homework2

Na Yun Cho

```
library(caret)
```

```
## Loading required package: lattice
```

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

```
library(splines)
library(mgcv)
```

```
## Loading required package: nlme
```

```
## This is mgcv 1.8-33. For overview type 'help("mgcv-package")'.
```

```
library(pdp)
library(earth)
```

```
## Loading required package: Formula
```

```
## Loading required package: plotmo
```

```
## Loading required package: plotrix
```

```
## Loading required package: TeachingDemos
```

```
library(tidyverse)
```

```
## -- Attaching packages --------------------------------------- tidyverse 1.3.0 --
```

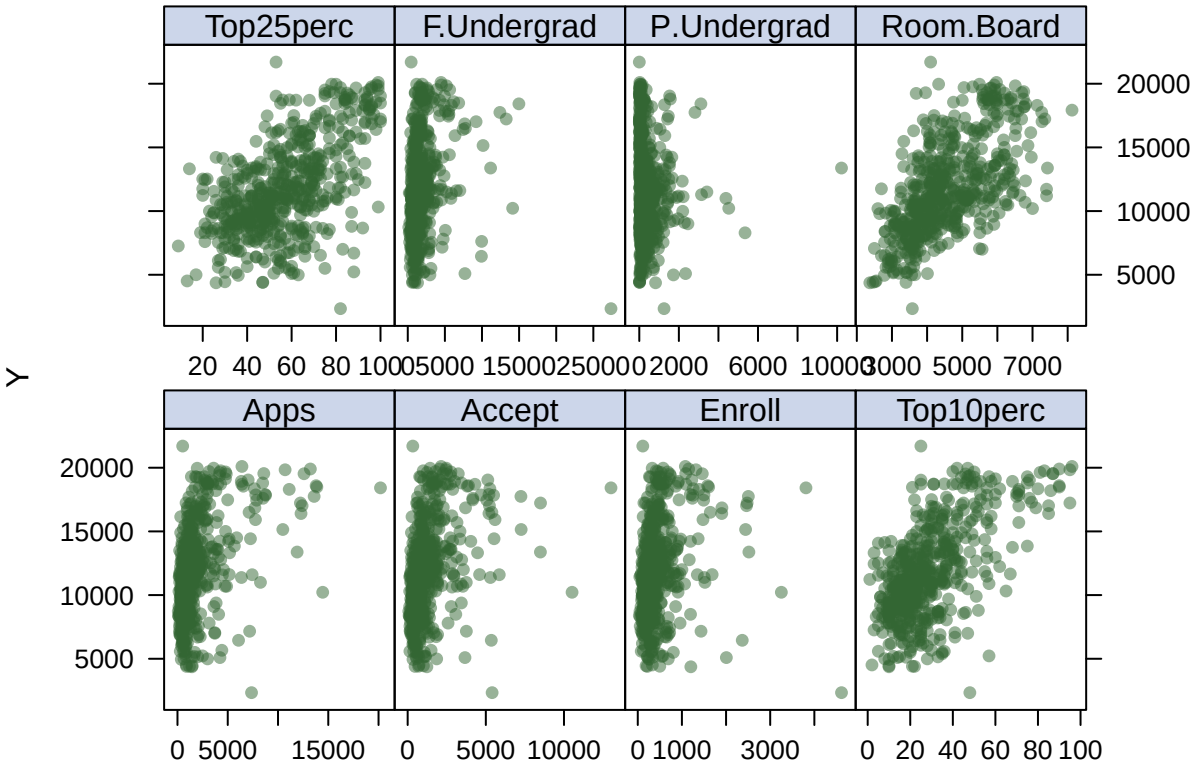
```
## v tibble  3.0.6     v dplyr   1.0.4
## v tidyr   1.1.2     v stringr 1.4.0
## v readr   1.4.0     v forcats 0.5.1
## v purrr   0.3.4
```

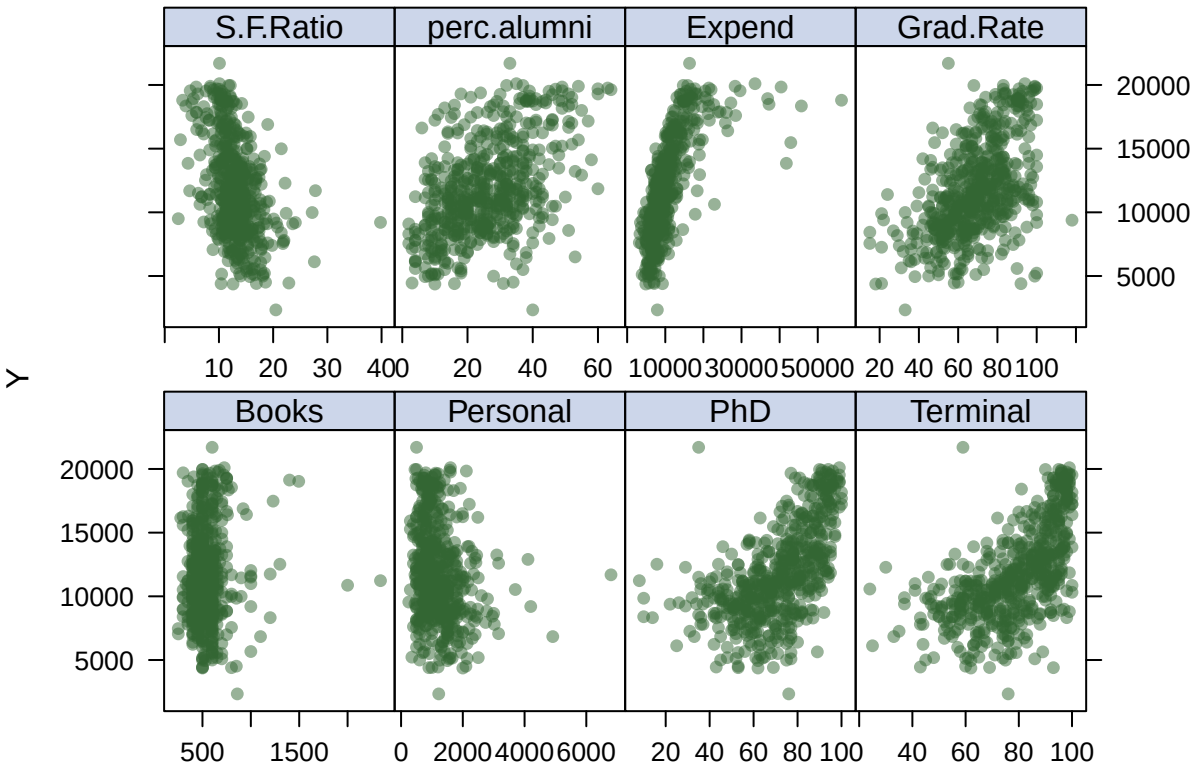
```
## -- Conflicts ------------------------------------------ tidyverse_conflicts() --
## x dplyr::collapse() masks nlme::collapse()
## x dplyr::filter()   masks stats::filter()
## x dplyr::lag()      masks stats::lag()
## x purrr::lift()     masks caret::lift()
## x purrr::partial()  masks pdp::partial()
```

```
library(ggplot2)
```

