospective** [welfareDecisionAnalysis](#) object for `prospectiveEstimate`  
**evi** Expected Value of Information (EVI) of gained by the prospective estimate w.r.t. the current estimate

## See Also

[welfareDecisionAnalysis](#), [mcSimulation](#), [estimate](#)

## Examples

```
#####
# Example 1 Only one prospective estimate:
#####
numberOfSimulations=10000
# Create the estimate object:
variable=c("revenue","costs")
distribution=c("posnorm","posnorm")
lower=c(10000, 5000)
upper=c(100000, 50000)
currentEstimate<-estimate(variable, distribution, lower, upper)
prospectiveEstimate<-currentEstimate
revenueConst<-mean(c(currentEstimate$base["revenue","lower"],
                     currentEstimate$base["revenue","upper"]))
prospectiveEstimate$base["revenue",]<-data.frame(distribution="const",
                                                  lower=revenueConst,
                                                  upper=revenueConst,
                                                  row.names="revenue",
                                                  stringsAsFactors=FALSE)

# (a) Define the model function without name for the return value:
profit<-function(x){
```

```

x$revenue-x$costs
}

# Calculate the Expected Value of Information:
eviSimulationResult<-eviSimulation(model=profit,
                                   currentEstimate=currentEstimate,
                                   prospectiveEstimate=prospectiveEstimate,
                                   numberOfSimulations=numberOfSimulations,
                                   functionSyntax="data.frameNames")

# Show the simulation results:
print(summary(eviSimulationResult))
#####
# (b) Define the model function with a name for the return value:
profit<-function(x){
  list(Profit=x$revenue-x$costs)
}
# Calculate the Expected Value of Information:
eviSimulationResult<-eviSimulation(model=profit,
                                   currentEstimate=currentEstimate,
                                   prospectiveEstimate=prospectiveEstimate,
                                   numberOfSimulations=numberOfSimulations,
                                   functionSyntax="data.frameNames")

# Show the simulation results:
print(summary((eviSimulationResult)))
#####
# (c) Two decision variables:
decisionModel<-function(x){
  list(Profit=x$revenue-x$costs,
       Costs=-x$costs)
}
# Calculate the Expected Value of Information:
eviSimulationResult<-eviSimulation(model=decisionModel,
                                   currentEstimate=currentEstimate,
                                   prospectiveEstimate=prospectiveEstimate,
                                   numberOfSimulations=numberOfSimulations,
                                   functionSyntax="data.frameNames")

# Show the simulation results:
print(summary((eviSimulationResult)))
#####
# Example 2 A list of prospective estimates:
#####
numberOfSimulations=10000
# Define the model function with a name for the return value:
profit<-function(x){
  list(Profit=x$revenue-x$costs)
}
# Create the estimate object:
variable=c("revenue","costs")
distribution=c("posnorm","posnorm")
lower=c(10000, 5000)
upper=c(100000, 50000)
currentEstimate<-estimate(variable, distribution, lower, upper)
perfectInformationRevenue<-currentEstimate

```

[illegible]

```

upper=revenueConst,
row.names="revenue",
stringsAsFactors=FALSE)

perfectInformationCosts<-currentEstimate
costsConst<-mean(c(currentEstimate$base["costs", "lower"], currentEstimate$base["costs", "upper"]))
perfectInformationCosts$base["costs", ]<-data.frame(distribution="const",
lower=costsConst,
upper=costsConst,
row.names="costs",
stringsAsFactors=FALSE)

prospectiveEstimate<-list(perfectInformationRevenue=perfectInformationRevenue,
perfectInformationCosts=perfectInformationCosts)

# Define the model function with two decision variables:
decisionModel<-function(x){
  list(Profit=x$revenue-x$costs,
Costs=-x$costs)
}

# Calculate the Expected Value of Information:
eviSimulationResult<-eviSimulation(model=decisionModel,
currentEstimate=currentEstimate,
prospectiveEstimate=prospectiveEstimate,
numberOfSimulations=numberOfSimulations,
functionSyntax="data.frameNames")

# Show the simulation results:
print(sort(summary(eviSimulationResult)),decreasing=TRUE,along="Profit")

```

---

hist.mcSimulation	<i>Plot Histogram of results of a Monte Carlo Simulation</i>
-------------------	--

---

## Description

This function plots the histograms of the results of [mcSimulation](#).

