

# Package ‘SEL’

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**Type** Package

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**Description** Implements a method for fitting a bounded probability distribution to quantiles (for example stated by an expert), see Bornkamp and Ickstadt (2009) for details. For this purpose B-splines are used, and the density is obtained by penalized least squares based on a Brier entropy penalty. The package provides methods for fitting the distribution as well as methods for evaluating the underlying density and cdf. In addition methods for plotting the distribution, drawing random numbers and calculating quantiles of the obtained distribution are provided.

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SEL-package	<i>Semiparametric Elicitation of a bounded parameter.</i>
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## Description

This package implements a novel method for fitting a bounded probability distribution to quantiles stated for example by an expert (see Bornkamp and Ickstadt (2009)). For this purpose B-splines are used, and the density is obtained by penalized least squares based on a Brier entropy penalty. The package provides methods for fitting the distribution as well as methods for evaluating the underlying density and cdf. In addition methods for plotting the distribution, drawing random numbers and calculating quantiles of the obtained distribution are provided.

## Details

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## Author(s)

Bjoern Bornkamp

Maintainer: Bjoern Bornkamp <bornkamp@statistik.tu-dortmund.de>

## References

- Bornkamp, B. and Ickstadt, K. (2009). A Note on B-Splines for Semiparametric Elicitation. *The American Statistician*, **63**, 373–377
- O’Hagan A., Buck C. E., Daneshkhah, A., Eiser, R., Garthwaite, P., Jenkinson, D., Oakley, J. and Rakow, T. (2006), *Uncertain Judgements: Eliciting Expert Probabilities*, John Wiley and Sons Inc.
- Garthwaite, P., Kadane, J. O’Hagan, A. (2005), Statistical Methods for Eliciting Probability Distributions, *Journal of the American Statistical Association*, **100**, 680–701
- Dierckx, P. (1993), *Curve and Surface Fitting with Splines*, Clarendon Press.

**Examples**

```
## example from O'Hagan et al. (2006)
x <- c(177.5, 183.75, 190, 205, 220)
y <- c(0.175, 0.33, 0.5, 0.75, 0.95)

default <- SEL(x, y, Delta = 0.05, bounds = c(165, 250))
bernst <- SEL(x, y, d = 10, N = 0, Delta = 0.05, bounds = c(165, 250))
unifknots <- SEL(x, y, d = 3, N = 5, Delta = 0.05, bounds = c(165, 250))
lin <- SEL(x, y, d = 1, inknts = x, Delta = 0.05, bounds = c(165, 250))
comparePlot(default, bernst, unifknots, lin, type = "cdf")
comparePlot(default, bernst, unifknots, lin, type = "density")

## compare summaries
summary(default)
summary(bernst)
summary(unifknots)
summary(lin)

## sample from SEL object and evaluate density
xxx <- rvSEL(50000, bernst)
hist(xxx, breaks=100, freq=FALSE)
curve(predict(bernst, newdata=x), add=TRUE)
```

---

comparePlot

*Compare different elicited densities.*

---

**Description**

Compare different elicited distributions in a trellis display.

**Usage**

```
comparePlot(..., type = c("density", "cdf"), deriv,
            points = TRUE, superpose = FALSE, n = 101,
            xlab = "", ylab, addArgs = NULL)
```

**Arguments**

...	Fitted SEL objects separated by a comma.
type	Determines whether to plot densities or cdfs (ignored if deriv is not missing).
deriv	Specify derivative of the expert's density to be plotted.
points	Logical indicating whether elicited quantiles should be displayed, when displaying the cdf.
superpose	Logical indicate if plots should be superposed.
n	Integer, number of points used for plotting.

xlab, ylab	Labels for x-axis and y-axis. If ylab is missing the value of type is used.
addArgs	List specifying additional arguments for xypLOT function, list elements should match the corresponding arguments of the xypLOT function.