(a) Exploratory data analysis

```
college = read.csv("./data/data.csv")
college1 <- college[-125,]

college2 = data.matrix(college1, rownames.force = NA)
x <- college2 [ ,-c(1,9)]
y <- college2 [ , 9]


theme1 <- trellis.par.get()
theme1$plot.symbol$col <- rgb(.2, .4, .2, .5)
theme1$plot.symbol$pch <- 16
theme1$plot.line$col <- rgb(.8, .1, .1, 1)
theme1$plot.line$lwd <- 2
theme1$strip.background$col <- rgb(.0, .2, .6, .2)
trellis.par.set(theme1)
featurePlot(x, y, plot = "scatter", labels = c("","Y"),
            type = c("p"), layout = c(4, 2))
```





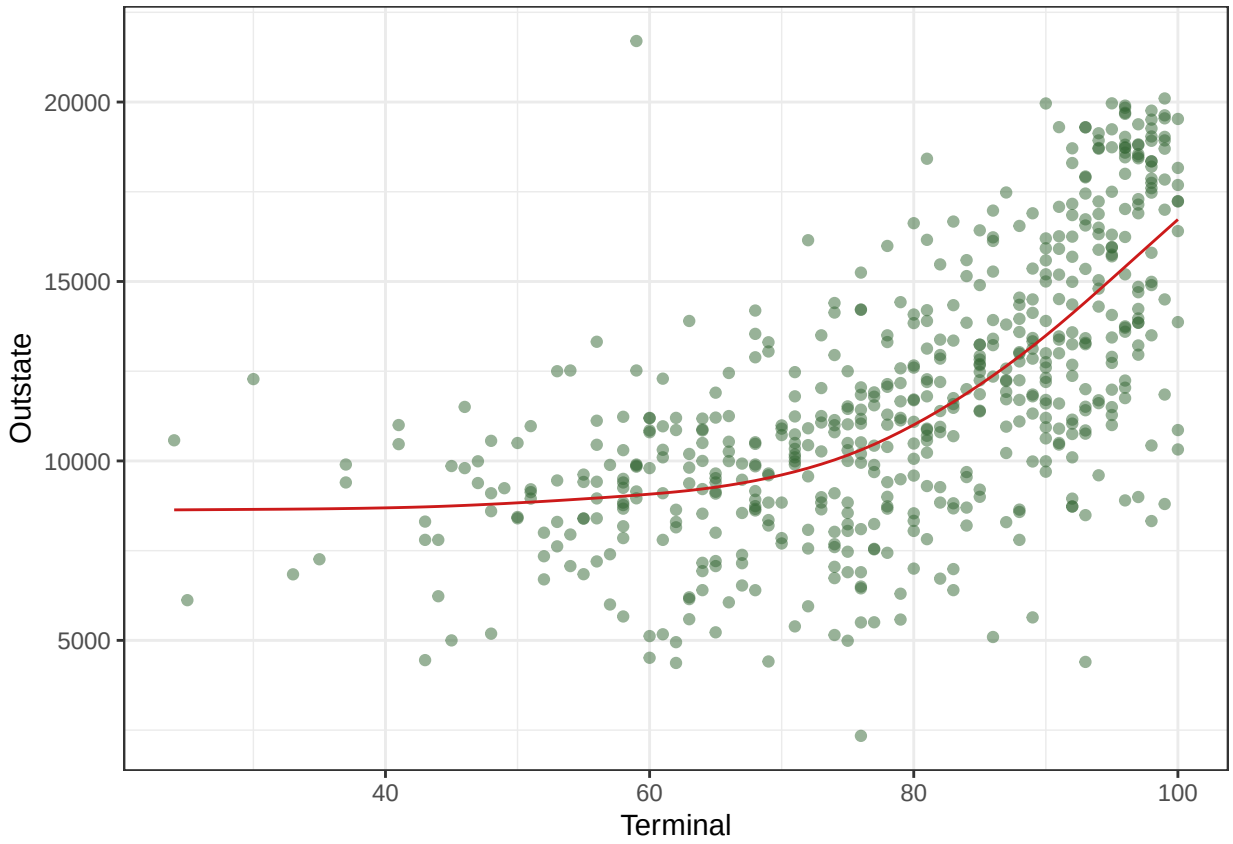
Interpretation: From this exploratory data analysis, I could see that the predictors 'F.Undergrad', 'P.Undergrad', 'Apps', 'Accept', 'Enroll', 'Terminal', and 'Books' show a relatively non-linear trend compared to other predictors. The predictors 'Top25perc', 'Room.Board', 'Top10perc', 'perc.alumni', 'Grad.Rate', 'Expend', and 'PhD' showed a generally increasing trend that looks quite linear. On the other hand, 'S.F.Ratio' and 'Personal' seemed to show a slightly decreasing trend that is quite linear. To check the associations of each predictor with the outcome 'Outstate' in more detail, further analyses would have to be done.

(b) Fit a smoothing spline model using 'Terminal' as the only predictor

```
# using GCV method
fit.ss <- smooth.spline(college1$Terminal, college1$Outstate)
fit.ss$df
```

```
## [1] 4.468629
```

```
Terminallims <- range(college1$Terminal)
Terminal.grid <- seq(from = Terminallims[1],to = Terminallims[2])

pred.ss <- predict(fit.ss, x = Terminal.grid)
pred.ss.df <- data.frame(pred = pred.ss$y, Terminal = Terminal.grid)

p <- ggplot(data= college1, aes(x = Terminal, y = Outstate)) +geom_point(color = rgb(0.2, 0.4, 0.2, 0.5
p + geom_line(aes(x = Terminal, y =pred), data = pred.ss.df, color = rgb(0.8, 0.1, 0.1, 1)) +theme_bw()
```



