ir_choc_calibration_with_pca

2022-05-21

R Markdown : Interest rate term structure choc calibration using Principal component analysis (PCA) (Solvency II default calibration method)

```
library(FactoMineR)
library(RcppRoll)
library(factoextra)
```

```
## Loading required package: ggplot2
```

```
## Welcome! Want to learn more? See two factoextra-related books at https://goo.gl/ve3WBa
```

```
library(ggplot2)
library(reshape2)
library(xts)
```

```
## Loading required package: zoo
```

```
##
## Attaching package: 'zoo'
```

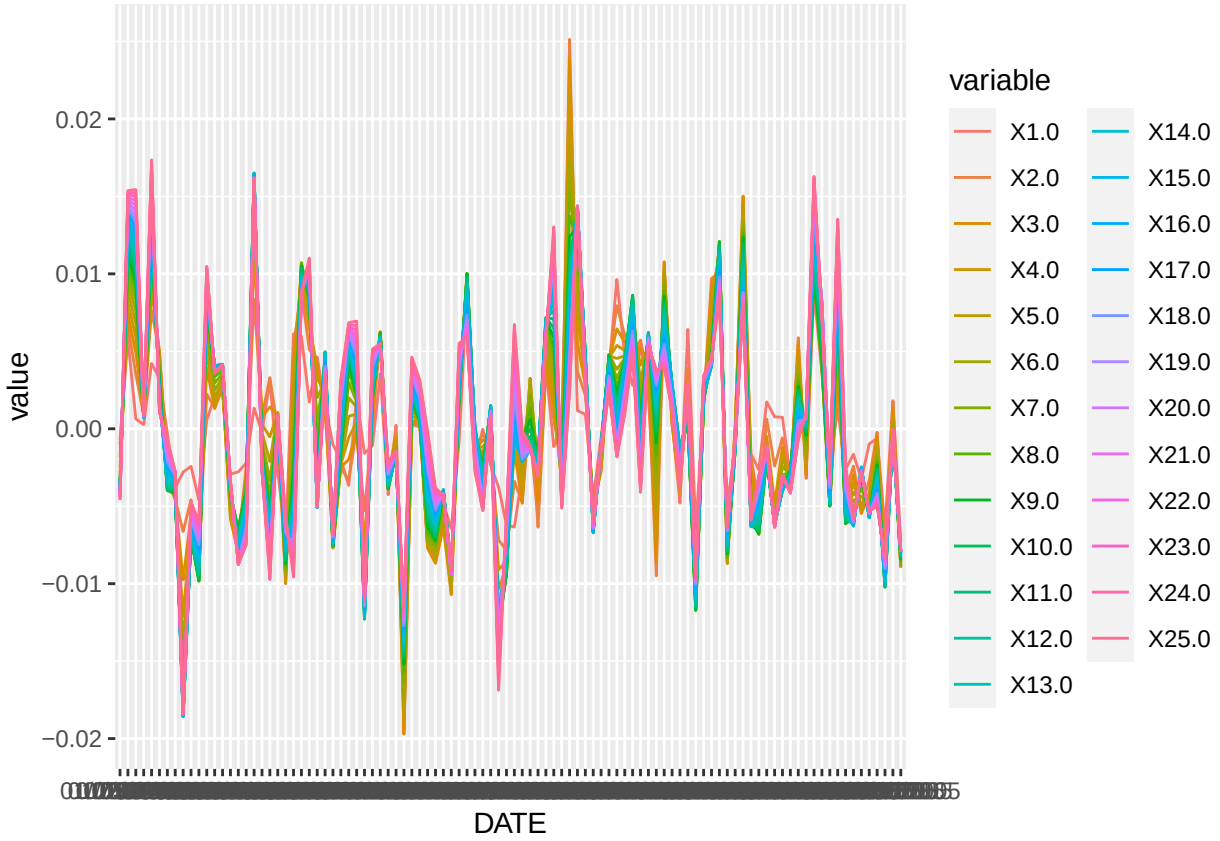
```
## The following objects are masked from 'package:base':
##
##     as.Date, as.Date.numeric
```

```
library(reshape2)
```

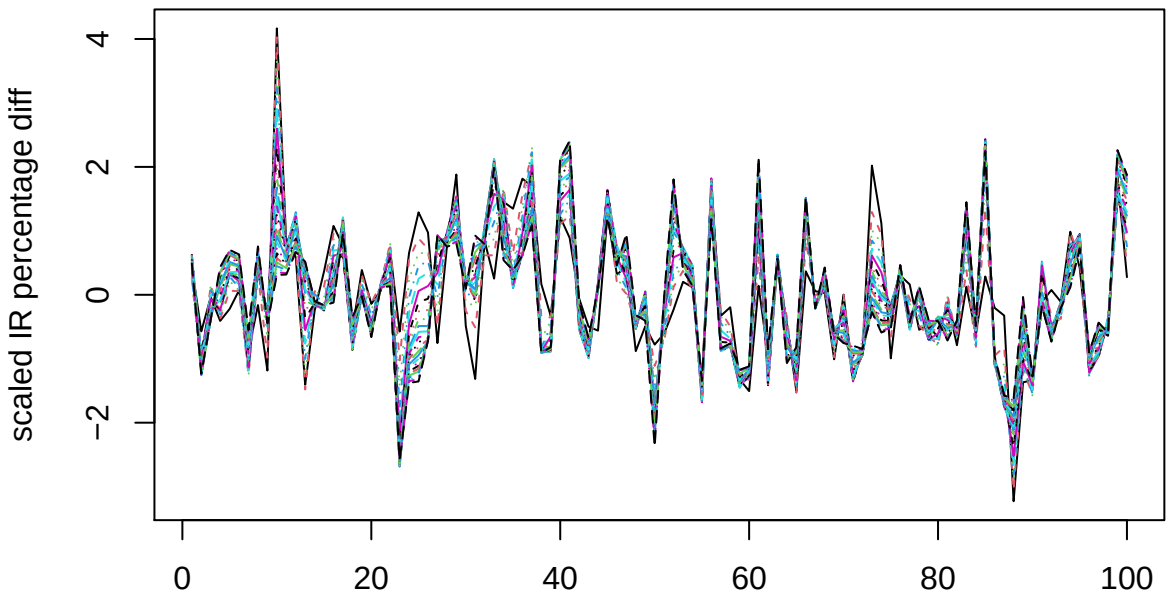
```
#############################################################################################################
# Lecture des données de de la courbe de taux
data_origin <- read.csv("~/Documents/projet_sta217/sta217/data/GLC Nominal daily data_2005 to 2020.csv"
#############################################################################################################
# Lecture des données de variation de la courbe de taux
data <- read.csv("data/GLC_Nominal_daily_data_2005_to_2020_return.csv", header=TRUE, sep = ";", dec = "
```

```
# Représentation des données :
ggplot(melt(data[,1:26]), aes(DATE, value, group=variable, color=variable)) + geom_line(show.legend = TR
```