## Usage

```

## S3 method for class 'mcSimulation'
hist(x, breaks = 100, col = NULL, xlab = NULL,
main = paste("Histogram of ", xlab), ..., colorQuantile = c("GREY",
"YELLOW", "ORANGE", "DARK GREEN", "ORANGE", "YELLOW", "GREY"),
colorProbability = c(1, 0.95, 0.75, 0.55, 0.45, 0.25, 0.05),
resultName = NULL)

```

## Arguments

x	An object of class mcSimulation.
breaks	one of: <ul style="list-style-type: none"> <li>a vector giving the breakpoints between histogram cells,</li> <li>a function to compute the vector of breakpoints,</li> </ul>

- a single number giving the number of cells for the histogram,
- a character string naming an algorithm to compute the number of cells (see ‘Details’),
- a function to compute the number of cells.

In the last three cases the number is a suggestion only; the breakpoints will be set to [pretty](#) values. If breaks is a function, the x vector is supplied to it as the only argument.

col	a colour to be used to fill the bars. The default of NULL yields unfilled bars.
xlab	character; x label of the histogram. If it is not provided, i.e. equals NULL the name of the chosen variable by argument resultName is used.
main	character; main title of the histogram.
...	Further arguments to be passed to <a href="#">hist</a> .
colorQuantile	character vector encoding the color of the quantiles defined in argument colorProbability.
colorProbability	numeric vector; defines the quantiles that shall be distinguished by the colors chosen in argument colorQuantile. Must be of the same length as colorQuantile.
resultName	character; indicating the name of the component of the simulation function (model_function) which results histogram shall be generated. If model_function is single valued, no name needs to be supplied. Otherwise, one valid name has to be specified. Defaults to NULL.

### Value

an object of class "histogram". For details see [hist](#).

### See Also

[mcSimulation](#), [hist](#). For a list of colors available in R see [colors](#).

---

individualEvpISimulation

*Individual Expected Value of Perfect Information Simulation*

---

### Description

The Individual Expected Value of Perfect Information (Individual EVPI) is calculated based on a Monte Carlo simulation of the values of two different decision alternatives.

### Usage

```
individualEvpISimulation(model, currentEstimate,
  perfectProspectiveNames = row.names(currentEstimate),
  perfectProspectiveValues = colMeans(random(rho = currentEstimate, n =
    numberOfSimulations)[, perfectProspectiveNames]), numberOfSimulations,
  functionSyntax = "data.frameNames")
```



**Arguments**

model	either a function or a list with two functions: <code>list(p1,p2)</code> . In the first case the function is the net benefit of project approval vs. the status quo. In the second case the element p1 is the function valuing the first project and the element p2 valuing the second project.
currentEstimate	<a href="#">estimate</a> object describing the distribution of the input variables as currently estimated.
perfectProspectiveNames	character vector; input variable names that are assumed to be known perfectly with prospective information.
perfectProspectiveValues	numeric vector of the same length as <code>perfectProspectiveNames</code> with the corresponding values assumed to be known perfectly.
numberOfSimulations	integer; number of simulations to be used in the underlying Monte Carlo analysis
functionSyntax	function character; function syntax used in the model function(s).

**Details**

This principle is along the line described in Hubbard (2014). The Expected Value of Information is the decrease in the EOL for an information improvement from the current estimate ( $I_{\text{current}}$ ) to a better prospective (or hypothetical) information ( $I_{\text{prospective}}$ ):  $\text{EVI} := \text{EOL}(I_{\text{current}}) - \text{EOL}(I_{\text{prospective}})$ . If one variables under  $I_{\text{prospective}}$  is assumed to be known with certainty the EVI is called the Individual Expected Value of Perfect Information (Individual EVPI). More precisely, if one assumes under  $I_{\text{prospective}}$  to perfectly know  $(x_1, \dots, x_k)$  to equal  $(a_1, \dots, a_k)$  then one can specify the notation as Individual EVPI[ $x_i = a_i$ ]. Summarizing, the Individual EVPI depends on the model for valuing a decision, the current information, i.e. the current estimate, and the specification of the variable that is assumed to be known with certainty, viz. the improvement in information, i.e. a prospective estimate.