**Author(s)**

Bjoern Bornkamp

**References**

Bornkamp, B. and Ickstadt, K. (2009). A Note on B-Splines for Semiparametric Elicitation. *The American Statistician*, **63**, 373–377

**See Also**

[SEL](#), [plot.SEL](#)

**Examples**

```
# example from O'Hagan et al. (2006)
x <- c(177.5, 183.75, 190, 205, 220)
y <- c(0.175, 0.33, 0.5, 0.75, 0.95)

default <- SEL(x, y, Delta = 0.05, bounds = c(165, 250))
bernst <- SEL(x, y, d = 10, N = 0, Delta = 0.05, bounds = c(165, 250))
unifknots <- SEL(x, y, d = 3, N = 5, Delta = 0.05, bounds = c(165, 250))
lin <- SEL(x, y, d = 1, inknts = x, Delta = 0.05, bounds = c(165, 250))
comparePlot(default, bernst, unifknots, lin, type = "cdf")
comparePlot(default, bernst, unifknots, lin, type = "density")
```

---

fit.SEL

*Fit an SEL object*

---

**Description**

Function that performs the actual fitting of the expert's distribution via quadratic programming (using the [solve.QP](#) function from the quadprog package). This function is mainly for internal use.

**Usage**

```
fit.SEL(N, alpha, P, A, b, gamma, dplus = 0)
```

**Arguments**

N	Matrix containing the B-spline basis functions evaluated at the elicited quantiles.
alpha	Vector giving the levels of the elicited quantiles.
P	Penalty matrix (called Omega in the reference below).
A, b	Matrix and vector containing the specifying the constraints $A'b \geq 0$ .
gamma	Gamma parameter trading of goodness of fit and Brier entropy/Brier divergence.
dplus	Additional offset for dvec in solve.QP.

**Value**

Returns solution of the quadratic programming problem.

**Author(s)**

Bjoern Bornkamp

**References**

Bornkamp, B. and Ickstadt, K. (2009). A Note on B-Splines for Semiparametric Elicitation. *The American Statistician*, **63**, 373–377

Goldfarb, D., and Idnani, A. (1982), Dual and Primal-Dual Methods for Solving Strictly Convex Quadratic Programs, in *Numerical Analysis*, (eds.) J. Hennart, Springer Verlag, Berlin, pp. 226–239.

Goldfarb, D., and Idnani, A. (1983), A Numerically Stable Dual Method for Solving Strictly Convex Quadratic Programs”, *Mathematical Programming*, *27*, 1–33.

**See Also**

[SEL](#), [solve.QP](#)

---

getbinPost

*Calculate posterior distribution for binomial model*

---

**Description**

Calculate posterior distribution for the simple beta-binomial model

**Usage**

```
getbinPost(x, object, k, n, type = c("density", "cdf"),
           rel.tol = .Machine$double.eps^0.5)
```

**Arguments**

x	Vector specifying, where posterior distribution should be evaluated.
object	An SEL object.
k	Number of observed successes in the binomial model.
n	Number of total trials.
type	Character specifying, whether posterior density or cdf should be evaluated.
rel.tol	rel.tol argument of the integrate subroutine, which numerically calculates the normalization constant, when a non-conjugate prior is used (ie a B-spline basis not leading to a Bernstein mixture).

**Value**

Numeric containing the function values corresponding to x values

**Author(s)**

Bjoern Bornkamp

**References**

Bornkamp, B. and Ickstadt, K. (2009). A Note on B-Splines for Semiparametric Elicitation. *The American Statistician*, **63**, 373–377

Diaconis, P., and Ylvisaker, D. (1985), Quantifying Prior Opinion, *Bayesian Statistics 2*, (eds.) J.M. Bernardo, M.H. DeGroot, D.V. Lindley and A.F.M. Smith, Elsevier Science Publishers B.V., Amsterdam, pp. 133–156.