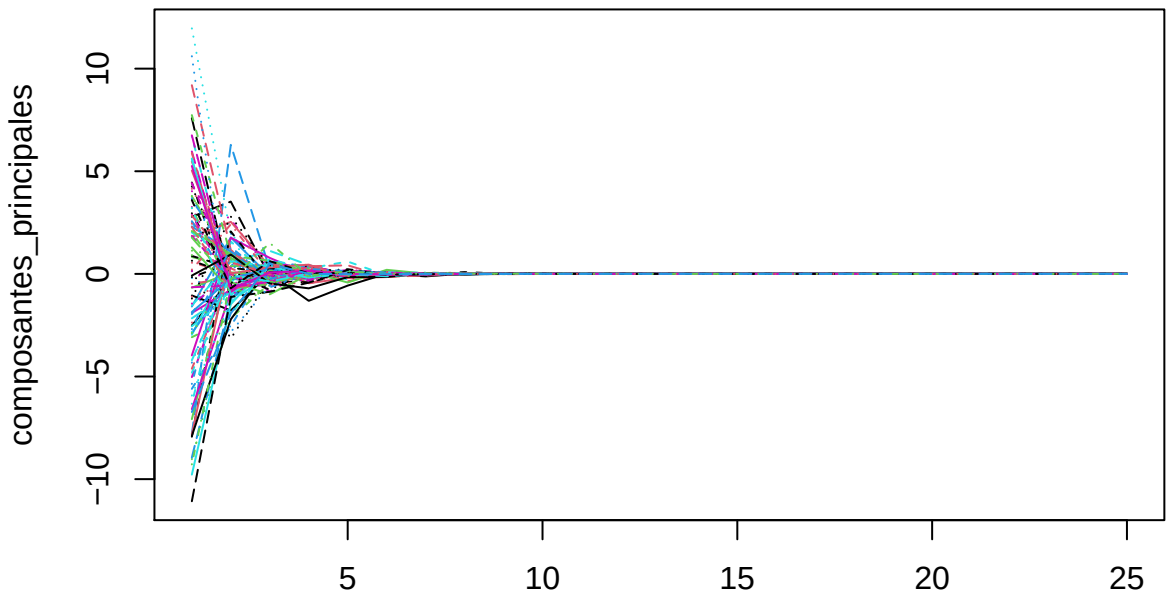
```
## Using DATE as id variables
```



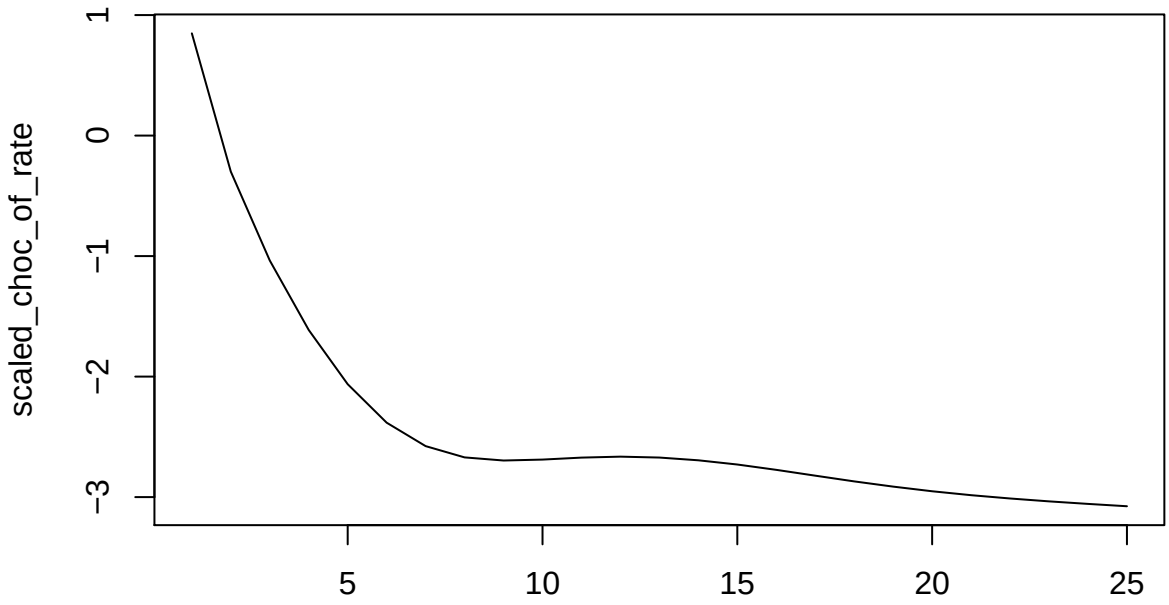

```
# scale les colonnes des données : centre et réduit les données de chaque colonne individuellement
# chaque maturité est centrée et réduite individuellement.
# On peut faire l'hypothèse de la normalité (0,1) des variables qui sont des rendements journaliers des
scaledSpotPctDiff <- scale(data[,2:26])
each_column_mean <- apply(data[,2:26], 2, mean)
each_column_var <- apply(data[,2:26], 2, var)
# Représentation des données :
matplot(as.data.frame(scaledSpotPctDiff),type="l", ylab = "scaled IR percentage diff")
```



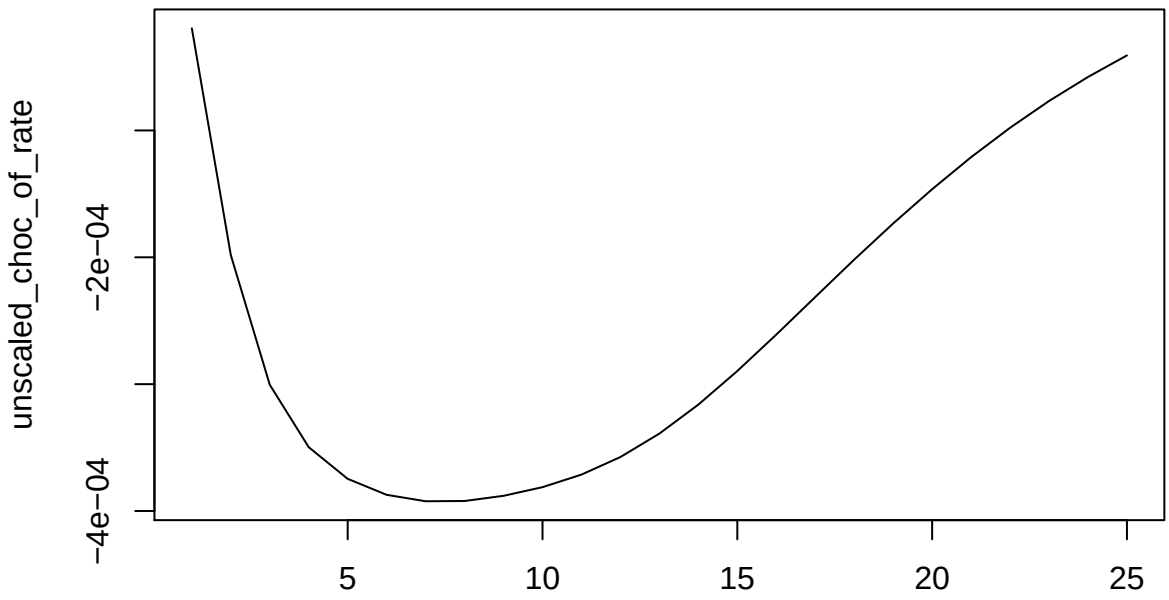

```r
# Decomposition en elements propres (vecteur et valeurs propres) de la matrice des correlations.
# Chaque variable étant centrée et réduite : la matrice des corrélations est égale à celle de des covar
pca <- eigen(cor(scaledSpotPctDiff))

#res.pca <- PCA(scaledSpotPctDiff, scale.unit = FALSE, graph = TRUE, ncp = 25)
# Valeurs propres résultantes de la décomposition en element propres : variances des composantes princi
valeurs_propres <- pca$values
valeurs_propres <- replace(valeurs_propres, valeurs_propres<0, 0)

# Vecteurs propres résultantes de la décomposition en éléments propres :
vecteurs_propres <- pca$vectors

# Niveau de Variance expliquée par PC : pourcentage de variance expliquée par chaque composantes princi
variance_explic <- pca$values/sum(pca$values)

# Calcul des composantes principales : les composantes principales sont les représentation des données
composantes_principales <- data.matrix(scaledSpotPctDiff) %*% vecteurs_propres
matplot(t(composantes_principales), type = "l", ylab = "composantes_principales")
```



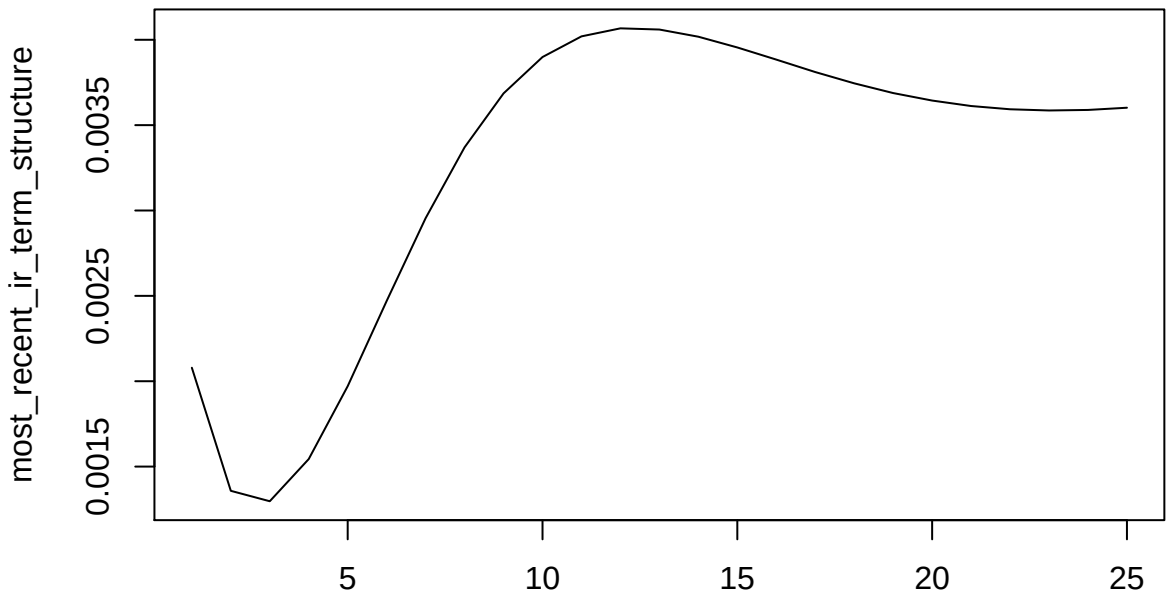

```r
# Les composantes principales étant des variables indépendantes, on peut calculer les Value at risk ind
# qu'on ramenera ensuite dans le plan des variables initiales (des données initiales).
# En supposant les composantes principales de loi normale (TODO : test de normalité sur chaque composan
value_at_risk <- valeurs_propres^.5 * qnorm(.995)

# Var historique : peut etre calculée également.
# On ramene les value at risk dans le referentiel des variables initiales des données initiales/ (si de
scaled_choc_of_rate <- value_at_risk %*% solve(vecteurs_propres)
matplot(t(scaled_choc_of_rate), type = "l", ylab = "scaled_choc_of_rate")
```