**Value**

An object of class `eviSimulation` with the following elements:

current	<a href="#">welfareDecisionAnalysis</a> object for currentEstimate
prospective	<a href="#">welfareDecisionAnalysis</a> object for prospectiveEstimate
evi	Expected Value of Information (EVI) of gained by the prospective estimate w.r.t. the current estimate

**See Also**

[eviSimulation](#), [welfareDecisionAnalysis](#), [mcSimulation](#), [estimate](#)

**Examples**

```
# Number of simulations:
n=100000
# Create the current estimate from text:
```

```

estimateText<-"variable, distribution, lower, upper
      revenue1, posnorm,      100,   1000
      revenue2, posnorm,      50,   2000
      costs1,   posnorm,      50,   2000
      costs2,   posnorm,     100,   1000"
currentEstimate<-estimate(read.csv(header=TRUE, text=estimateText,
      strip.white=TRUE, stringsAsFactors=FALSE))

# The model function:
profitModel <- function(x){
  list(Profit=x$revenue1 + x$revenue2 - x$costs1 - x$costs2)
}
# Calculate the Individual EVPI:
individualEvpiResult<-individualEvpiSimulation(model=profitModel,
      currentEstimate=currentEstimate,
      numberOfSimulations=n,
      functionSyntax="data.frameNames")

# Show the simulation results:
print(sort(summary(individualEvpiResult)),decreasing=TRUE,along="Profit")

```

---

mcSimulation

---

*Perform a Monte Carlo Simulation.*


---

## Description

This method solves the following problem. Given a multivariate random variable  $x = (x_1, \dots, x_k)$  with joint probability distribution  $P$ , i.e.

$$x \sim P.$$

Then the continuous function

$$f : R^k \rightarrow R^l, y = f(x)$$

defines another random variable with distribution

$$y \sim f(P).$$

Given a probability density  $\rho$  of  $x$  that defines  $P$  the problem is the determination of the probability density  $\phi$  that defines  $f(P)$ . This method samples the probability density  $\phi$  of  $y$  by Monte Carlo simulation.

## Usage

```

mcSimulation(estimate, model_function, ..., numberOfSimulations,
  randomMethod = "calculate", functionSyntax = "data.frameNames")

```

## Arguments

**estimate**            Filename or estimate object representing the joint probability distribution of the input variables.

**model\_function**    A numeric function; The function that describes the value of a certain project.



```

                                functionSyntax="data.frameNames")

# Show the simulation results:
print(summary(predictionProfit1))
hist(predictionProfit1,xlab="Profit")
#####
# (b) Define the model function with a name for the return value:
profit1<-function(x){
  list(Profit=x$revenue-x$costs)
}
# Perform the Monte Carlo simulation:
predictionProfit1<-mcSimulation( estimate=costBenefitEstimate,
                                model_function=profit1,
                                numberOfSimulations=100000,
                                functionSyntax="data.frameNames")

# Show the simulation results:
print(summary(predictionProfit1, classicView=TRUE))
hist(predictionProfit1)
#####
# (c) Using global names in the model function syntax
# (CAVE: currently slow!):
profit1<-function(){
  list(Profit=revenue-costs)
}
# Perform the Monte Carlo simulation:
predictionProfit1<-mcSimulation( estimate=costBenefitEstimate,
                                model_function=profit1,
                                numberOfSimulations=10000,
                                functionSyntax="globalNames")

# Show the simulation results:
print(summary(predictionProfit1, probs=c(0.05,0.50,0.95)))
hist(predictionProfit1)

#####
# Example 2(Reading the estimate from file):
#####
# Define the model function:
profit2<-function(x){
  Profit<-x[["sales"]]*(x[["productprice"]] - x[["costprice"]])
  list(Profit=Profit)
}
# Read the estimate of sales, productprice and costprice from file:
inputFileName=system.file("extdata","profit-4.csv",package="decisionSupport")
parameterEstimate<-estimate_read_csv(fileName=inputFileName)
print(parameterEstimate)
# Perform the Monte Carlo simulation:
predictionProfit2<-mcSimulation( estimate=parameterEstimate,
                                model_function=profit2,
                                numberOfSimulations=100000,
                                functionSyntax="data.frameNames")

# Show the simulation results:
print(summary(predictionProfit2))
hist(predictionProfit2)

```

---

names.estimate	<i>Return the column names of an estimate object.</i>
----------------	---

---

### Description

This function returns the column names of an [estimate](#) object which is identical to `names(x$base)`.

### Usage

```
## S3 method for class 'estimate'
names(x)
```

### Arguments

`x` an [estimate](#) object.

### See Also

[estimate](#), [row.names.estimate](#), [corMat.estimate](#)

---

paramposnorm90ci	<i>Return parameters of positive normal random distribution based on the 90%-confidence interval.</i>
------------------	---

---

### Description

This function calculates the distribution parameters from the 90%-confidence interval.

### Usage

```
paramposnorm90ci(lower, upper, relativeTolerance = 0.05, method = "numeric")
```

### Arguments

<code>lower</code>	numeric; lower bound of the 90% confidence intervall.
<code>upper</code>	numeric; upper bound of the 90% confidence intervall.
<code>relativeTolerance</code>	numeric; the relative tolerance level of deviation of the generated confidence interval from the specified interval.
<code>method</code>	The method to calculate the parameters. Default is "numeric".