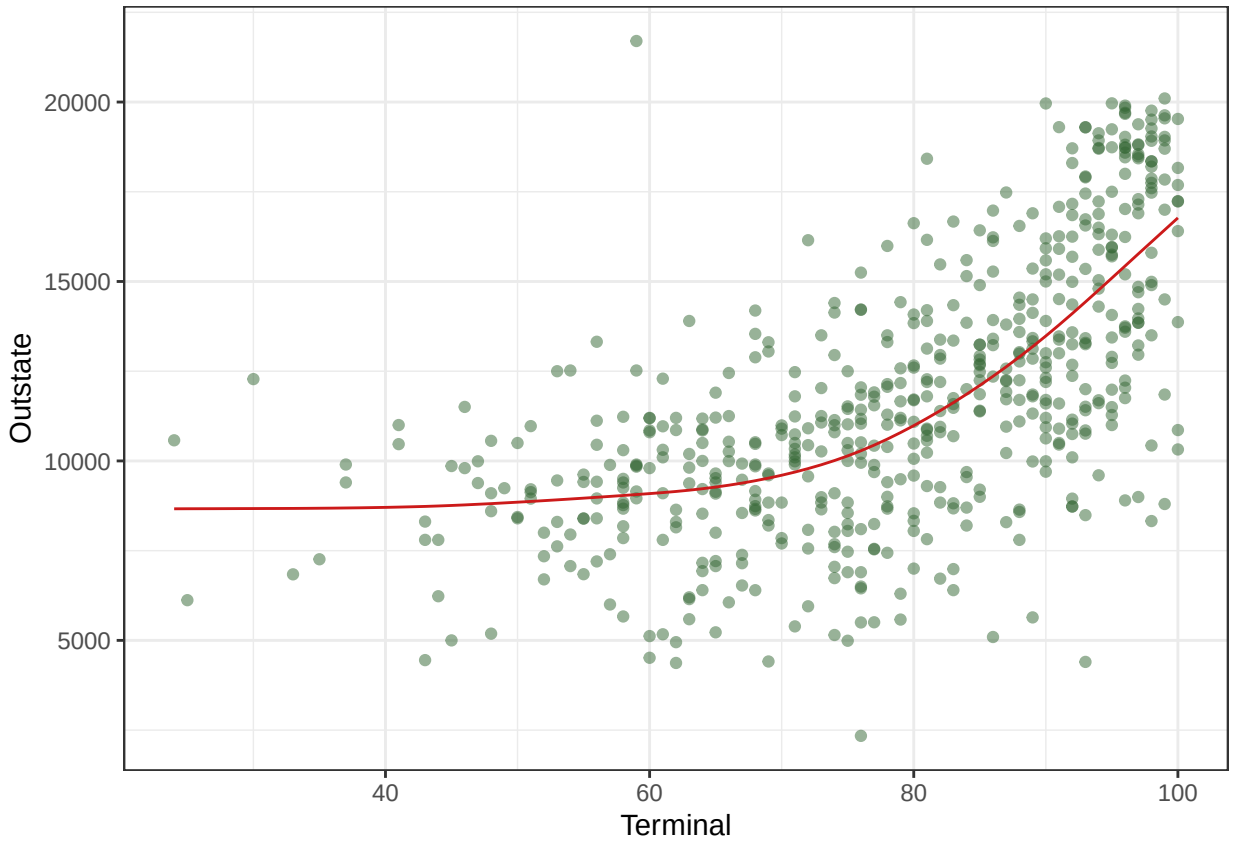

```
#Using LOOCV method
fit.ss <- smooth.spline(college1$Terminal, college1$Outstate, cv = TRUE)
```

```
## Warning in smooth.spline(college1$Terminal, college1$Outstate, cv = TRUE):
## cross-validation with non-unique 'x' values seems doubtful
```

```
fit.ss$df
```

```
## [1] 4.686019
```

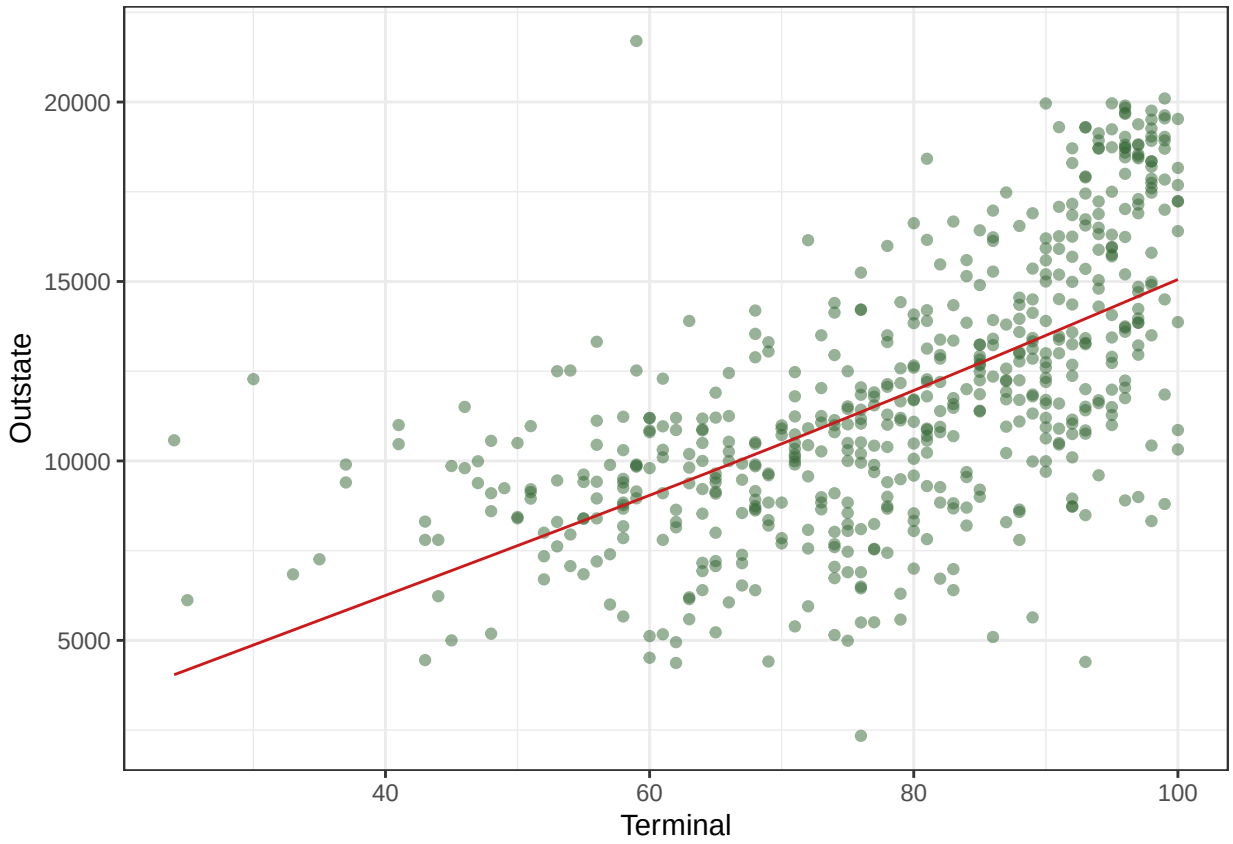
```
Terminallims <- range(college1$Terminal)
Terminal.grid <- seq(from = Terminallims[1],to = Terminallims[2])

pred.ss <- predict(fit.ss, x = Terminal.grid)
pred.ss.df <- data.frame(pred = pred.ss$y, Terminal = Terminal.grid)

p <- ggplot(data= college1, aes(x = Terminal, y = Outstate)) +geom_point(color = rgb(0.2, 0.4, 0.2, 0.5
p + geom_line(aes(x = Terminal, y =pred), data = pred.ss.df, color = rgb(0.8, 0.1, 0.1, 1)) +theme_bw()
```




```
#Using arbitrary lambda values
#Using lambda = 10
fit.ss <- smooth.spline(college1$Terminal, college1$Outstate, lambda=10)
fit.ss$df
```

```
## [1] 2.06511
```