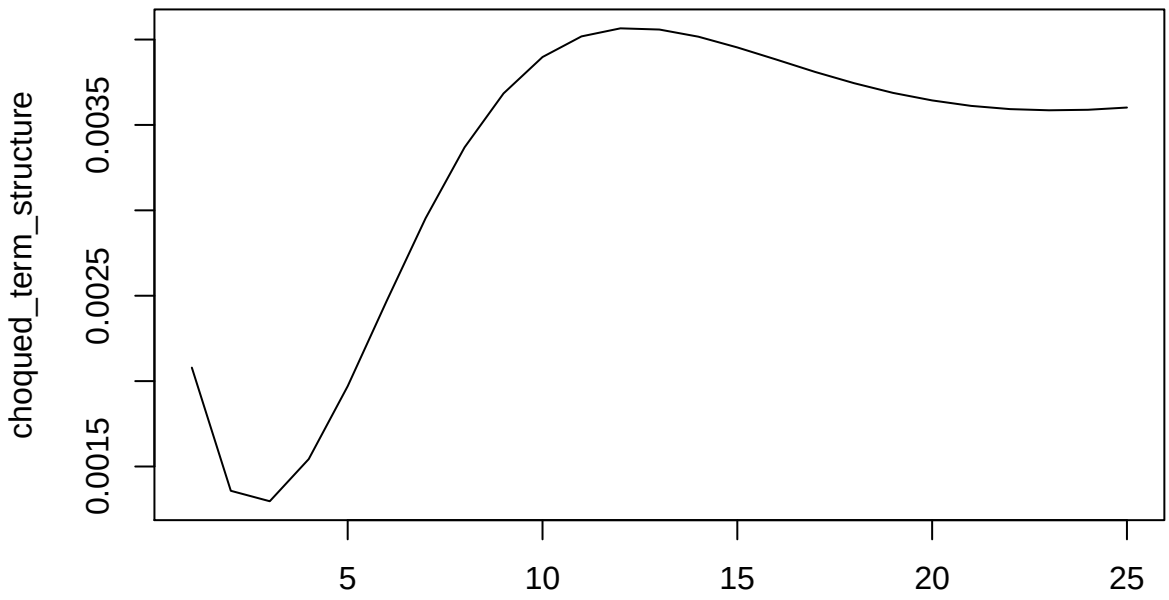

```
# Unscaled the choc rate
unscaled_choc_of_rate = scaled_choc_of_rate * each_column_var + each_column_mean
matplot(t(unscaled_choc_of_rate), type = "l", ylab = "unscaled_choc_of_rate")
```




```
# to obtain the choqued interest rate term structure based on the spot interest rate term structure <-
choqued_term_structure <- data[1,2:26] * (1 + unscaled_choc_of_rate)
matplot(t(data[1,2:26]), type = "l", ylab = "most_recent_ir_term_structure")
```




```
matplot(t(choqued_term_structure), type = "l", ylab = "choqued_term_structure")
```



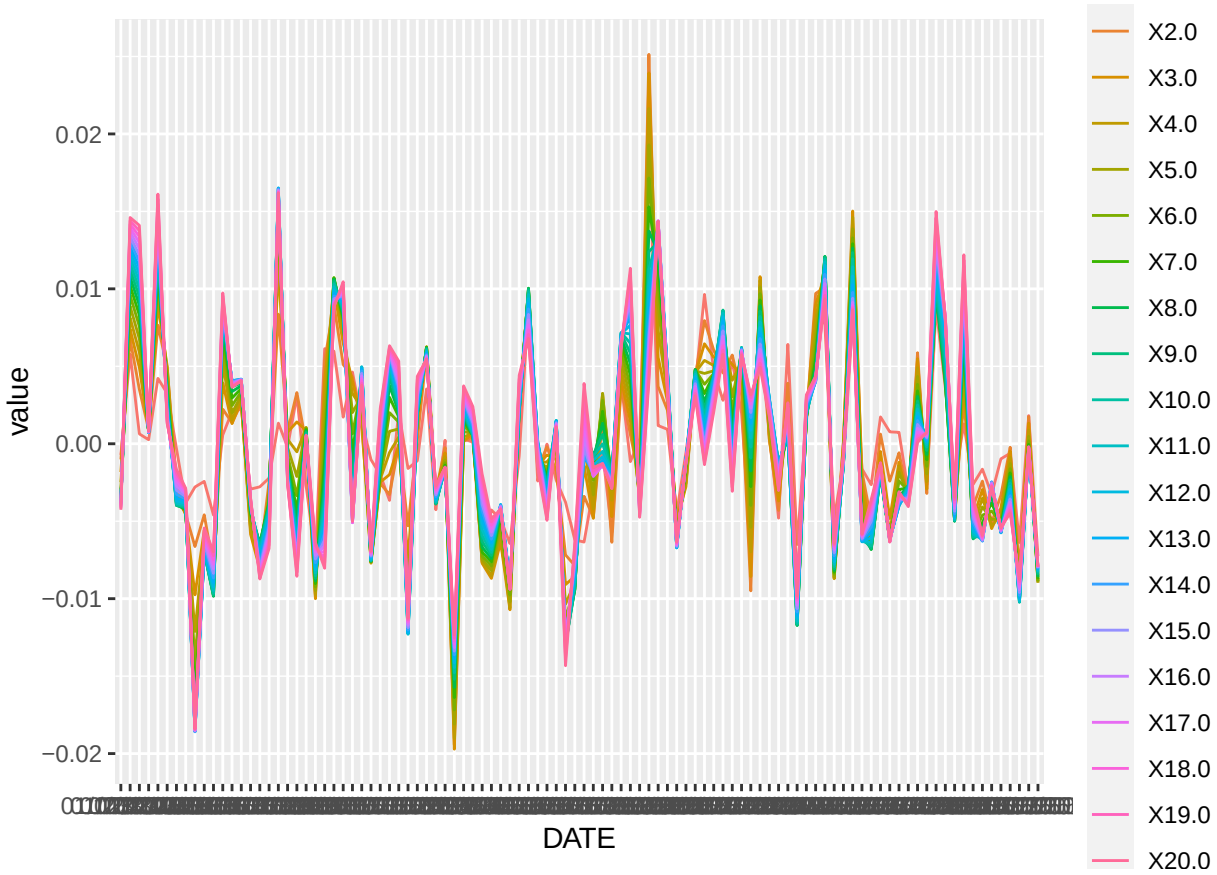

```
#
```

```
# Develop the shocked pc's and the rateShocks
# pcaShockUp <- pca$vectors * eigenGoodForm^.5 * qnorm(.995)
# rateShockUp <- (1+pcaShockUp*stdevRateGoodForm *sqrt(12))* lastRateGoodForm
```

```
# Représentation des données :
data_plot =  melt(data[,1:21])
```