**See Also**

[SEL](#)

**Examples**

```
## Diaconis, Ylvisaker spun coin example (see references)
## simulate elicitation
x <- seq(0, 1, length=9)[2:8]
ymu <- 0.5*pbeta(x, 10, 20)+0.5*pbeta(x, 20, 10)
sig <- 0.05
set.seed(4)
y <- ymu+rnorm(7, 0, sqrt(ymu*(1-ymu))*sig)

## perform fitting with different selections
A <- SEL(x, y, d = 1, Delta = 0.001, inknts = x)
foo1 <- function(x) dbeta(x, 0.5, 0.5)
B <- SEL(x, y, d = 19, N=0, Delta = 0.02, pstar = foo1)
C <- SEL(x, y, d = 19, N=0, Delta = 0.05, pstar = foo1)
comparePlot(A, B, C, addArgs = list(layout = c(3,1)))

## posterior
sq <- seq(0,1,length=201)
```

```
res1 <- getbinPost(sq, A, 3, 10, type = "density")
res2 <- getbinPost(sq, B, 3, 10, type = "density")
res3 <- getbinPost(sq, C, 3, 10, type = "density")

## parametric posterior (corresponding to B(0.5,0.5) prior)
plot(sq, dbeta(sq, 3.5, 7.5), type="l", xlab = "",
      ylab = "Posterior density", lty = 4,
      ylim=c(0,max(c(res1, res2, res3))))
## "semiparametric" posteriors
lines(sq, res1, lty = 1)
lines(sq, res2, lty = 2)
lines(sq, res3, lty = 3)
legend(0.65,4, legend=c("Scenario A", "Scenario B", "Scenario C",
                       "B(0.5,0.5) prior"), lty = 1:4)
```

---

knotave

*Calculate the knot averages of a B-spline basis.*

---

### Description

Calculates the knot averages of a B-spline basis.

### Usage

```
knotave(knots, d)
```

### Arguments

knots	Knot Vector (with $d+1$ coincident knots on the boundaries).
d	Degree of the B-spline basis.

### Value

Numeric containing knot averages

### Author(s)

Bjoern Bornkamp

### References

Bornkamp, B. and Ickstadt, K. (2009). A Note on B-Splines for Semiparametric Elicitation. *The American Statistician*, **63**, 373–377

Dierckx, P. (1993), *Curve and Surface Fitting with Splines*, Clarendon Press

### See Also

[SEL](#)

**Examples**

```
## Example for calculation of a control polygon
knts <- c(rep(0, 4), rep(1, 4))
cf <- c(-1, -1, 1/2, 0)
sq <- seq(0, 1, length = 101)
N <- splineDesign(sq, knots = knts, ord = 4)
res <- colSums(t(N)*cf)
plot(sq, res, type = "l", ylim = c(-1, 0.6))
kntAv <- knotave(knts, 3)
lines(kntAv, cf, col = "red") # add control polygon
```

min\_abs

*Find gamma given Delta***Description**

Find gamma so that squareroot of average squared distance of fitted distribution and statements is equal to Delta (using the uniroot function). This function is not meant to be called by the user, unless one is familiar with the source code.

**Usage**

```
min_abs(Delta, N, alpha, P, A, b, lb, ub, dplus = 0)
```

**Arguments**

Delta	Average root of squared error to be achieved with fitted distribution.
N	Matrix containing the B-spline basis functions evaluated at the elicited quantiles.
alpha	Vector giving the levels of the elicited quantiles.
P	Penalty matrix (called Omega in reference below).
A, b	Matrix and vector containing the specifying the constraints $A'b \geq 0$ .
lb, ub	lower and upper bound to search for gamma.
dplus	offset integral needed when divergence instead of entropy is used.