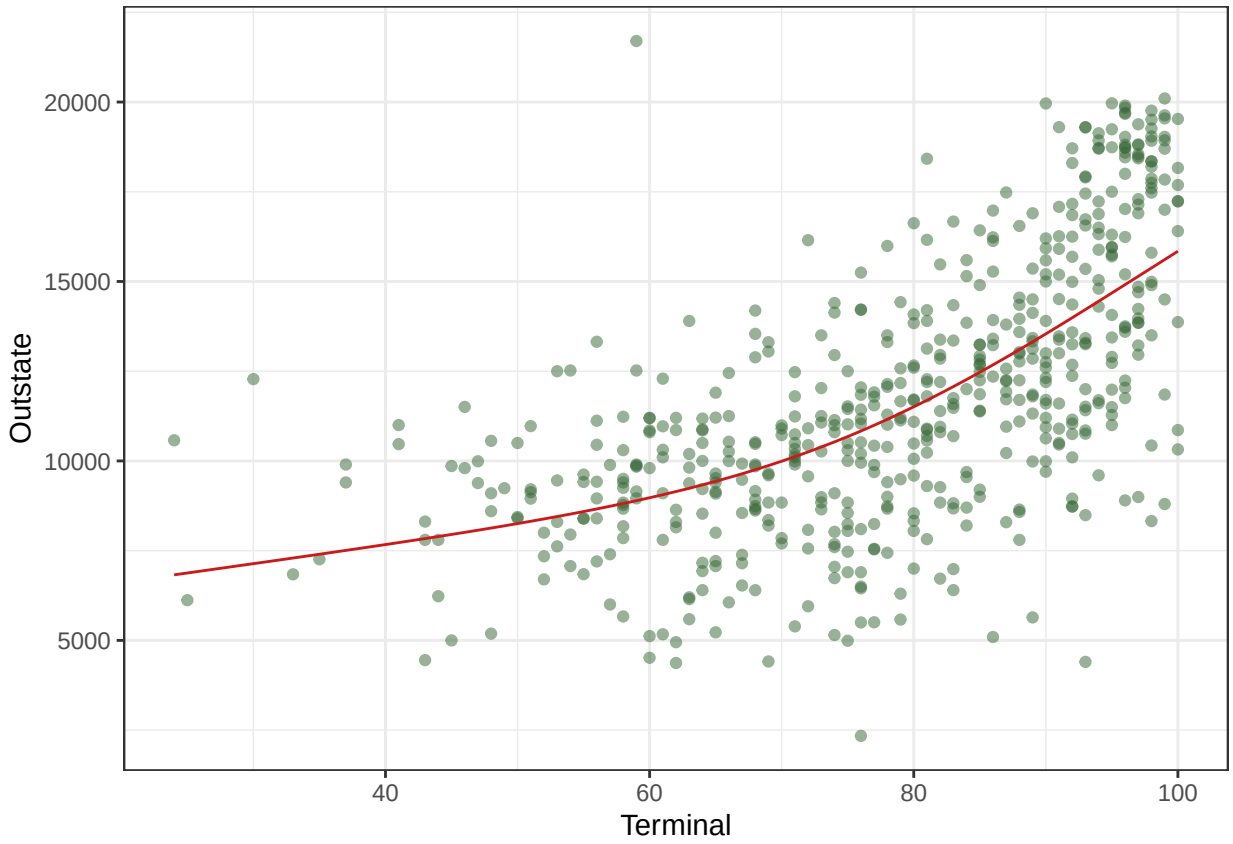
```
Terminallims <- range(college1$Terminal)
Terminal.grid <- seq(from = Terminallims[1],to = Terminallims[2])

pred.ss <- predict(fit.ss, x = Terminal.grid)
pred.ss.df <- data.frame(pred = pred.ss$y, Terminal = Terminal.grid)

p <- ggplot(data= college1, aes(x = Terminal, y = Outstate)) +geom_point(color = rgb(0.2, 0.4, 0.2, 0.5
p + geom_line(aes(x = Terminal, y =pred), data = pred.ss.df, color = rgb(0.8, 0.1, 0.1, 1)) +theme_bw()
```




```
#Using lambda = 0.5
fit.ss <- smooth.spline(college1$Terminal, college1$Outstate, lambda=0.5)
fit.ss$df
```

```
## [1] 2.761186
```

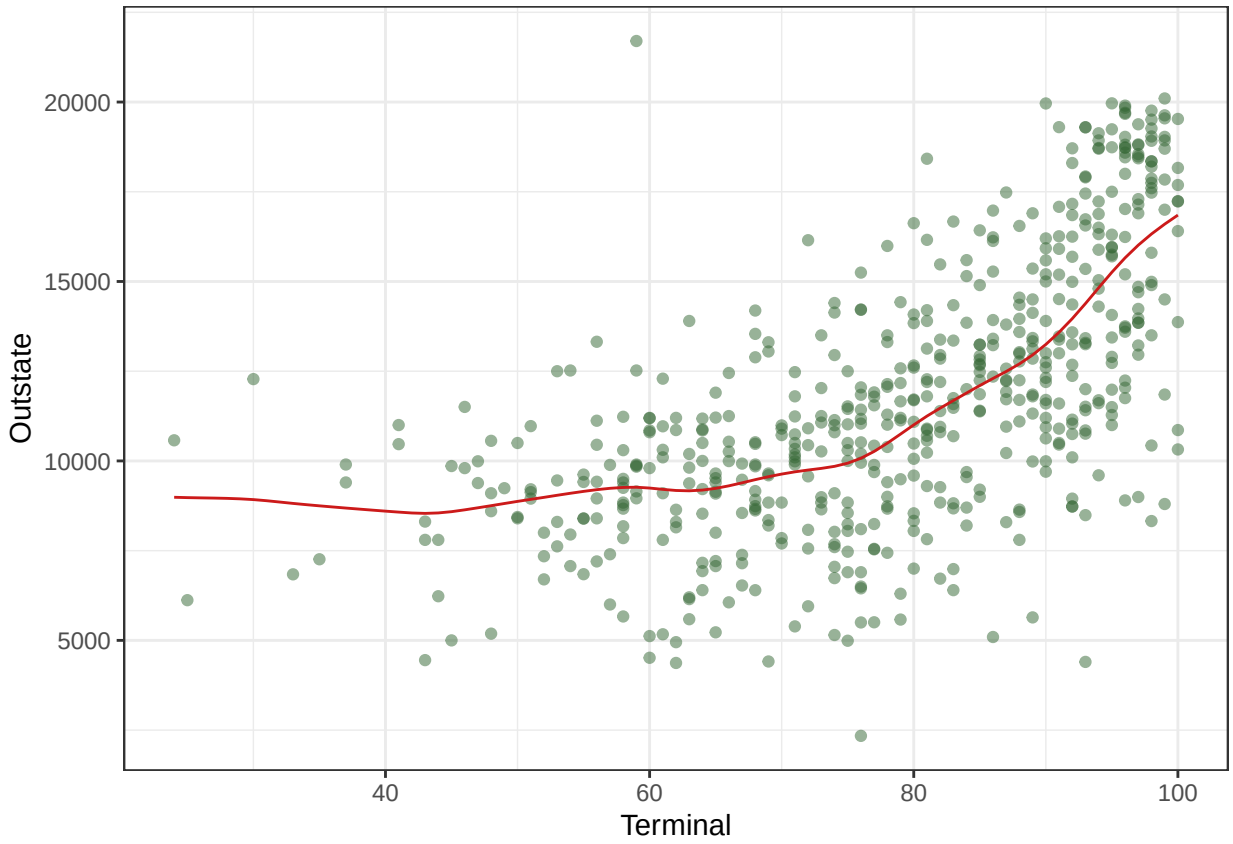
```
Terminallims <- range(college1$Terminal)
Terminal.grid <- seq(from = Terminallims[1],to = Terminallims[2])

pred.ss <- predict(fit.ss, x = Terminal.grid)
pred.ss.df <- data.frame(pred = pred.ss$y, Terminal = Terminal.grid)

p <- ggplot(data= college1, aes(x = Terminal, y = Outstate)) +geom_point(color = rgb(0.2, 0.4, 0.2, 0.5)
p + geom_line(aes(x = Terminal, y =pred), data = pred.ss.df, color = rgb(0.8, 0.1, 0.1, 1)) +theme_bw()
```




```
#Using lambda = 0.001
fit.ss <- smooth.spline(college1$Terminal, college1$Outstate, lambda=0.001)
fit.ss$df
```

```
## [1] 9.838879
```

```
Terminallims <- range(college1$Terminal)
Terminal.grid <- seq(from = Terminallims[1],to = Terminallims[2])

pred.ss <- predict(fit.ss, x = Terminal.grid)
pred.ss.df <- data.frame(pred = pred.ss$y, Terminal = Terminal.grid)

p <- ggplot(data= college1, aes(x = Terminal, y = Outstate)) +geom_point(color = rgb(0.2, 0.4, 0.2, 0.5)
p + geom_line(aes(x = Terminal, y =pred), data = pred.ss.df, color = rgb(0.8, 0.1, 0.1, 1)) +theme_bw()
```