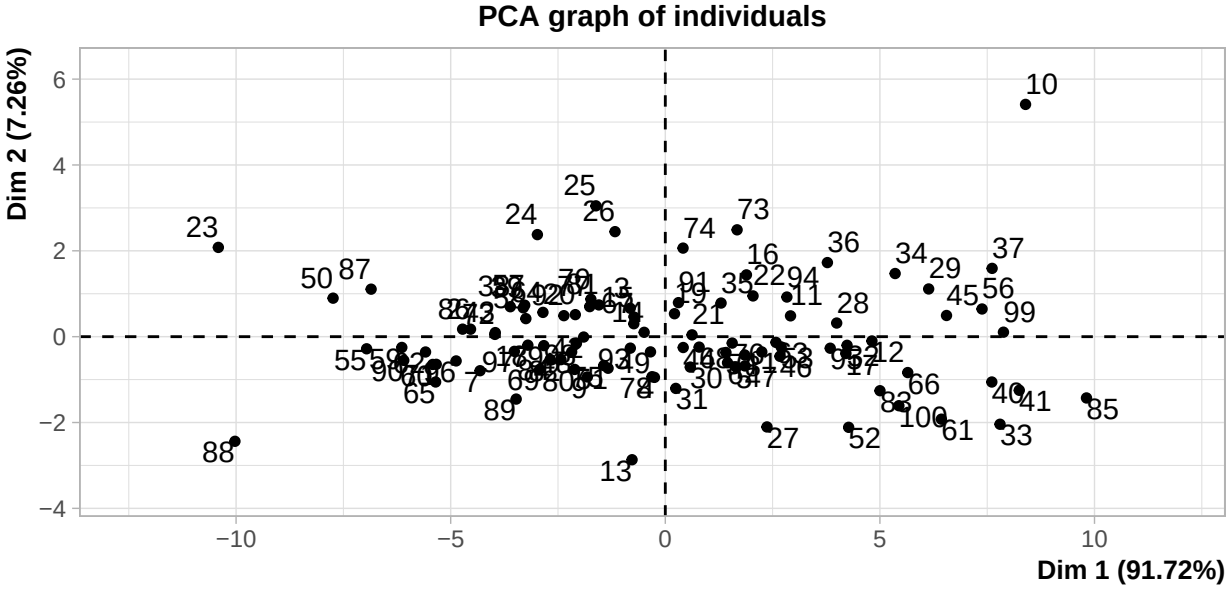
```
## Using DATE as id variables
```

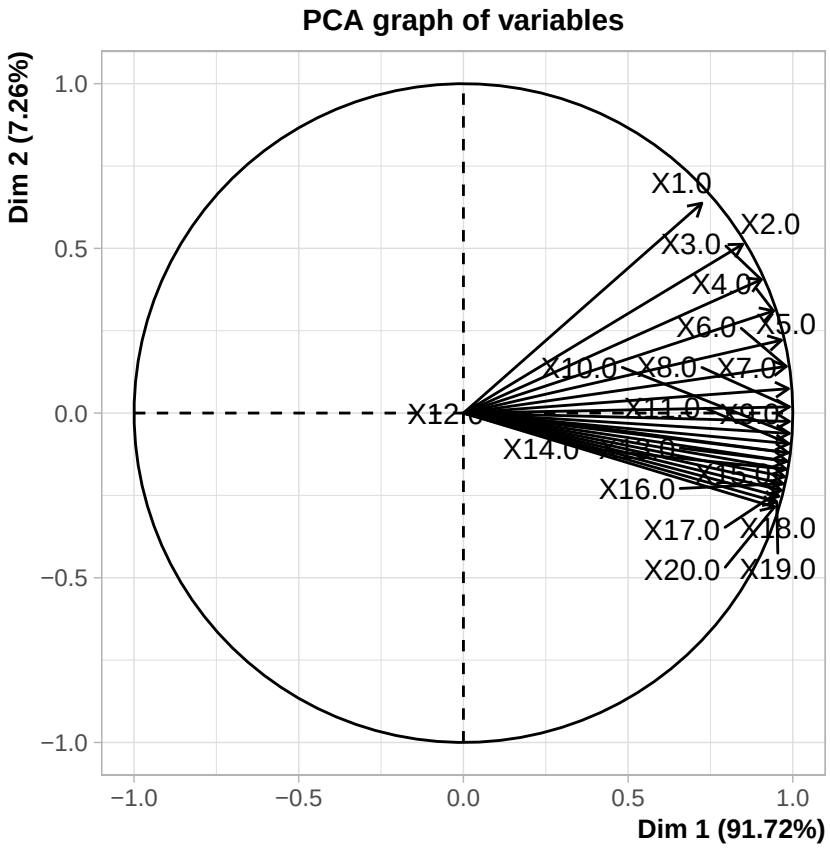
```
ggplot(data_plot, aes(DATE, value, group=variable, color=variable)) + geom_line(show.legend = TRUE)
```



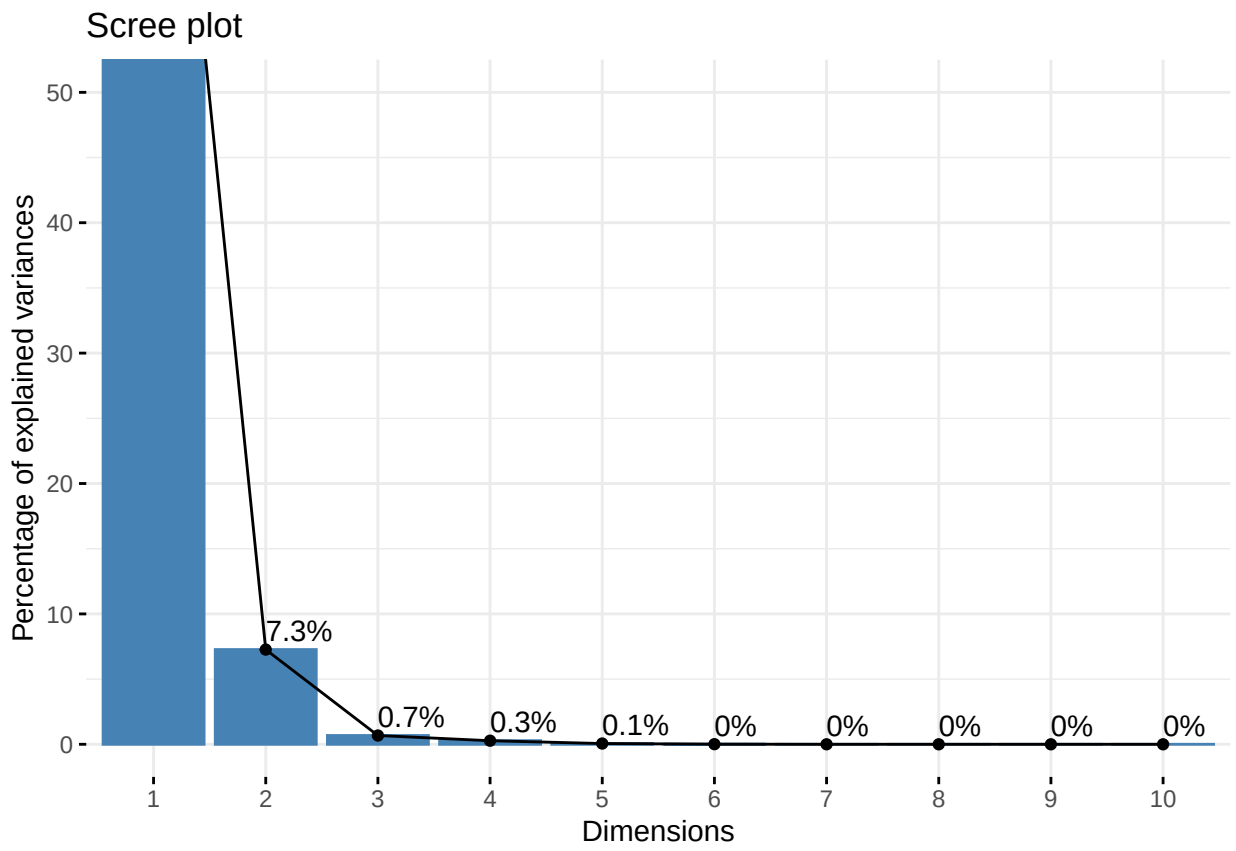

```
# Elimination de la colonne date pour ne traiter que les taux de return
data.active = data.matrix(data[,2:21])

# Annualisation des données journalières puis on centre et réduction des données
# data.active = apply(X = data.active+1, 2,  RcppRoll::roll_prod, n=250)-1
data.active = data.matrix(scale(data.active))
```

```
# Pour visualiser les niveaux de variances explliqués
res.pca <- PCA(data.active, scale.unit = FALSE, ncp = 4, graph = TRUE)
```


PCA graph of individuals
Dim 2 (7.26%)
Dim 1 (91.72%)
6
4
2
0
−2
−4
−10
−5
0
5
10
10
25
24
26
73
23
74
36
16
34
37
50
87
29
56
45
99
28
11
21
55
12
66
40
41
85
65
89
31
27
52
83
100
61
33
88
13