**Value**

Returns gamma

**Author(s)**

Bjoern Bornkamp

**References**

Bornkamp, B. and Ickstadt, K. (2009). A Note on B-Splines for Semiparametric Elicitation. *The American Statistician*, **63**, 373–377

**See Also**

[uniroot](#), [solve.QP](#)

---

plot.SEL	<i>Plotting an SEL object</i>
----------	-------------------------------

---

**Description**

This function displays a fitted SEL object and displays the expert's cdf or pdf (depending on the `deriv` argument)

**Usage**

```
## S3 method for class 'SEL'
plot(x, ..., type = c("density", "cdf"), deriv,
     points = TRUE, n = 101, xlab="", ylab="", ylim)
```

**Arguments**

<code>x</code>	An SEL object.
<code>...</code>	Additional arguments to plot function.
<code>type</code>	Determines whether to plot the expert's density or cdf (only if <code>deriv</code> is missing).
<code>deriv</code>	Determines which derivative of the expert's distribution should be plotted. If specified the <code>type</code> argument is ignored.
<code>points</code>	Logical indicating whether elicited quantiles should be displayed, when displaying the cdf.
<code>n</code>	Integer, number of points used for plotting.
<code>xlab, ylab</code>	Label of x-axis and y-axis.
<code>ylim</code>	Limits of y axis.

**Author(s)**

Bjoern Bornkamp

**References**

Bornkamp, B. and Ickstadt, K. (2009). A Note on B-Splines for Semiparametric Elicitation. *The American Statistician*, **63**, 373–377

**See Also**

[comparePlot](#), [SEL](#)

**Examples**

```
# example from O'Hagan et al. (2006)
x <- c(177.5, 183.75, 190, 205, 220)
y <- c(0.175, 0.33, 0.5, 0.75, 0.95)

fit <- SEL(x, y, Delta = 0.05, bounds = c(165, 250))
plot(fit)
plot(fit, type = "cdf")
plot(fit, deriv = 1)
```

---

predict.SEL

*Evaluate the expert's density (or cdf)*


---

**Description**

Evaluate the density or cdf of an SEL object.

**Usage**

```
## S3 method for class 'SEL'
predict(object, newdata = seq(object$bounds[1],
  object$bounds[2], length = 101), type = c("density", "cdf"), deriv, ...)
```

**Arguments**

object	An SEL object.
newdata	Where to evaluate the distribution.
type	Determines whether to evaluate the expert's density or cdf (only if deriv is missing).
deriv	Determines which derivative of the expert's distribution should be evaluated.
...	...

**Value**

A numeric vector

**Author(s)**

Bjoern Bornkamp

**References**

Bornkamp, B. and Ickstadt, K. (2009). A Note on B-Splines for Semiparametric Elicitation. *The American Statistician*, **63**, 373–377

**See Also**

[SEL](#)

**Examples**

```
# example from O'Hagan et al. (2006)
x <- c(177.5, 183.75, 190, 205, 220)
y <- c(0.175, 0.33, 0.5, 0.75, 0.95)

default <- SEL(x, y, Delta = 0.05, bounds = c(165, 250))
predict(default, newdata = c(200, 205))
```

---

quantSEL                      *Calculate quantiles of an SEL object.*

---

**Description**

Returns the quantiles of the fitted distribution.

**Usage**

```
quantSEL(q, object, nPoints = 1000)
```

**Arguments**

q	A vector of quantiles.
object	An SEL object.
nPoints	Number of evaluations for the brute force inversion of the expert cdf (see details).

**Details**

The inverse of the distribution function is formed by evaluating the distribution function at nPoints points and interchanging the role of dependent and independent variable when building a function interpolating the data (using `splinefun` with "monoH.FC" option). Note that there are also direct ways of inverting a B-spline function, which however turned out to be less efficient for our purposes.

**Value**

A vector of quantiles.

**Author(s)**

Bjoern Bornkamp

**References**

Bornkamp, B. and Ickstadt, K. (2009). A Note on B-Splines for Semiparametric Elicitation. *The American Statistician*, **63**, 373–377

**See Also**

[SEL](#), [splinefun](#)