### Details

#ToDo

---

paramtnormci	<i>Return parameters of truncated normal distribution based on a confidence interval.</i>
--------------	---

---

## Description

This function calculates the distribution parameters, i.e. mean and sd, of a truncated normal distribution from an arbitrary confidence interval.

## Usage

```
paramtnormci(p, ci, lowerTrunc = -Inf, upperTrunc = Inf,
  relativeTolerance = 0.05, method = "numeric")
```

## Arguments

p	numeric 2-dimensional vector; probabilities of upper and lower bound of the corresponding confidence interval.
ci	numeric 2-dimensional vector; lower and upper bound of the confidence interval.
lowerTrunc	numeric; lower truncation point of the distribution ( $\geq -\text{Inf}$ ).
upperTrunc	numeric; upper truncation point of the distribution ( $\leq \text{Inf}$ ).
relativeTolerance	numeric; the relative tolerance level of deviation of the generated confidence interval from the specified interval. If this deviation is greater than relativeTolerance a warning is given.
method	The method to calculate the parameters. Default is "numeric".

## Details

For details of the truncated normal distribution see [tnorm](#).

p-% confidence interval:  $[c_l, c_u]$

$$tN(\mu, \sigma)$$

$$\int_{-\infty}^{c_l} dtN(\mu, \sigma) = p_l$$

$$\int_{-\infty}^{c_u} dtN(\mu, \sigma) = p_u$$

$p_l - p_u = p$  and  $p_l = 1 - p_u$

## Value

A list with elements mean and sd.

**Warning**

This method has not been tested systematically!

**See Also**

[tnorm](#)

---

print.mcSimulation	<i>Print Basic Results from Monte Carlo Simulation.</i>
--------------------	---

---

**Description**

This function prints basic results from Monte Carlo simulation and returns it invisible.

**Usage**

```
## S3 method for class 'mcSimulation'  
print(x, ...)
```

**Arguments**

x	An object of class mcSimulation.
...	Further arguments #ToDo

**See Also**

[mcSimulation](#)

---

print.summary.eviSimulation	<i>Print the Summarized EVI Simulation Results.</i>
-----------------------------	---

---

**Description**

This function prints the summary of of eviSimulation obtained by [summary.eviSimulation](#).

**Usage**

```
## S3 method for class 'summary.eviSimulation'  
print(x, ...)
```

**Arguments**

x	An object of class summary.eviSimulation.
...	Further arguments #ToDo

**See Also**[eviSimulation](#)

---

```
print.summary.mcSimulation
```

*Print the Summary of a Monte Carlo Simulation.*

---

**Description**

This function prints the summary of of mcSimulation obtained by [summary.mcSimulation](#).

**Usage**

```
## S3 method for class 'summary.mcSimulation'  
print(x, ...)
```

**Arguments**

x	An object of class mcSimulation.
...	Further arguments #ToDo

**See Also**[mcSimulation](#)

---

```
print.summary.welfareDecisionAnalysis
```

*Print the Summarized Decsion Analysis Results..*

---

**Description**

This function prints the summary of of welfareDecisionAnalysis obtained by [summary.welfareDecisionAnalysis](#).

**Usage**

```
## S3 method for class 'summary.welfareDecisionAnalysis'  
print(x, ...)
```

**Arguments**

x	An object of class summary.welfareDecisionAnalysis.
...	Further arguments #ToDo

**See Also**[welfareDecisionAnalysis](#)



---

r0_1norm90ci_numeric	<i>Generate normal random numbers truncated to <math>[0, 1]</math> based on the 90%-confidence interval.</i>
----------------------	--

---

### Description

This function generates normal random numbers truncated to  $[0, 1]$  based on the 90% confidence interval calculating the distribution parameter numerically from the 90%-confidence interval.

### Usage

```
r0_1norm90ci_numeric(n, lower, upper, relativeTolerance = 0.05)
```

### Arguments

n	Number of generated observations.
lower	numeric; lower bound of the 90% confidence interval.
upper	numeric; upper bound of the 90% confidence interval.
relativeTolerance	numeric; the relative tolerance level of deviation of the generated confidence interval from the specified interval.

### Details

#ToDo

---

random	<i>Generate random numbers for a certain probability distribution.</i>
--------	--

---

### Description

This function generates multivariate random numbers for general multivariate distributions.