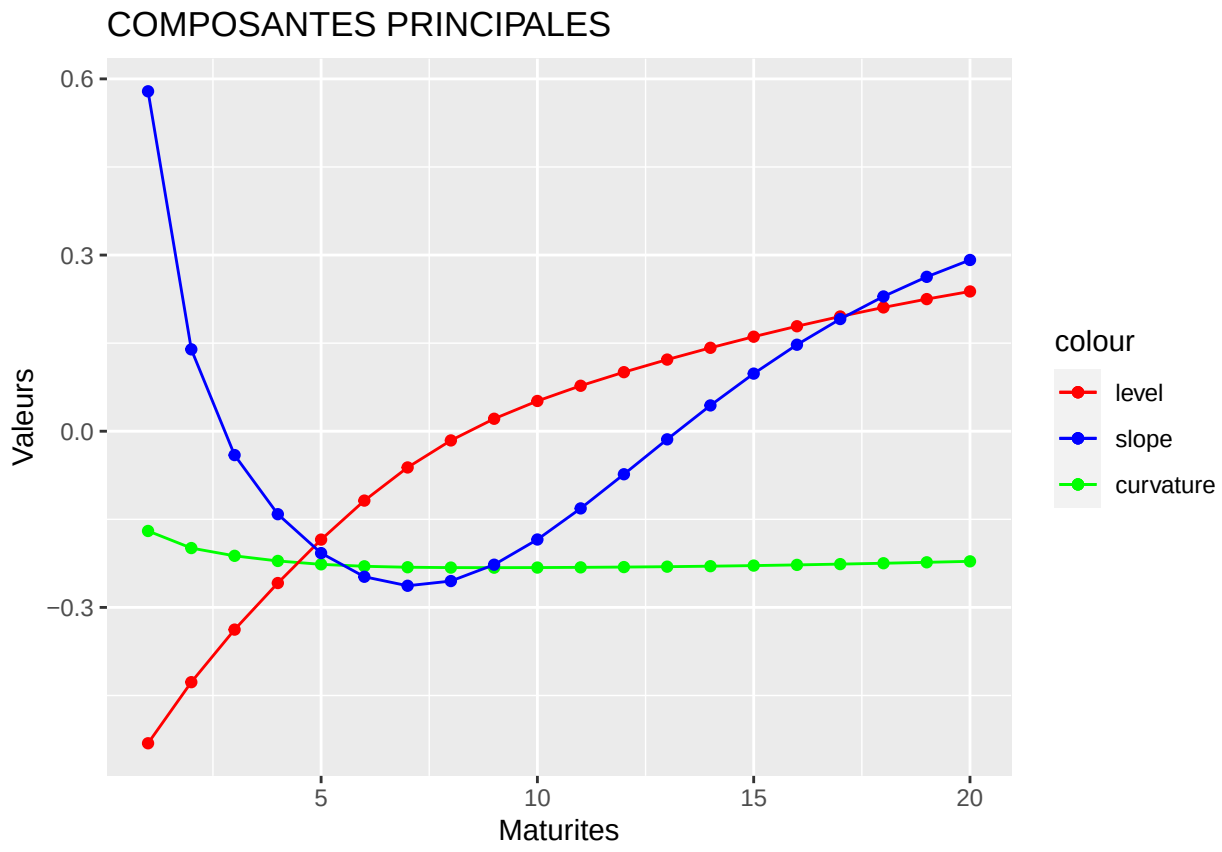

```
fviz_eig(res.pca, addlabels = TRUE, ylim = c(0, 50))
```




```
get_eigenvalue(res.pca)
```

```
##          eigenvalue variance.percent cumulative.variance.percent
## Dim.1  1.816022e+01     9.171830e+01                    91.71830
## Dim.2  1.438281e+00     7.264046e+00                    98.98235
## Dim.3  1.332998e-01     6.732315e-01                    99.65558
## Dim.4  5.451907e-02     2.753489e-01                    99.93093
## Dim.5  1.161586e-02     5.866594e-02                    99.98960
## Dim.6  1.815922e-03     9.171321e-03                    99.99877
## Dim.7  2.007794e-04     1.014037e-03                    99.99978
## Dim.8  3.475001e-05     1.755051e-04                    99.99996
## Dim.9  7.614324e-06     3.845618e-05                   100.00000
## Dim.10 7.434775e-07     3.754937e-06                   100.00000
## Dim.11 1.398698e-07     7.064129e-07                   100.00000
## Dim.12 2.271219e-08     1.147080e-07                   100.00000
## Dim.13 6.239980e-09     3.151505e-08                   100.00000
## Dim.14 3.075197e-09     1.553130e-08                   100.00000
## Dim.15 2.515580e-09     1.270495e-08                   100.00000
## Dim.16 2.262286e-09     1.142569e-08                   100.00000
## Dim.17 1.536139e-09     7.758276e-09                   100.00000
## Dim.18 1.459185e-09     7.369619e-09                   100.00000
## Dim.19 1.303984e-09     6.585777e-09                   100.00000
## Dim.20 1.099262e-09     5.551830e-09                   100.00000
```

```r
# Choix du nombre de composantes principales / suite aux résultats de l'ACP donnant les nivaux de varia
n_pc = 3

# Valeurs propres et vecteurs propres des donnees originales annualisees
vectval_propres = eigen(cov(data.active))

vect_propre = vectval_propres$vectors[,1:n_pc]
colnames(vect_propre) <- c('level', 'slope', 'curvature')
vect_propre = as.data.frame(vect_propre)

val_propre = vectval_propres$values[1:n_pc]

# Plot des valeurs propres et des vecteurs propres
vect_propre_plot = vect_propre
vect_propre_plot$maturite=c(1:ncol(data.active))
ggplot(vect_propre_plot) +
  geom_line(aes(x = maturite, y = level,  color = "red")) + geom_point(aes(x = maturite, y = level, col
  geom_line(aes(x = maturite, y = slope, color = "blue")) + geom_point(aes(x = maturite, y = slope, col
  geom_line(aes(x = maturite, y = curvature, color = "green")) + geom_point(aes(x = maturite, y = curva
  scale_color_manual(labels = c("level", "slope", "curvature"), values = c("red", "blue", "green")) +
  labs(title = "COMPOSANTES PRINCIPALES", x = "Maturites", y ="Valeurs")
```




```r
theme_bw() + guides(color=guide_legend("Axes principaux"))
```

```
## List of 94
```

```
##  $ line                     :List of 6
##   ..$ colour       : chr "black"
##   ..$ size         : num 0.5
##   ..$ linetype     : num 1
##   ..$ lineend      : chr "butt"
##   ..$ arrow        : logi FALSE
##   ..$ inherit.blank: logi TRUE
##   ..- attr(*, "class")= chr [1:2] "element_line" "element"
##  $ rect                     :List of 5
##   ..$ fill         : chr "white"
##   ..$ colour       : chr "black"
##   ..$ size         : num 0.5
##   ..$ linetype     : num 1
##   ..$ inherit.blank: logi TRUE
##   ..- attr(*, "class")= chr [1:2] "element_rect" "element"
##  $ text                     :List of 11
##   ..$ family       : chr ""
##   ..$ face         : chr "plain"
##   ..$ colour       : chr "black"
##   ..$ size         : num 11
##   ..$ hjust        : num 0.5
##   ..$ vjust        : num 0.5
##   ..$ angle        : num 0
##   ..$ lineheight   : num 0.9
##   ..$ margin       : 'margin' num [1:4] 0points 0points 0points 0points
##   .. ..- attr(*, "unit")= int 8
##   ..$ debug        : logi FALSE
##   ..$ inherit.blank: logi TRUE
##   ..- attr(*, "class")= chr [1:2] "element_text" "element"
##  $ title                    : NULL
##  $ aspect.ratio             : NULL
##  $ axis.title               : NULL
##  $ axis.title.x             :List of 11
##   ..$ family       : NULL
##   ..$ face         : NULL
##   ..$ colour       : NULL
##   ..$ size         : NULL
##   ..$ hjust        : NULL
##   ..$ vjust        : num 1
##   ..$ angle        : NULL
##   ..$ lineheight   : NULL
##   ..$ margin       : 'margin' num [1:4] 2.75points 0points 0points 0points
##   .. ..- attr(*, "unit")= int 8
##   ..$ debug        : NULL
##   ..$ inherit.blank: logi TRUE
##   ..- attr(*, "class")= chr [1:2] "element_text" "element"
##  $ axis.title.x.top         :List of 11
##   ..$ family       : NULL
##   ..$ face         : NULL
##   ..$ colour       : NULL
##   ..$ size         : NULL
##   ..$ hjust        : NULL
##   ..$ vjust        : num 0
##   ..$ angle        : NULL
```

```
##   ..$ lineheight   : NULL
##   ..$ margin       : 'margin' num [1:4] 0points 0points 2.75points 0points
##   .. ..- attr(*, "unit")= int 8
##   ..$ debug        : NULL
##   ..$ inherit.blank: logi TRUE
##   ..- attr(*, "class")= chr [1:2] "element_text" "element"
##  $ axis.title.x.bottom       : NULL
##  $ axis.title.y              :List of 11
##   ..$ family       : NULL
##   ..$ face         : NULL
##   ..$ colour       : NULL
##   ..$ size         : NULL
##   ..$ hjust        : NULL
##   ..$ vjust        : num 1
##   ..$ angle        : num 90
##   ..$ lineheight   : NULL
##   ..$ margin       : 'margin' num [1:4] 0points 2.75points 0points 0points
##   .. ..- attr(*, "unit")= int 8
##   ..$ debug        : NULL
##   ..$ inherit.blank: logi TRUE
##   ..- attr(*, "class")= chr [1:2] "element_text" "element"
##  $ axis.title.y.left         : NULL
##  $ axis.title.y.right        :List of 11
##   ..$ family       : NULL
##   ..$ face         : NULL
##   ..$ colour       : NULL
##   ..$ size         : NULL
##   ..$ hjust        : NULL
##   ..$ vjust        : num 0
##   ..$ angle        : num -90
##   ..$ lineheight   : NULL
##   ..$ margin       : 'margin' num [1:4] 0points 0points 0points 2.75points
##   .. ..- attr(*, "unit")= int 8
##   ..$ debug        : NULL
##   ..$ inherit.blank: logi TRUE
##   ..- attr(*, "class")= chr [1:2] "element_text" "element"
##  $ axis.text                 :List of 11
##   ..$ family       : NULL
##   ..$ face         : NULL
##   ..$ colour       : chr "grey30"
##   ..$ size         : 'rel' num 0.8
##   ..$ hjust        : NULL
##   ..$ vjust        : NULL
##   ..$ angle        : NULL
##   ..$ lineheight   : NULL
##   ..$ margin       : NULL
##   ..$ debug        : NULL
##   ..$ inherit.blank: logi TRUE
##   ..- attr(*, "class")= chr [1:2] "element_text" "element"
##  $ axis.text.x               :List of 11
##   ..$ family       : NULL
##   ..$ face         : NULL
##   ..$ colour       : NULL
##   ..$ size         : NULL
```