**Examples**

```
## example from O'Hagan et al. (2006)
x <- c(177.5, 183.75, 190, 205, 220)
y <- c(0.175, 0.33, 0.5, 0.75, 0.95)

default <- SEL(x, y, Delta = 0.05, bounds = c(165, 250))
bernst <- SEL(x, y, d = 10, N = 0, Delta = 0.05, bounds = c(165, 250))
unifknots <- SEL(x, y, d = 3, N = 5, Delta = 0.05, bounds = c(165, 250))
lin <- SEL(x, y, d = 1, inknts = x, Delta = 0.05, bounds = c(165,250))
quantSEL(c(0.25, 0.5, 0.75), default)
quantSEL(c(0.25, 0.5, 0.75), bernst)
quantSEL(c(0.25, 0.5, 0.75), unifknots)
quantSEL(c(0.25, 0.5, 0.75), lin)
```

---

 rvSEL

*Simulate from the expert's distribution*


---

**Description**

Simulate random variables from an SEL object.

**Usage**

```
rvSEL(n, object, nPoints = 1000)
```

**Arguments**

n	Number of simulated values.
object	An SEL object.
nPoints	Number of evaluations for the brute force inversion of the expert cdf.

**Details**

The inverse of the distribution function is formed by evaluating the distribution function at nPoints points and interchanging the role of dependent and independent variable when building an function interpolating the data (using `splinefun` with "monoH.FC" option). Note that there are also direct ways of inverting a B-spline function, which however turned out to be less efficient for our purposes.

**Value**

A numeric vector containing pseudo-random variates from the expert's density.

**Author(s)**

Bjoern Bornkamp

## References

Bornkamp, B. and Ickstadt, K. (2009). A Note on B-Splines for Semiparametric Elicitation. *The American Statistician*, **63**, 373–377

## See Also

[SEL](#), [splinefun](#)

## Examples

```
## bimodal example
x2 <- c(0.1, 0.2, 0.5, 0.8, 0.9)
y2 <- c(0.2, 0.4, 0.45, 0.85, 0.99)

fit1 <- SEL(x2, y2, Delta=0.05, d = 4, inknts = x2)
fit2 <- SEL(x2, y2, Delta=0.05, d = 15, N = 0)
comparePlot(fit1, fit2, superpose = TRUE)

## sample from SEL object
xxx <- rvSEL(50000, fit1)
hist(xxx, breaks=100, freq=FALSE)
curve(predict(fit1, newdata=x), add=TRUE)
```

---

SEL

*Semiparametric Elicitation of a bounded parameter*

---

## Description

Fits a distribution to quantiles (stated for example by an expert) using B-splines with a Brier entropy penalty.

There exists a `print` and a `summary` method to display details of the fitted SEL object. The fitted density (or cdf) can be displayed with the `plot` method. Different SEL objects can be displayed in one plot with the `comparePlot` function. The fitted density (or cdf) can be evaluated with the `predict` method. The `coef` method extracts the coefficients of the fitted B-spline basis. The `quantSEL` function calculates quantiles of the fitted distribution and the `rvSEL` function generates random variables from a fitted SEL object.

## Usage

```
SEL(x, alpha, bounds = c(0, 1), d = 4, inknts = x, N, gamma, Delta,
    fitbnds = c(1e-8, 10)*diff(bounds), pistar = NULL,
    constr = c("none", "unimodal", "decreasing", "increasing"),
    mode)
```

**Arguments**

x	Numeric vector of quantiles.
alpha	Numeric vector determining the levels of the quantiles specified in x.
bounds	Vector containing the bounds for the expert's density.
N	Number of equally spaced inner knots (ignored if inknts is specified).
d	Degree of the spline (the order of the spline is d+1), values larger than 20 are to be avoided; they can lead to numerical instabilities.
inknts	Vector specifying the inner knots. If equal to NULL, the B-spline basis reduces to the Bernstein polynomial basis. Per default the inner knots are located on the values specified via x.
gamma	Parameter controlling the weight of the negative entropy in the objective function to be optimized (see Bornkamp and Ickstadt (2009)).
Delta	The code calculates the gamma parameter achieving a certain overall L2 distance between the specified quantiles and the fitted distribution function (only if gamma is not specified).
fitbnds	Numeric of length 2 for the bisection search algorithm searching for gamma giving the error Delta (only relevant if gamma is missing).
pistar	Prior density function used in Brier divergence (see Bornkamp and Ickstadt (2009)). If NULL Brier entropy is used.
constr	Character vector specifying, which shape constraint should be used, should be one of "none", "unimodal", "decreasing", "increasing".
mode	Numerical value needed when constraint = "unimodal". The code selects the knot average closest to mode as the location of the mode for the finite dimensional constraints on the coefficients of the B-spline in the optimization (note that the final density will only have a mode close to the value specified via mode).