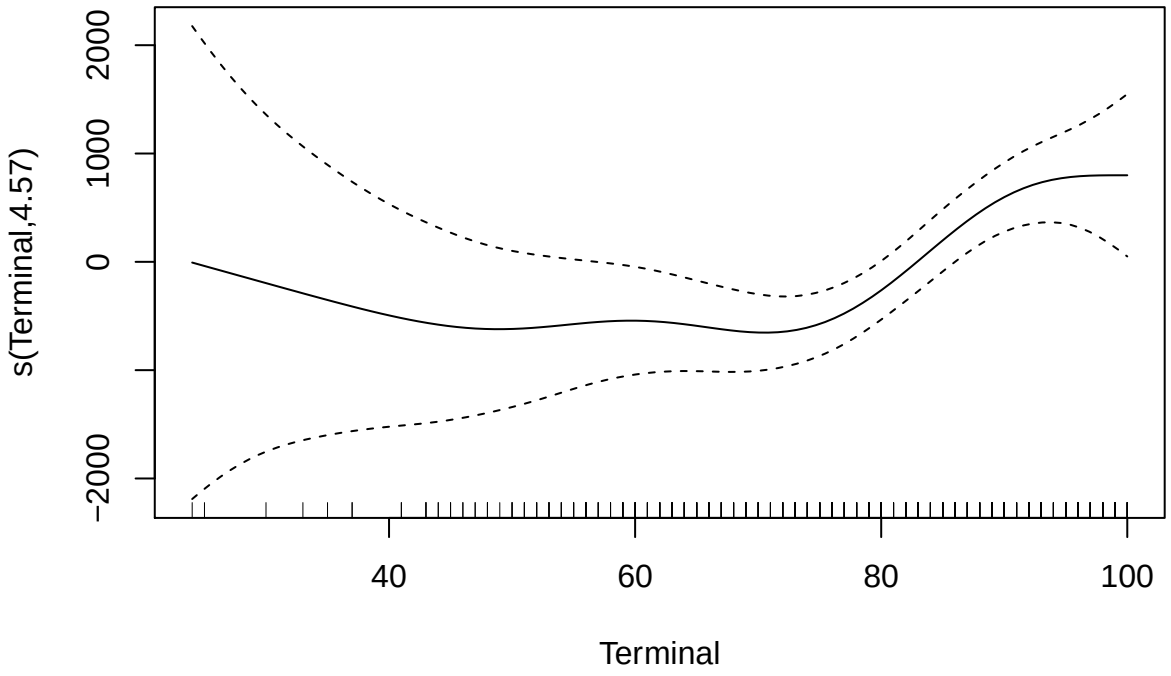
(c) Fit a GAM model using all the predictors

```
gam.m1 <- gam(Outstate~ Apps+Accept+Enroll+Top10perc+Top25perc+F.Undergrad+P.Undergrad+Room.Board+Books
              +Personal+Terminal+PhD+S.F.Ratio+perc.alumni+Expend+Grad.Rate, data = college1)

gam.m2 <- gam(Outstate~ Apps+Accept+Enroll+Top10perc+Top25perc+F.Undergrad+P.Undergrad+Room.Board+Books
              +Personal+s(Terminal)+PhD+S.F.Ratio+perc.alumni+Expend+Grad.Rate, data = college1)

gam.m3 <- gam(Outstate~ s(Apps)+s(Accept)+s(Enroll)+Top10perc+Top25perc+s(F.Undergrad)+s(P.Undergrad)
              +Room.Board+s(Books)+Personal+s(Terminal)+PhD+S.F.Ratio+perc.alumni+Expend+Grad.Rate,
              data = college1)

gam.m4 <- gam(Outstate~ s(Apps)+s(Accept)+ s(Enroll)+Top10perc+Top25perc+te(F.Undergrad,P.Undergrad)
              +Room.Board+s(Books)+Personal+s(Terminal)+PhD+S.F.Ratio+perc.alumni+Expend+Grad.Rate,
              data = college1)

anova(gam.m1, gam.m2, gam.m3, gam.m4, test = "F")
```

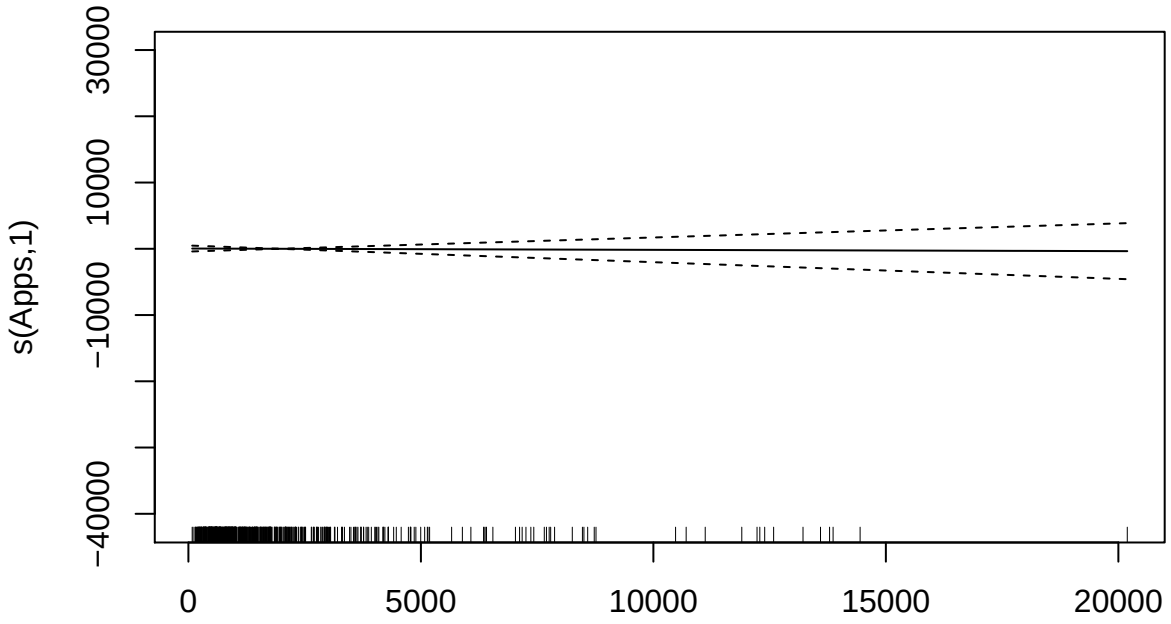
```
## Analysis of Deviance Table
##
## Model 1: Outstate ~ Apps + Accept + Enroll + Top10perc + Top25perc + F.Undergrad +
##     P.Undergrad + Room.Board + Books + Personal + Terminal +
##     PhD + S.F.Ratio + perc.alumni + Expend + Grad.Rate
## Model 2: Outstate ~ Apps + Accept + Enroll + Top10perc + Top25perc + F.Undergrad +
```