### Usage

```
random(rho, n, method, ...)
```

### Arguments

rho	Distribution to be randomly sampled.
n	Number of generated observations.
method	Particular method to be used for random number generation.
...	Optional arguments to be passed to the particular random number generating function.

---

random.default	<i>Generate random numbers based on the first two moments of a certain probability distribution.</i>
----------------	--

---

### Description

This function generates random numbers for general multivariate distributions that can be characterized by the joint first two moments, viz. the mean and covariance.

### Usage

```
## Default S3 method:
random(rho, n, method, ...)
```

### Arguments

rho	list; Distribution to be randomly sampled.
n	Number of generated observations
method	Particular method to be used for random number generation.
...	Optional arguments to be passed to the particular random number generating function.

---

random.estimate	<i>Generate Random Numbers for an Estimate.</i>
-----------------	---

---

### Description

This function generates random numbers for general multivariate distributions that are defined as an [estimate](#).

### Usage

```
## S3 method for class 'estimate'
random(rho, n, method = "calculate", ...)
```

### Arguments

rho	estimate object; Multivariate distribution to be randomly sampled.
n	Number of generated observations
method	Particular method to be used for random number generation.
...	Optional arguments to be passed to the particular random number generating function.

## Details

**Generation of uncorrelated components:** Implementation: [random\\_estimate\\_1d](#)

**Generation of correlated components:** Implementation: [rmvnorm90ci\\_exact](#)

## See Also

[estimate](#)

## Examples

```
variable=c("revenue","costs")
distribution=c("norm","norm")
lower=c(10000, 5000)
upper=c(100000, 50000)
estimateObject<-estimate(variable, distribution, lower, upper)
x<-random(rho=estimateObject, n=10000)
apply(X=x, MARGIN=2, FUN=quantile, probs=c(0.05, 0.95))
cor(x)
colnames(x)
summary(x)
hist(x[, "revenue"])
hist(x[, "costs"])
```

---

random_estimate_1d	<i>Generate univariate random numbers based on an estimate.</i>
--------------------	---

---

## Description

This function generates random numbers for general univariate distributions.

## Usage

```
random_estimate_1d(rho, n, method = "calculate", ...)
```

## Arguments

rho	estimate object; Univariate distribution to be randomly sampled.
n	Number of generated observations
method	Particular method to be used for random number generation.
...	Optional arguments to be passed to the particular random number generating function.

## Details

method can be either "calculate" (the default) or "fit".

The following table shows the available distributions and the implemented generation method:

Identification	Distribution	method
const	ToDo	calculate
norm	Normal distribution	calculate, <a href="#">fit</a>
posnorm	ToDo	calculate
0_1norm	ToDo	calculate
beta	Beta distribution	<a href="#">fit</a>
cauchy	ToDo	<a href="#">fit</a>
logis	ToDo	<a href="#">fit</a>
t	ToDo	<a href="#">fit</a>
chisq	ToDo	<a href="#">fit</a>
chisqnc	ToDo: implement?	<a href="#">fit</a>
exp	ToDo	<a href="#">fit</a>
f	ToDo	<a href="#">fit</a>
gamma	ToDo	<a href="#">fit</a>
lnorm	ToDo	<a href="#">fit</a>
unif	ToDo	calculate, <a href="#">fit</a>
weibull	ToDo	<a href="#">fit</a>
triang	ToDo	<a href="#">fit</a>
gompertz	ToDo	<a href="#">fit</a>
pert	ToDo	<a href="#">fit</a>
tnorm	Truncated normal distribution	<a href="#">fit</a>

**See Also**

For method="calculate": [rdist90ci\\_exact](#), [rposnorm90ci\\_numeric](#) and [r0\\_1norm90ci\\_numeric](#);  
for method="fit": [rdistq\\_fit](#)

---

<code>rdist90ci_exact</code>	<i>Generate univariate random numbers based on the 90%-confidence interval.</i>
------------------------------	---

---

**Description**

This function generates random numbers for general univariate distributions based on the 90% confidence interval.

**Usage**

```
rdist90ci_exact(distribution, n, lower, upper)
```

**Arguments**

- distribution     character; A character string that defines the univariate distribution to be randomly sampled.
- n                Number of generated observations.
- lower            numeric; lower bound of the 90% confidence intervall.
- upper            numeric; upper bound of the 90% confidence intervall.

## Details

The following table shows the available distributions and their identification as a character string:

Distribution encoding	Distribution
const	ToDo
norm	ToDo
pos_norm	ToDo
norm_0_1	ToDo
pois	ToDo
binom	ToDo
unif	ToDo
lnorm	ToDo
lnorm_lim2	ToDo

---

rdistq_fit	<i>Generate univariate random numbers based on quantiles.</i>
------------	---

---

## Description

This function generates random numbers for a set of univariate distributions based on the distribution quantiles. Internally, this is achieved by fitting the distribution function to the given quantiles using [rriskFitdist.perc](#).