```
##   ..$ hjust        : NULL
##   ..$ vjust        : num 1
##   ..$ angle        : NULL
##   ..$ lineheight   : NULL
##   ..$ margin       : 'margin' num [1:4] 2.2points 0points 0points 0points
##   .. ..- attr(*, "unit")= int 8
##   ..$ debug        : NULL
##   ..$ inherit.blank: logi TRUE
##   ..- attr(*, "class")= chr [1:2] "element_text" "element"
##  $ axis.text.x.top           :List of 11
##   ..$ family       : NULL
##   ..$ face         : NULL
##   ..$ colour       : NULL
##   ..$ size         : NULL
##   ..$ hjust        : NULL
##   ..$ vjust        : num 0
##   ..$ angle        : NULL
##   ..$ lineheight   : NULL
##   ..$ margin       : 'margin' num [1:4] 0points 0points 2.2points 0points
##   .. ..- attr(*, "unit")= int 8
##   ..$ debug        : NULL
##   ..$ inherit.blank: logi TRUE
##   ..- attr(*, "class")= chr [1:2] "element_text" "element"
##  $ axis.text.x.bottom        : NULL
##  $ axis.text.y               :List of 11
##   ..$ family       : NULL
##   ..$ face         : NULL
##   ..$ colour       : NULL
##   ..$ size         : NULL
##   ..$ hjust        : num 1
##   ..$ vjust        : NULL
##   ..$ angle        : NULL
##   ..$ lineheight   : NULL
##   ..$ margin       : 'margin' num [1:4] 0points 2.2points 0points 0points
##   .. ..- attr(*, "unit")= int 8
##   ..$ debug        : NULL
##   ..$ inherit.blank: logi TRUE
##   ..- attr(*, "class")= chr [1:2] "element_text" "element"
##  $ axis.text.y.left          : NULL
##  $ axis.text.y.right         :List of 11
##   ..$ family       : NULL
##   ..$ face         : NULL
##   ..$ colour       : NULL
##   ..$ size         : NULL
##   ..$ hjust        : num 0
##   ..$ vjust        : NULL
##   ..$ angle        : NULL
##   ..$ lineheight   : NULL
##   ..$ margin       : 'margin' num [1:4] 0points 0points 0points 2.2points
##   .. ..- attr(*, "unit")= int 8
##   ..$ debug        : NULL
##   ..$ inherit.blank: logi TRUE
##   ..- attr(*, "class")= chr [1:2] "element_text" "element"
##  $ axis.ticks                :List of 6
```

```
##   ..$ colour       : chr "grey20"
##   ..$ size         : NULL
##   ..$ linetype     : NULL
##   ..$ lineend      : NULL
##   ..$ arrow        : logi FALSE
##   ..$ inherit.blank: logi TRUE
##   ..- attr(*, "class")= chr [1:2] "element_line" "element"
##  $ axis.ticks.x              : NULL
##  $ axis.ticks.x.top          : NULL
##  $ axis.ticks.x.bottom       : NULL
##  $ axis.ticks.y              : NULL
##  $ axis.ticks.y.left         : NULL
##  $ axis.ticks.y.right        : NULL
##  $ axis.ticks.length         : 'simpleUnit' num 2.75points
##   ..- attr(*, "unit")= int 8
##  $ axis.ticks.length.x       : NULL
##  $ axis.ticks.length.x.top   : NULL
##  $ axis.ticks.length.x.bottom: NULL
##  $ axis.ticks.length.y       : NULL
##  $ axis.ticks.length.y.left  : NULL
##  $ axis.ticks.length.y.right : NULL
##  $ axis.line                 : list()
##   ..- attr(*, "class")= chr [1:2] "element_blank" "element"
##  $ axis.line.x               : NULL
##  $ axis.line.x.top           : NULL
##  $ axis.line.x.bottom        : NULL
##  $ axis.line.y               : NULL
##  $ axis.line.y.left          : NULL
##  $ axis.line.y.right         : NULL
##  $ legend.background         :List of 5
##   ..$ fill         : NULL
##   ..$ colour       : logi NA
##   ..$ size         : NULL
##   ..$ linetype     : NULL
##   ..$ inherit.blank: logi TRUE
##   ..- attr(*, "class")= chr [1:2] "element_rect" "element"
##  $ legend.margin             : 'margin' num [1:4] 5.5points 5.5points 5.5points 5.5points
##   ..- attr(*, "unit")= int 8
##  $ legend.spacing            : 'simpleUnit' num 11points
##   ..- attr(*, "unit")= int 8
##  $ legend.spacing.x          : NULL
##  $ legend.spacing.y          : NULL
##  $ legend.key                :List of 5
##   ..$ fill         : chr "white"
##   ..$ colour       : logi NA
##   ..$ size         : NULL
##   ..$ linetype     : NULL
##   ..$ inherit.blank: logi TRUE
##   ..- attr(*, "class")= chr [1:2] "element_rect" "element"
##  $ legend.key.size           : 'simpleUnit' num 1.2lines
##   ..- attr(*, "unit")= int 3
##  $ legend.key.height         : NULL
##  $ legend.key.width          : NULL
##  $ legend.text               :List of 11
```

```
##   ..$ family       : NULL
##   ..$ face         : NULL
##   ..$ colour       : NULL
##   ..$ size         : 'rel' num 0.8
##   ..$ hjust        : NULL
##   ..$ vjust        : NULL
##   ..$ angle        : NULL
##   ..$ lineheight   : NULL
##   ..$ margin       : NULL
##   ..$ debug        : NULL
##   ..$ inherit.blank: logi TRUE
##   ..- attr(*, "class")= chr [1:2] "element_text" "element"
##  $ legend.text.align         : NULL
##  $ legend.title              :List of 11
##   ..$ family       : NULL
##   ..$ face         : NULL
##   ..$ colour       : NULL
##   ..$ size         : NULL
##   ..$ hjust        : num 0
##   ..$ vjust        : NULL
##   ..$ angle        : NULL
##   ..$ lineheight   : NULL
##   ..$ margin       : NULL
##   ..$ debug        : NULL
##   ..$ inherit.blank: logi TRUE
##   ..- attr(*, "class")= chr [1:2] "element_text" "element"
##  $ legend.title.align        : NULL
##  $ legend.position           : chr "right"
##  $ legend.direction          : NULL
##  $ legend.justification      : chr "center"
##  $ legend.box                : NULL
##  $ legend.box.just           : NULL
##  $ legend.box.margin         : 'margin' num [1:4] 0cm 0cm 0cm 0cm
##   ..- attr(*, "unit")= int 1
##  $ legend.box.background     : list()
##   ..- attr(*, "class")= chr [1:2] "element_blank" "element"
##  $ legend.box.spacing        : 'simpleUnit' num 11points
##   ..- attr(*, "unit")= int 8
##  $ panel.background          :List of 5
##   ..$ fill         : chr "white"
##   ..$ colour       : logi NA
##   ..$ size         : NULL
##   ..$ linetype     : NULL
##   ..$ inherit.blank: logi TRUE
##   ..- attr(*, "class")= chr [1:2] "element_rect" "element"
##  $ panel.border              :List of 5
##   ..$ fill         : logi NA
##   ..$ colour       : chr "grey20"
##   ..$ size         : NULL
##   ..$ linetype     : NULL
##   ..$ inherit.blank: logi TRUE
##   ..- attr(*, "class")= chr [1:2] "element_rect" "element"
##  $ panel.spacing             : 'simpleUnit' num 5.5points
##   ..- attr(*, "unit")= int 8
```