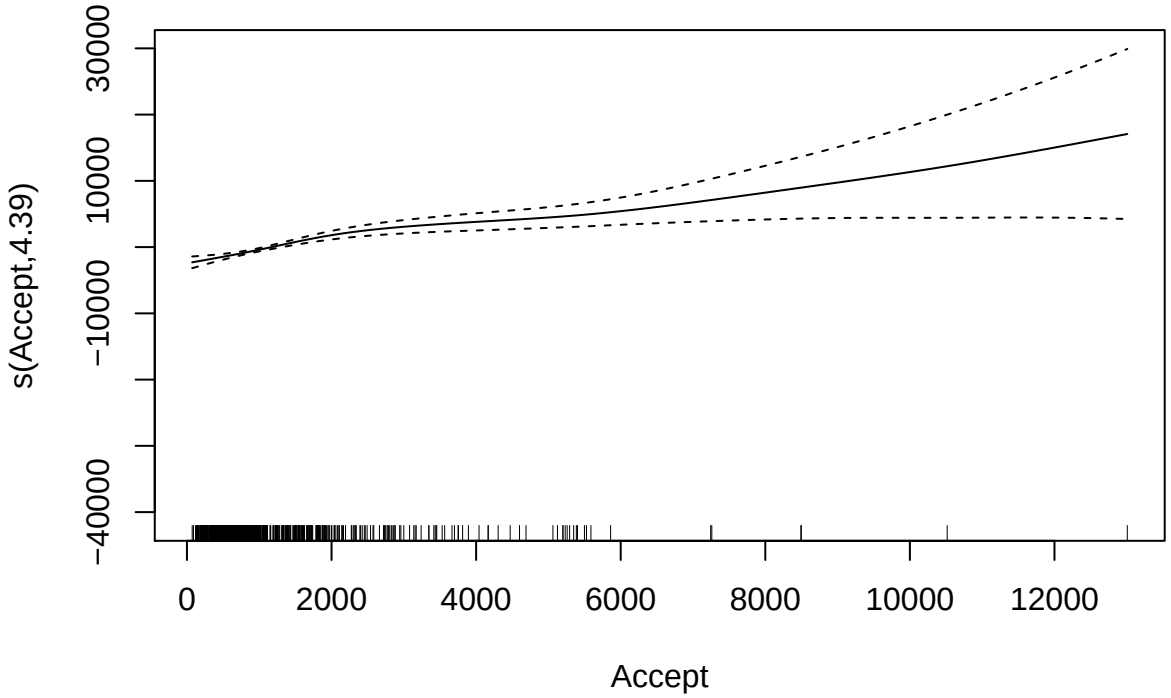
```
##     P.Undergrad + Room.Board + Books + Personal + s(Terminal) +
##     PhD + S.F.Ratio + perc.alumni + Expend + Grad.Rate
## Model 3: Outstate ~ s(Apps) + s(Accept) + s(Enroll) + Top10perc + Top25perc +
##     s(F.Undergrad) + s(P.Undergrad) + Room.Board + s(Books) +
##     Personal + s(Terminal) + PhD + S.F.Ratio + perc.alumni +
##     Expend + Grad.Rate
## Model 4: Outstate ~ s(Apps) + s(Accept) + s(Enroll) + Top10perc + Top25perc +
##     te(F.Undergrad, P.Undergrad) + Room.Board + s(Books) + Personal +
##     s(Terminal) + PhD + S.F.Ratio + perc.alumni + Expend + Grad.Rate
##   Resid. Df Resid. Dev      Df  Deviance      F    Pr(>F)
## 1    547.00 2092185295
## 2    542.37 2026858216  4.6295  65327078 4.1413  0.001481 **
## 3    527.63 1829988934 14.7408 196869282 3.9195 1.244e-06 ***
## 4    521.24 1793985069  6.3874  36003865 1.6543  0.125309
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

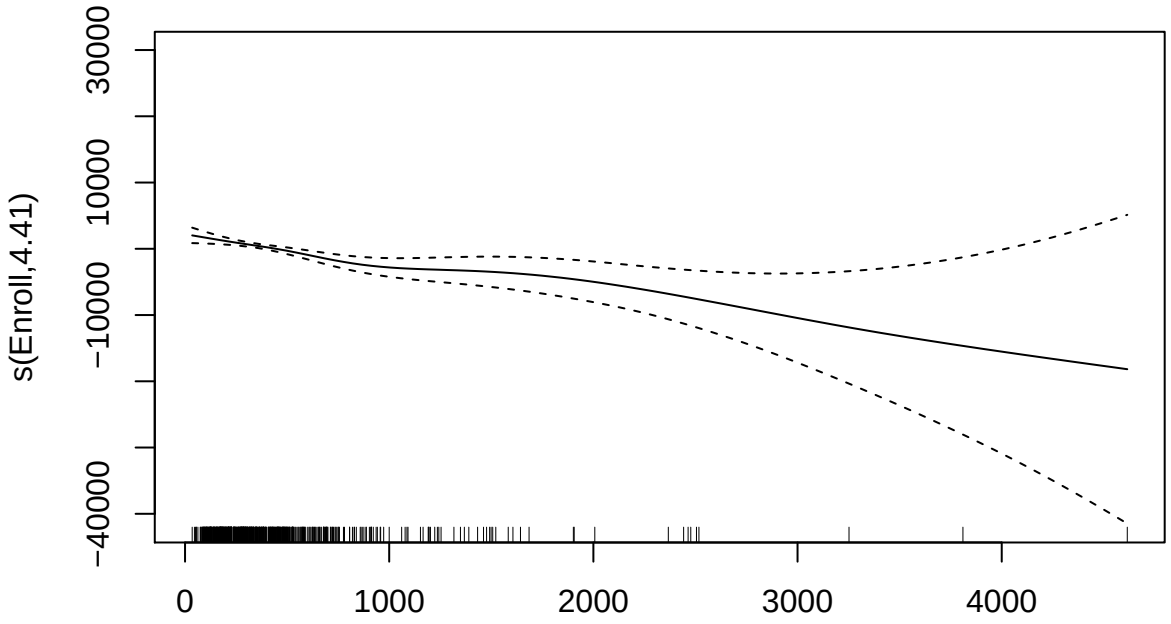
```
plot(gam.m2)
```

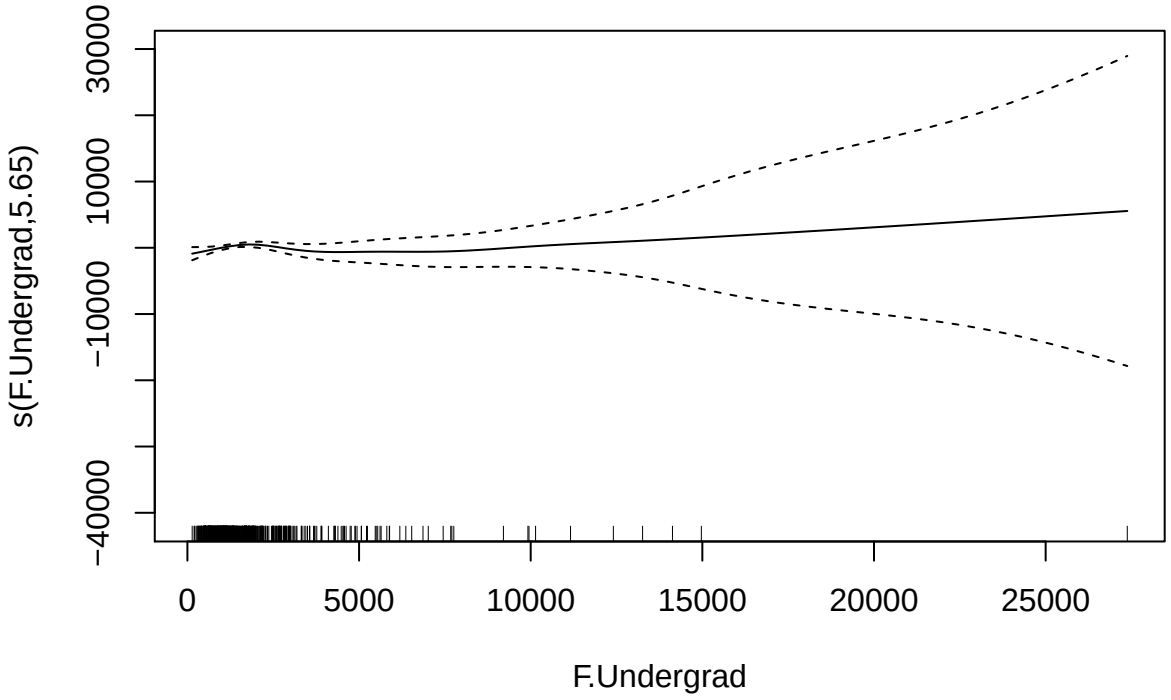


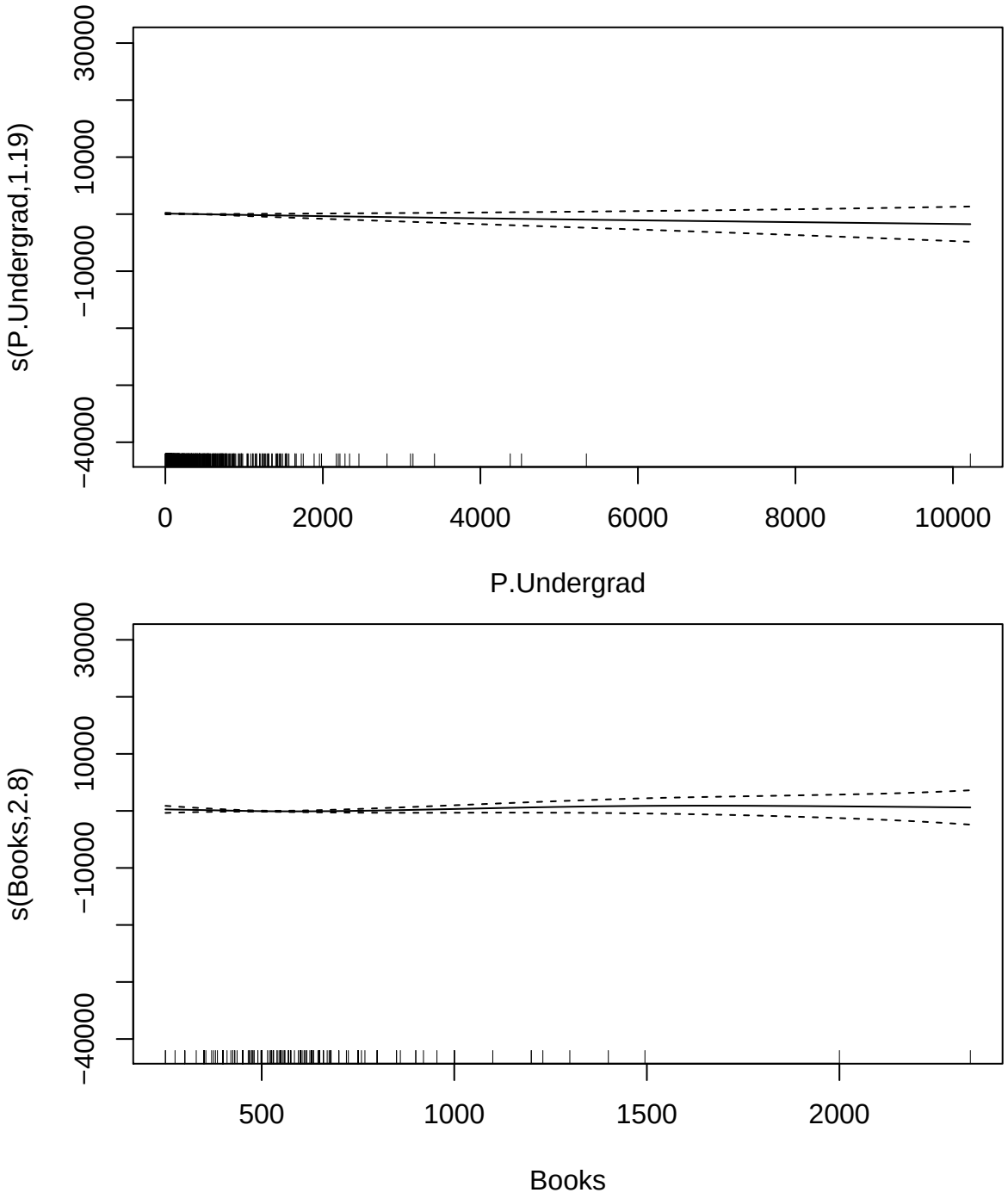