## Usage

```
rdistq_fit(distribution, n, percentiles = c(0.05, 0.5, 0.95), quantiles)
```

## Arguments

distribution	A character string that defines the univariate distribution to be randomly sampled.
n	Number of generated observations.
percentiles	Numeric vector giving the percentiles.
quantiles	Numeric vector giving the quantiles.

## Details

The following table shows the available distributions and their identification as a character string:

Identification	Distribution	Number of quantiles
<a href="#">norm</a>	Normal distribution	$\geq 2$
<a href="#">beta</a>	Beta distribution	ToDo
cauchy	ToDo	ToDo
logis	ToDo	ToDo
t	ToDo	ToDo
chisq	ToDo	ToDo

chisqnc	ToDo: implement?	ToDo
exp	ToDo	ToDo
f	ToDo	ToDo
gamma	ToDo	ToDo
lnorm	ToDo	ToDo
unif	ToDo	ToDo
weibull	ToDo	ToDo
triang	Triangular Distribution, Note: package mc2d needed.	ToDo
gompertz	Gompertz distribution, Note: package eha needed.	ToDo
pert	The (modified) PERT distribution, Note: package mc2d needed.	ToDo
tnorm	Truncated normal distribution	ToDo

The default for percentiles is 0.05, 0.5 and 0.95, so for the default, the quantiles argument should be a vector with 3 elements. If this is to be longer, the percentiles argument has to be adjusted to match the length of quantiles.

### Value

ToDo

---

rmvnorm90ci_exact	<i>Generate normal distributed multivariate random numbers based on the 90%-confidence interval.</i>
-------------------	--

---

### Description

This function generates normal distributed multivariate random numbers based on the 90%-confidence interval.

### Usage

```
rmvnorm90ci_exact(n, lower, upper, correlationMatrix)
```

### Arguments

n	Number of generated observations.
lower	numeric vector; lower bound of the 90% confidence intervall.
upper	numeric vector; upper bound of the 90% confidence intervall.
correlationMatrix	numeric symmetric matrix; correlation matrix; In particular, all diagonal elements must be equal to 1.

---

row.names.estimate	<i>Return the variable names of an estimate object.</i>
--------------------	---

---

### Description

This function returns the variable names of an [estimate](#) object which is identical to `row.names(x$base)`.

### Usage

```
## S3 method for class 'estimate'
row.names(x)
```

### Arguments

`x` an [estimate](#) object.

### See Also

[estimate](#), [names.estimate](#), [corMat.estimate](#)

---

rposnorm90ci_iter	<i>Generate positive normal random numbers based on the 90%-confidence interval.</i>
-------------------	--

---

### Description

This function generates positive normal random numbers based on the 90% confidence interval using an iteration algorithm.

### Usage

```
rposnorm90ci_iter(n, lower, upper, relativeTolerance = 0.05, maxIter = 40)
```

### Arguments

<code>n</code>	Number of generated observations.
<code>lower</code>	numeric; lower bound of the 90% confidence intervall.
<code>upper</code>	numeric; upper bound of the 90% confidence intervall.
<code>relativeTolerance</code>	numeric; the relative tolerance level of deviation of the generated confidence interval from the specified interval.
<code>maxIter</code>	numeric; maximum number of iterations.

### Details

The generation of random numbers is repeated until the generated 90% - confidence interval is close enough to the desired value.

---

rposnorm90ci_numeric	<i>Generate positive normal random numbers based on the 90%-confidence interval.</i>
----------------------	--

---

### Description

This function generates positive normal random numbers based on the 90% confidence interval calculating the distribution parameter numerically from the 90%-confidence interval.

### Usage

```
rposnorm90ci_numeric(n, lower, upper, relativeTolerance = 0.05)
```

### Arguments

n	Number of generated observations.
lower	numeric; lower bound of the 90% confidence intervall.
upper	numeric; upper bound of the 90% confidence intervall.
relativeTolerance	numeric; the relative tolerance level of deviation of the generated confidence interval from the specified interval.

### Details

#ToDo

---

sort.summary.eviSimulation	<i>Sort Summarized EVI Simulation Results..</i>
----------------------------	---

---

### Description

Sort summarized EVI simulation results according to their EVI.