```
##  $ panel.spacing.x           : NULL
##  $ panel.spacing.y           : NULL
##  $ panel.grid                :List of 6
##   ..$ colour       : chr "grey92"
##   ..$ size         : NULL
##   ..$ linetype     : NULL
##   ..$ lineend      : NULL
##   ..$ arrow        : logi FALSE
##   ..$ inherit.blank: logi TRUE
##   ..- attr(*, "class")= chr [1:2] "element_line" "element"
##  $ panel.grid.major          : NULL
##  $ panel.grid.minor          :List of 6
##   ..$ colour       : NULL
##   ..$ size         : 'rel' num 0.5
##   ..$ linetype     : NULL
##   ..$ lineend      : NULL
##   ..$ arrow        : logi FALSE
##   ..$ inherit.blank: logi TRUE
##   ..- attr(*, "class")= chr [1:2] "element_line" "element"
##  $ panel.grid.major.x        : NULL
##  $ panel.grid.major.y        : NULL
##  $ panel.grid.minor.x        : NULL
##  $ panel.grid.minor.y        : NULL
##  $ panel.ontop               : logi FALSE
##  $ plot.background           :List of 5
##   ..$ fill         : NULL
##   ..$ colour       : chr "white"
##   ..$ size         : NULL
##   ..$ linetype     : NULL
##   ..$ inherit.blank: logi TRUE
##   ..- attr(*, "class")= chr [1:2] "element_rect" "element"
##  $ plot.title                :List of 11
##   ..$ family       : NULL
##   ..$ face         : NULL
##   ..$ colour       : NULL
##   ..$ size         : 'rel' num 1.2
##   ..$ hjust        : num 0
##   ..$ vjust        : num 1
##   ..$ angle        : NULL
##   ..$ lineheight   : NULL
##   ..$ margin       : 'margin' num [1:4] 0points 0points 5.5points 0points
##   .. ..- attr(*, "unit")= int 8
##   ..$ debug        : NULL
##   ..$ inherit.blank: logi TRUE
##   ..- attr(*, "class")= chr [1:2] "element_text" "element"
##  $ plot.title.position       : chr "panel"
##  $ plot.subtitle             :List of 11
##   ..$ family       : NULL
##   ..$ face         : NULL
##   ..$ colour       : NULL
##   ..$ size         : NULL
##   ..$ hjust        : num 0
##   ..$ vjust        : num 1
##   ..$ angle        : NULL
```

```
##   ..$ lineheight   : NULL
##   ..$ margin       : 'margin' num [1:4] 0points 0points 5.5points 0points
##   .. ..- attr(*, "unit")= int 8
##   ..$ debug        : NULL
##   ..$ inherit.blank: logi TRUE
##   ..- attr(*, "class")= chr [1:2] "element_text" "element"
##  $ plot.caption              :List of 11
##   ..$ family       : NULL
##   ..$ face         : NULL
##   ..$ colour       : NULL
##   ..$ size         : 'rel' num 0.8
##   ..$ hjust        : num 1
##   ..$ vjust        : num 1
##   ..$ angle        : NULL
##   ..$ lineheight   : NULL
##   ..$ margin       : 'margin' num [1:4] 5.5points 0points 0points 0points
##   .. ..- attr(*, "unit")= int 8
##   ..$ debug        : NULL
##   ..$ inherit.blank: logi TRUE
##   ..- attr(*, "class")= chr [1:2] "element_text" "element"
##  $ plot.caption.position     : chr "panel"
##  $ plot.tag                  :List of 11
##   ..$ family       : NULL
##   ..$ face         : NULL
##   ..$ colour       : NULL
##   ..$ size         : 'rel' num 1.2
##   ..$ hjust        : num 0.5
##   ..$ vjust        : num 0.5
##   ..$ angle        : NULL
##   ..$ lineheight   : NULL
##   ..$ margin       : NULL
##   ..$ debug        : NULL
##   ..$ inherit.blank: logi TRUE
##   ..- attr(*, "class")= chr [1:2] "element_text" "element"
##  $ plot.tag.position         : chr "topleft"
##  $ plot.margin               : 'margin' num [1:4] 5.5points 5.5points 5.5points 5.5points
##   ..- attr(*, "unit")= int 8
##  $ strip.background          :List of 5
##   ..$ fill         : chr "grey85"
##   ..$ colour       : chr "grey20"
##   ..$ size         : NULL
##   ..$ linetype     : NULL
##   ..$ inherit.blank: logi TRUE
##   ..- attr(*, "class")= chr [1:2] "element_rect" "element"
##  $ strip.background.x        : NULL
##  $ strip.background.y        : NULL
##  $ strip.placement           : chr "inside"
##  $ strip.text                :List of 11
##   ..$ family       : NULL
##   ..$ face         : NULL
##   ..$ colour       : chr "grey10"
##   ..$ size         : 'rel' num 0.8
##   ..$ hjust        : NULL
##   ..$ vjust        : NULL
```

```
##   ..$ angle        : NULL
##   ..$ lineheight   : NULL
##   ..$ margin       : 'margin' num [1:4] 4.4points 4.4points 4.4points 4.4points
##   .. ..- attr(*, "unit")= int 8
##   ..$ debug        : NULL
##   ..$ inherit.blank: logi TRUE
##   ..- attr(*, "class")= chr [1:2] "element_text" "element"
##  $ strip.text.x              : NULL
##  $ strip.text.y              :List of 11
##   ..$ family       : NULL
##   ..$ face         : NULL
##   ..$ colour       : NULL
##   ..$ size         : NULL
##   ..$ hjust        : NULL
##   ..$ vjust        : NULL
##   ..$ angle        : num -90
##   ..$ lineheight   : NULL
##   ..$ margin       : NULL
##   ..$ debug        : NULL
##   ..$ inherit.blank: logi TRUE
##   ..- attr(*, "class")= chr [1:2] "element_text" "element"
##  $ strip.switch.pad.grid     : 'simpleUnit' num 2.75points
##   ..- attr(*, "unit")= int 8
##  $ strip.switch.pad.wrap     : 'simpleUnit' num 2.75points
##   ..- attr(*, "unit")= int 8
##  $ strip.text.y.left         :List of 11
##   ..$ family       : NULL
##   ..$ face         : NULL
##   ..$ colour       : NULL
##   ..$ size         : NULL
##   ..$ hjust        : NULL
##   ..$ vjust        : NULL
##   ..$ angle        : num 90
##   ..$ lineheight   : NULL
##   ..$ margin       : NULL
##   ..$ debug        : NULL
##   ..$ inherit.blank: logi TRUE
##   ..- attr(*, "class")= chr [1:2] "element_text" "element"
##  $ colour                    :List of 21
##   ..$ title         : chr "Axes principaux"
##   ..$ title.position: NULL
##   ..$ title.theme   : NULL
##   ..$ title.hjust   : NULL
##   ..$ title.vjust   : NULL
##   ..$ label         : logi TRUE
##   ..$ label.position: NULL
##   ..$ label.theme   : NULL
##   ..$ label.hjust   : NULL
##   ..$ label.vjust   : NULL
##   ..$ keywidth      : NULL
##   ..$ keyheight     : NULL
##   ..$ direction     : NULL
##   ..$ override.aes  : Named list()
##   ..$ nrow          : NULL
```

```