```
plot(gam.m3)
```

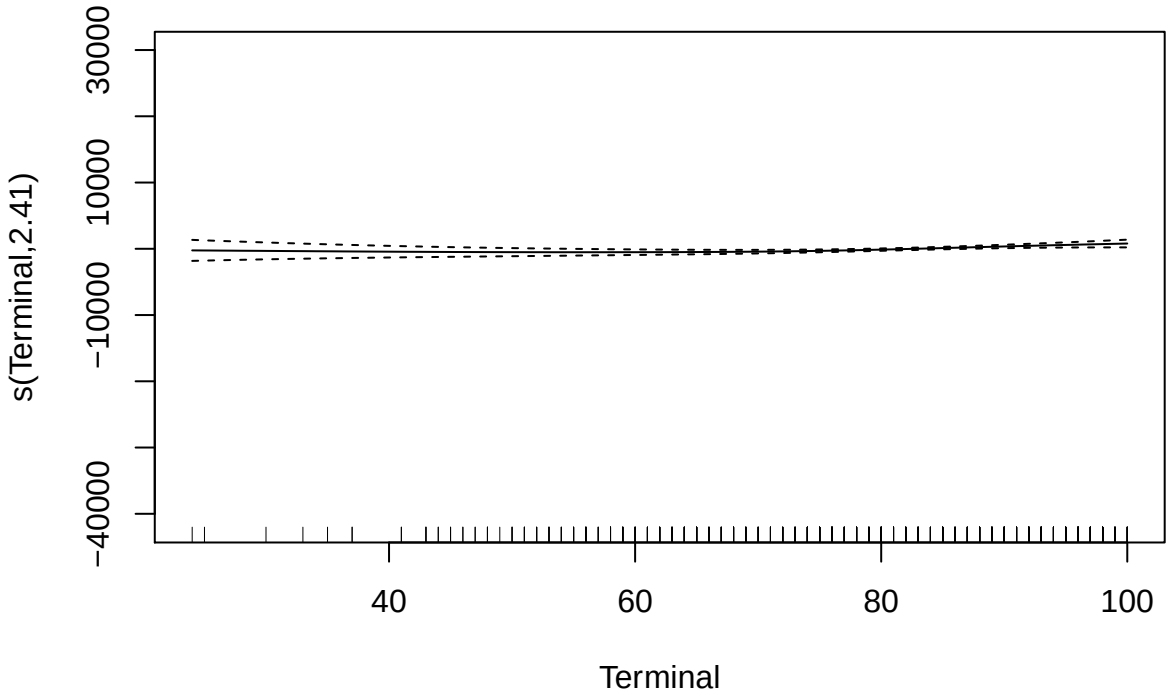

s(Apps,1)
30000
10000
−10000
−40000
0
5000
10000
15000
20000
Apps


s(Accept,4.39)
30000
10000
−10000
−40000
0
2000
4000
6000
8000
10000
12000
Accept

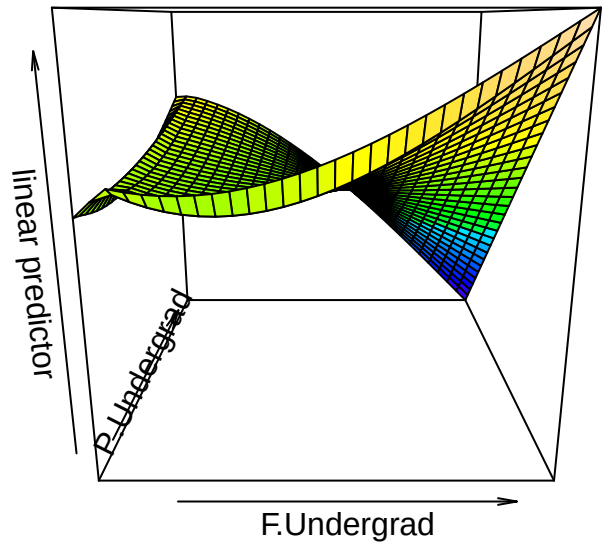

s(Enroll,4.41)
30000
10000
−10000
−40000
0
1000
2000
3000
4000
Enroll


s(F.Undergrad,5.65)
30000
10000
−10000
−40000
0
5000
10000
15000
20000
25000
F.Undergrad

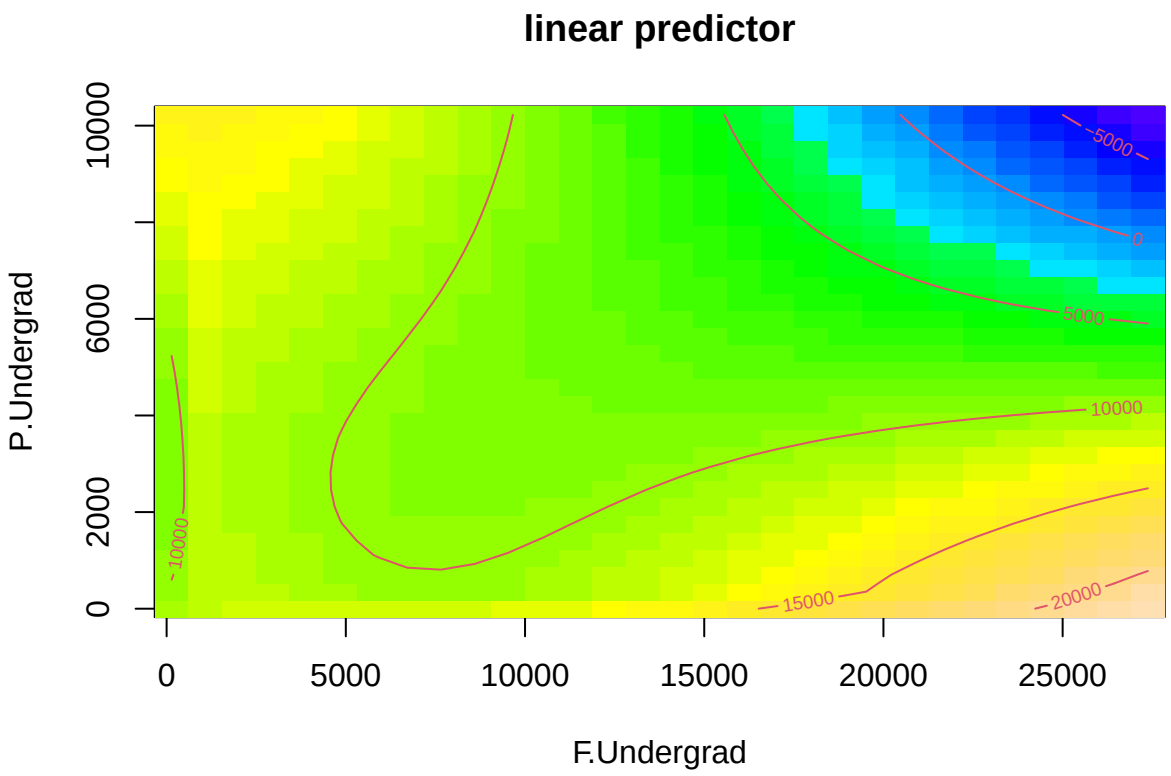

s(P.Undergrad,1.19)
30000
10000
−10000
−40000
0
2000
4000
6000
8000
10000
P.Undergrad
s(Books,2.8)
30000
10000
−10000
−40000
500
1000
1500
2000
Books




```
vis.gam(gam.m4, view=c("F.Undergrad","P.Undergrad"), color = "topo")
```




```
vis.gam(gam.m4, view=c("F.Undergrad","P.Undergrad"), color = "topo", plot.type = "contour")
```


linear predictor
P.Undergrad
F.Undergrad
0
2000
6000
10000
0
5000
10000
15000
20000
25000
-10000
-5000
0
5000
10000
15000
20000