### Usage

```
## S3 method for class 'summary.eviSimulation'
sort(x, decreasing = TRUE, ...,
     along = row.names(x$summary$evi)[[1]])
```

### Arguments

x	An object of class summary.eviSimulation.
decreasing	logical; if the evi should be sorted in decreasing order.
...	Further arguments #ToDo
along	character; the name of the valuation variable along which evi should be sorted.



**Value**

An object of class `summary.eviSimulation`.

**See Also**

[eviSimulation](#), [summary.eviSimulation](#), [sort](#)

---

`summary.eviSimulation` *Summarize EVI Simulation Results*

---

**Description**

`summary.eviSimulation` produces result summaries of the results of Expected Value of Information (EVI) simulation obtained by the function [eviSimulation](#).

**Usage**

```
## S3 method for class 'eviSimulation'
summary(object, ..., digits = max(3,
  getOption("digits") - 3))
```

**Arguments**

<code>object</code>	An object of class <code>eviSimulation</code> .
<code>...</code>	Further arguments passed to <a href="#">summary.welfareDecisionAnalysis</a> .
<code>digits</code>	how many significant digits are to be used for numeric and complex x. The default, NULL, uses <a href="#">getOption("digits")</a> . This is a suggestion: enough decimal places will be used so that the smallest (in magnitude) number has this many significant digits, and also to satisfy <code>nsml</code> . (For the interpretation for complex numbers see <a href="#">signif</a> .)

**Value**

An object of class `summary.eviSimulation`.

**See Also**

[eviSimulation](#), [print.summary.eviSimulation](#), [summary.welfareDecisionAnalysis](#)

---

summary.mcSimulation    *Summarize Results from Monte Carlo Simulation.*


---

## Description

A summary of the results of a Monte Carlo simulation obtained by the function `mcSimulation` is produced.

## Usage

```
## S3 method for class 'mcSimulation'
summary(object, ..., digits = max(3,
  getOption("digits") - 3), variables.y = names(object$y), variables.x = if
  (classicView) names(object$x), classicView = FALSE, probs = c(0, 0.1,
  0.25, 0.5, 0.75, 0.9, 1))
```

## Arguments

object	An object of class <code>mcSimulation</code> .
...	Further arguments passed to <code>summary.data.frame</code> ( <code>classicView=TRUE</code> ) or <code>format</code> ( <code>classicView=FALSE</code> ).
digits	how many significant digits are to be used for numeric and complex x. The default, <code>NULL</code> , uses <code>getOption("digits")</code> . This is a suggestion: enough decimal places will be used so that the smallest (in magnitude) number has this many significant digits, and also to satisfy <code>nsmall</code> . (For the interpretation for complex numbers see <code>signif</code> .)
variables.y	character or character vector; Names of the components of the simulation function ( <code>model_function</code> ) which results shall be displayed. Defaults to all components.
variables.x	character or character vector; Names of the components of the input variables to the simulation function, i.e. the names of the variables in the input estimate which random sampling results shall be displayed. Defaults to all components.
classicView	logical; if <code>TRUE</code> the results are summarized using <code>summary.data.frame</code> , if <code>FALSE</code> further output is produced and the quantile information can be chosen. Cf. section Value and argument <code>probs</code> . Default is <code>FALSE</code> .
probs	numeric vector of quantiles that shall be displayed if <code>classicView=FALSE</code> .

## Value

An object of class `summary.mcSimulation`.

```
chance_loss
chance_zero
chance_gain
```

**See Also**

[mcSimulation](#), [print.summary.mcSimulation](#), [summary.data.frame](#)

---

summary.welfareDecisionAnalysis

*Summarize Decsion Analysis Results.*

---

**Description**

summary.welfareDecisionAnalysis produces result summaries of the results of decision analysis simulation obtained by the function [welfareDecisionAnalysis](#).

**Usage**

```
## S3 method for class 'welfareDecisionAnalysis'
summary(object, ..., digits = max(3,
  getOption("digits") - 3))
```

**Arguments**

object	An object of class welfareDecisionAnalysis.
...	Further arguments passed to <a href="#">format</a> .
digits	how many significant digits are to be used for numeric and complex x. The default, NULL, uses <a href="#">getOption("digits")</a> . This is a suggestion: enough decimal places will be used so that the smallest (in magnitude) number has this many significant digits, and also to satisfy nsmall. (For the interpretation for complex numbers see <a href="#">signif</a> .)

**Value**

An object of class summary.welfareDecisionAnalysis.