##   ..$ ncol          : NULL
##   ..$ byrow         : logi FALSE
##   ..$ reverse       : logi FALSE
##   ..$ order         : num 0
##   ..$ available_aes : chr "any"
##   ..$ name          : chr "legend"
##   ..- attr(*, "class")= chr [1:2] "guide" "legend"
##  - attr(*, "class")= chr [1:2] "theme" "gg"
##  - attr(*, "complete")= logi TRUE
##  - attr(*, "validate")= logi TRUE
```

```
#  Choc des composantes principales : Value at risk
pc_shoc_up = vect_propre * (sqrt(val_propre)) * qnorm(.995, mean = 0, sd = 1)
pc_shoc_down = vect_propre * (sqrt(val_propre)) * qnorm(1-0.995, mean = 0, sd = 1)
pc_shoc_down = vect_propre * qnorm(1-0.995, mean = 0, sd = 1)

pc = as.matrix(data.active) %*% as.matrix(vect_propre)

orig = pc %*% t(pc_shoc_up)
```

```
pc_shoc_down
```

```
##        level       slope  curvature
## 1  0.4375216  1.36866792 -1.4910525
## 2  0.5125169  1.10064146 -0.3590204
## 3  0.5465309  0.87018940  0.1045931
## 4  0.5689922  0.66586919  0.3638687
## 5  0.5838158  0.47540147  0.5345728
## 6  0.5924124  0.30427571  0.6382723
## 7  0.5965669  0.15885479  0.6778430
## 8  0.5981230  0.04043551  0.6571897
## 9  0.5983893 -0.05473059  0.5854413
## 10 0.5979968 -0.13272881  0.4749320
## 11 0.5971388 -0.19942598  0.3385470
## 12 0.5958430 -0.25908188  0.1887377
## 13 0.5941113 -0.31423233  0.0355396
## 14 0.5919427 -0.36594643 -0.1132468
## 15 0.5893346 -0.41467465 -0.2527066
## 16 0.5862914 -0.46049425 -0.3794334
## 17 0.5828367 -0.50330154 -0.4921632
## 18 0.5790254 -0.54300072 -0.5911330
## 19 0.5749417 -0.57959569 -0.6771688
## 20 0.5706970 -0.61310107 -0.7511443
```

```
pc
```

```
##             level        slope     curvature
##   [1,] -2.2479197  0.355326556  0.1324945609
##   [2,]  4.7225831 -0.174939217 -0.3169816287
##   [3,]  0.8175736 -0.661522555 -0.2309937459
##   [4,]  0.2527537  0.948806822  0.3744416513
##   [5,] -1.6483421  0.706746155  0.0258582729
##   [6,] -1.4498464  0.608313828  0.2135558083
```

```
##   [7,]  4.3155628  0.793248999  0.2839801081
##   [8,] -1.8495768  0.425880245  0.0248833270
##   [9,]  1.8149431  0.938007307 -0.7519072220
##  [10,] -8.3934466 -5.411128562 -0.1228567638
##  [11,] -2.9177828 -0.484779395 -0.1027405458
##  [12,] -4.8141124  0.100336291 -0.5605766851
##  [13,]  0.7742148  2.867182384  0.1264917344
##  [14,]  0.4922369 -0.101156792 -0.0764924100
##  [15,]  0.7237374 -0.454424385  0.3959741185
##  [16,] -1.8904750 -1.439718459 -0.0869439460
##  [17,] -4.2071940  0.392601474  0.7618098447
##  [18,]  3.2017373  0.198524289  0.3633671053
##  [19,] -0.2144229 -0.534564298  0.1520819210
##  [20,]  2.0963175 -0.513140123 -0.0163206607
##  [21,] -0.6234433 -0.042059390 -0.0508249723
##  [22,] -2.0442223 -0.949036703 -0.2050814763
##  [23,] 10.4134417 -2.079722835  0.3758044558
##  [24,]  2.9799665 -2.377375063  0.0172644334
##  [25,]  1.6160556 -3.047902651 -0.2045064743
##  [26,]  1.1711771 -2.446604319 -0.0706545206
##  [27,] -2.3690639  2.103294297 -0.2120709253
##  [28,] -3.9932189 -0.317398992 -0.1015741004
##  [29,] -6.1363505 -1.111582751  0.0004743495
##  [30,] -0.5820907  0.708854581 -0.3980721589
##  [31,] -0.2444730  1.205580790 -0.7357951044
##  [32,] -4.2352759  0.201217575 -0.0054909571
##  [33,] -7.7985818  2.040600040 -0.1853388474
##  [34,] -5.3549330 -1.470842332 -0.3778682380
##  [35,] -1.2996678 -0.783110946  1.0259655568
##  [36,] -3.7768750 -1.725997107  0.5167541160
##  [37,] -7.6145217 -1.591056850 -0.5221338592
##  [38,]  3.6108451 -0.697344753  0.4478717703
##  [39,]  3.3100087 -0.672170872 -0.0677232705
##  [40,] -7.6076501  1.056408920  0.6686681545
##  [41,] -8.2470261  1.248983140  0.4706525750
##  [42,]  1.9019568  0.008878044  0.4618069606
##  [43,]  3.9613858 -0.094033702  0.2668558631
##  [44,] -0.4172206  0.252695001 -0.5134125671
##  [45,] -6.5521091 -0.493171476 -0.2462573011
##  [46,] -2.6709084  0.457953468 -0.1793629567
##  [47,] -1.8531205  0.681772487  0.5916928557
##  [48,]  2.1817244  0.357098095 -0.1941422016
##  [49,]  0.3446417  0.354619331 -0.4388685500
##  [50,]  7.7399212 -0.896936980  0.0918147527
##  [51,]  1.3330910  0.736151385 -0.3657763397
##  [52,] -4.2716969  2.112145653  0.4958720900
##  [53,] -2.6996168  0.239202187 -0.3456211702
##  [54,] -1.4133367  0.369177314 -0.1154768158
##  [55,]  6.9588217  0.282661748  0.1367030370
##  [56,] -7.3797215 -0.645010506 -0.2107556062
##  [57,]  3.2753271 -0.733121469 -0.0050062743
##  [58,]  3.2487146 -0.419845013  0.1448394526
##  [59,]  6.1384674  0.251375414 -0.0546263303
##  [60,]  5.4192119  0.647297188 -0.2945220052
```

```
##  [61,] -6.4318169  1.922217096  0.3225243893
##  [62,]  5.5856424  0.357142794  0.3698829374
##  [63,] -2.5783816  0.133357309  0.0788295136
##  [64,]  2.8504756 -0.565635395 -0.5006202599
##  [65,]  5.3509571  1.056207831 -0.0266443705
##  [66,] -5.6491876  0.836450652 -0.0118729448
##  [67,]  0.7331021 -0.300916580  0.0474268660
##  [68,] -0.7892141  0.243470008  0.1767915326
##  [69,]  2.9221482  0.760938277 -0.3130088464
##  [70,]  1.7334551 -0.872130914 -0.3140852472
##  [71,]  5.3363457  0.644542619  0.1880910723
##  [72,]  3.9694191 -0.052846768 -0.2454159430
##  [73,] -1.6729129 -2.489133195  0.3043351856
##  [74,] -0.4135845 -2.063418315 -0.0768786131
##  [75,]  1.4333799  0.671753371 -0.7218199123
##  [76,] -1.5587426  0.149292306  0.2286136871
##  [77,]  1.7613694 -0.699899938  0.2064396520
##  [78,]  0.3092930  0.933061081 -0.0583816847
##  [79,]  2.8297065  0.208698028  0.1843074499
##  [80,]  2.1118219  0.763762326 -0.0578176821
##  [81,]  1.5478019 -0.739359525 -0.3732848268
##  [82,]  2.4310213  0.535527433 -0.0614563669
##  [83,] -5.0018280  1.259227534 -0.1200909652
##  [84,]  2.6813223  0.530254409  0.0254157356
##  [85,] -9.8129200  1.428147108 -0.7523832203
##  [86,]  4.5374515 -0.173603473  0.3980252327
##  [87,]  6.8537031 -1.106511145  0.4708630141
##  [88,] 10.0265960  2.437957336 -0.3895855148
##  [89,]  3.4742641  1.454179158  0.2461763081
##  [90,]  6.0936639  0.552282230 -0.2573035927
##  [91,] -0.3068804 -0.792931244 -0.7467516681
##  [92,]  2.3629569 -0.489076362  0.0898563354
##  [93,]  0.8146850  0.267375384  0.0126783746
##  [94,] -2.8327675 -0.923121424 -0.0632295607
##  [95,] -3.8427911  0.269235671 -0.2405038121
##  [96,]  4.8729793  0.565475531  0.1457006700
##  [97,]  3.5168980  0.342303181  0.5048114670
##  [98,]  2.0730045  0.160004345 -0.4310745944
##  [99,] -7.8786027 -0.104453679  1.1315725083
## [100,] -5.4420092  1.608932428  0.4286654501
```