**Value**

An SEL object containing the following entries

constr	Character determining the shape constraint used.
inknts	Inner knots.
nord	Order of the spline.
bounds	Bounds for the elicited quantity.
xalpha	List containing the specified quantiles.
Omega	Penalty matrix used for calculating Brier entropy.
coefs	Fitted coefficients of the B-spline basis.
pistar	Function handed over to SEL via the pistar argument (if any).
dplus	The d vector, only necessary when pistar is specified (see Bornkamp and Ickstadt (2009).)

**Author(s)**

Bjoern Bornkamp

**References**

Bornkamp, B. and Ickstadt, K. (2009). A Note on B-Splines for Semiparametric Elicitation. *The American Statistician*, **63**, 373–377

O'Hagan A., Buck C. E., Daneshkhah, A., Eiser, R., Garthwaite, P., Jenkinson, D., Oakley, J. and Rakow, T. (2006), *Uncertain Judgements: Eliciting Expert Probabilities*, John Wiley and Sons Inc.

Dierckx, P. (1993), *Curve and Surface Fitting with Splines*, Clarendon Press

**See Also**

[plot.SEL](#), [comparePlot](#), [quantSEL](#), [rvSEL](#)

**Examples**

```
### example from O'Hagan et al. (2006)
### 1st example in Bornkamp and Ickstadt (2009)
x <- c(177.5, 183.75, 190, 205, 220)
y <- c(0.175, 0.33, 0.5, 0.75, 0.95)
I <- SEL(x, y, d = 1, Delta = 0.015, bounds = c(165, 250), inknts = x)
II <- SEL(x, y, d = 14, N = 0, Delta = 0.015, bounds = c(165, 250))
III <- SEL(x, y, d = 4, Delta = 0.015, bounds = c(165, 250), inknts = x)
IV <- SEL(x, y, d = 4, Delta = 0.015, bounds = c(165, 250), inknts = x,
         constr = "u", mode = 185)
comparePlot(I, II, III, IV, type = "cdf")
comparePlot(I, II, III, IV, type = "density")
```

```
### bimodal example
x2 <- c(0.1, 0.2, 0.5, 0.8, 0.9)
y2 <- c(0.2, 0.4, 0.45, 0.85, 0.99)
fit1 <- SEL(x2, y2, Delta=0.05, d = 4, inknts = x2)
fit2 <- SEL(x2, y2, Delta=0.05, d = 15, N = 0)
comparePlot(fit1, fit2, superpose = TRUE)
```

```
### sample from SEL object and evaluate density
xxx <- rvSEL(50000, fit1)
hist(xxx, breaks=100, freq=FALSE)
curve(predict(fit1, newdata=x), add=TRUE)
```

```
### illustrate shrinkage against uniform dist.
gma01 <- SEL(x2, y2, gamma = 0.1)
gma02 <- SEL(x2, y2, gamma = 0.2)
gma04 <- SEL(x2, y2, gamma = 0.4)
```

```

gma10 <- SEL(x2, y2, gamma = 1.0)
comparePlot(gma01, gma02, gma04, gma10, superpose = TRUE)

### including shape constraints
x <- c(177.5, 183.75, 190, 205, 220)
y <- c(0.175, 0.33, 0.5, 0.75, 0.95)
unconstr1 <- SEL(x, y, Delta = 0.05, bounds = c(165, 250))
unconstr2 <- SEL(x, y, d = 10, N = 0, Delta = 0.05, bounds = c(165,250))
unimod1 <- SEL(x, y, Delta = 0.05, bounds = c(165, 250),
  constr = "unimodal", mode = 185)
unimod2 <- SEL(x, y, d = 10, N = 0, Delta = 0.05, bounds = c(165, 250),
  constr = "unimodal", mode = 185)
comparePlot(unconstr1, unconstr2, unimod1, unimod2)

### shrinkage against another distribution
pr <- function(x) dbeta(x, 2, 2)
pr01 <- SEL(x2, y2, gamma = 0.1, d = 3, pstar = pr)
pr03 <- SEL(x2, y2, gamma = 0.3, d = 3, pstar = pr)
pr12 <- SEL(x2, y2, gamma = 1.2, pstar = pr)
comparePlot(pr01, pr03, pr12, superpose = TRUE)

### 2nd example from Bornkamp and Ickstadt (2009)
# theta
# "true" density
pmixbeta <- function(x, a1, b1, a2, b2){
  0.3*pbeta(x/20,a1,b1)+0.7*pbeta(x/20,a2,b2)
}
dmixbeta <- function(x, a1, b1, a2, b2){
  out <- 0.3*dbeta(x/20,a1,b1)+0.7*dbeta(x/20,a2,b2)
  out/20
}
x <- c(2,10,15)
a1 <- 1;a2 <- 10;b1 <- 15;b2 <- 5
mu <- pmixbeta(x, a1, b1, a2, b2)
set.seed(1) # simulate experts statements
y <- rnorm(length(mu), mu, sqrt(mu*(1-mu)*0.05^2))
thet <- SEL(x, y, d = 4, Delta = 0.03, bounds = c(0, 20), inknts = x)
plot(thet, ylim = c(0,0.25))
curve(dmixbeta(x, a1, b1, a2, b2), add=TRUE, col="red")
abline(h=0.05, lty = 2)
legend("topright", c("true density", "elicited density", "uniform density"),
  col=c(2,1,1), lty=c(1,1,2))

# sigma
# "true" density
dtriang <- function(x,m,a,b){
  inds <- x < m;res <- numeric(length(x))