**See Also**

[welfareDecisionAnalysis](#), [print.summary.welfareDecisionAnalysis](#), [format](#)

---

uncertaintyAnalysis     *Uncertainty Analysis Wrapper Function.*

---

## Description

This function performs a Monte Carlo simulation from input files and analyses the results via Partial Least Squares Regression (PLSR) and calculates the Variable Importance on Projection (VIP). Results are saved as plots.

## Usage

```
uncertaintyAnalysis(inputFilePath, outputDirectory, modelFunction,
  NumberOfSimulations, randomMethod = "calculate",
  functionSyntax = "globalNames", write_table = TRUE, indicators = FALSE,
  log_scales = FALSE, oldInputStandard = FALSE)
```

## Arguments

inputFilePath	Path to input csv file, which gives the input <a href="#">estimate</a> .
outputDirectory	Path where the result plots and tables are saved.
modelFunction	The model function.
NumberOfSimulations	The number of Monte Carlo simulations to be performed.
randomMethod	ToDo
functionSyntax	ToDo
write_table	logical; If the full Monte Carlo simulation results and PLSR results should be written to file.
indicators	logical; If indicator variables should be respected specially.
log_scales	logical; If the scales in the pls plots should be logarithmic.
oldInputStandard	logical; If the old input standard should be used ( <a href="#">estimate_read_csv_old</a> ).

## See Also

[mcSimulation](#), [estimate](#), [estimate\\_read\\_csv](#)

---

welfareDecisionAnalysis

*Analysis of the Underlying Welfare Based Decision Problem*


---

## Description

The optimal choice between two different opportunities is calculated. This decision is based on minimizing the Expected Net Loss (ENL).

## Usage

```
welfareDecisionAnalysis(estimate, model, numberOfSimulations,
  functionSyntax = "data.frameNames")
```

## Arguments

estimate	<a href="#">estimate</a> object describing the distribution of the input variables.
model	either a function or a list with two functions: <code>list(p1,p2)</code> . In the first case the function is the net benefit of project approval vs. the status quo. In the second case the element p1 is the function valuing the first project and the element p2 valuing the second project.
numberOfSimulations	integer; number of simulations to be used in the underlying Monte Carlo analysis
functionSyntax	function character; function syntax used in the model function(s).

## Details

This principle is along the line described in Hubbard (2014). The Expected Opportunity Loss (EOL) is defined as the Expected Net Loss (ENL) for the best decision. The best decision minimises the ENL. The EOL is always conditional on the available information (I):  $EOL=EOL(I)$ . Here, the available information is the supplied estimate. One can show that in the case of two alternatives, minimization of EOL is equivalent to maximization of the Expected Net Benefit.

## Value

An object of class `welfareDecisionAnalysis` with the following elements:

enbPa	Expected Net Loss (ENL) in case of project approval (PA)
enbSq	Expected Net Loss (ENL) in case of status quo (SQ)
eol	Expected Oportunity Loss (EOL)
optimalChoice	The optimal choice, i.e. either project approval (PA) or the status quo (SQ)

## See Also

[mcSimulation](#), [estimate](#), [summary.welfareDecisionAnalysis](#)

## Examples

```
#####
# Example 1 (Creating the estimate from the command line):
#####
# Create the estimate object:
variable=c("revenue","costs")
distribution=c("posnorm","posnorm")
lower=c(10000, 5000)
upper=c(100000, 50000)
costBenefitEstimate<-estimate(variable, distribution, lower, upper)
# (a) Define the model function without name for the return value:
profit<-function(x){
  x$revenue-x$costs
}
# Perform the decision analysis:
myAnalysis<-welfareDecisionAnalysis(estimate=costBenefitEstimate,
                                   model=profit,
                                   numberOfSimulations=100000,
                                   functionSyntax="data.frameNames")

# Show the analysis results:
print(summary((myAnalysis)))
#####
# (b) Define the model function with a name for the return value:
profit<-function(x){
  list(Profit=x$revenue-x$costs)
}
# Perform the decision analysis:
myAnalysis<-welfareDecisionAnalysis(estimate=costBenefitEstimate,
                                   model=profit,
                                   numberOfSimulations=100000,
                                   functionSyntax="data.frameNames")

# Show the analysis results:
print(summary((myAnalysis)))
#####
# (c) Two decision variables:
decisionModel<-function(x){
  list(Profit=x$revenue-x$costs,
       Costs=-x$costs)
}
# Perform the decision analysis:
myAnalysis<-welfareDecisionAnalysis(estimate=costBenefitEstimate,
                                   model=decisionModel,
                                   numberOfSimulations=100000,
                                   functionSyntax="data.frameNames")

# Show the analysis results:
print(summary((myAnalysis)))
```

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