```

```

res[inds] <- 2*(x[inds]-a)/((b-a)*(m-a))
res[!inds] <- 2*(b-x[!inds])/((b-a)*(b-m))
res
}
ptriang <- function(x,m,a,b){
  inds <- x < m;res <- numeric(length(x))
  res[inds] <- (x[inds]-a)^2/((b-a)*(m-a))
  res[!inds] <- 1-(b-x[!inds])^2/((b-a)*(b-m))
  res
}
x <- c(1,2,4)
mu <- ptriang(x, 1, 0, 5)
set.seed(1) # simulate experts statements
y <- rnorm(length(mu), mu, sqrt(mu*(1-mu)*0.05^2))
sig <- SEL(x, y, d = 4, Delta = 0.03, bounds = c(0, 5),
  inknts = x, mode = 1, constr="unimodal")
plot(sig, ylim=c(0,0.4))
curve(dtriang(x, 1, 0, 5), add=TRUE, col="red")
abline(h=0.2, lty = 2)
legend("topright", c("true density", "elicited density", "uniform density"),
  col=c(2,1,1), lty=c(1,1,2))

## Not run:
### generate some random elicitation
numb <- max(rnbinom(1, mu = 4, size = 1), 1)
x0 <- runif(1, -1000, 1000)
x1 <- x0+runif(1, 0, 1000)
xs <- sort(runif(numb, x0, x1))
y <- runif(numb+1)
ys <- (cumsum(y)/sum(y))[1:numb]
fit1 <- SEL(xs, ys, bounds = c(x0, x1))
fit2 <- SEL(xs, ys, d = 1, inknts = xs, bounds = c(x0, x1))
fit3 <- SEL(xs, ys, d = 15, N = 0, bounds = c(x0, x1))
comparePlot(fit1, fit2, fit3, type="cdf")

## End(Not run)

```

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