Week 5 Questions

Dr L Scott-Hayward

Introduction

We are going to use the same data as for the last four weeks of the 'Weekly Questions' to look at regression splines with model selection chosen using the spatially adaptive local smoothing algorithm (SALSA).

SALSA-based selection

```
newdat <- read.table("../data/dataForWeeklyQuestions.csv", header = T)

newdat$response <- newdat$tobinsQ

varlist <- names(newdat)[c(2:12)]
factorlist <- c("indclass")

varlist
```

```
 [1] "year"    "assets"  "capex"   "ltd"     "ebitda"  "ppe"     "sales"
 [8] "ads"     "rd"      "bookval" "mv"
```

```
factorlist
```

```
[1] "indclass"
```

```
initialModel <- glm(response ~ as.factor(indclass), data = newdat)
Anova(initialModel)
```

```
Analysis of Deviance Table (Type II tests)

Response: response
                   LR Chisq Df Pr(>Chisq)
as.factor(indclass)   518.62 40  < 2.2e-16 ***
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

```
salsa1dlist <- list(fitnessMeasure = "BIC", minKnots_1d = c(rep(1, length(varlist))),
    maxKnots_1d = c(rep(10, length(varlist))), startKnots_1d = c(rep(2, length(varlist))),
    degree = c(rep(2, length(varlist))), gaps = c(rep(0, length(varlist))), cv.opts = list(K = 5,
        cv.gamMRSea.seed = 123))
```

```
# run SALSA
salsa1dOutput <- runSALSA1D(initialModel, salsa1dlist, varlist = varlist, factorlist = factorlist,
    newdat, splineParams = NULL, suppress.printout = TRUE, datain = newdat)
```

```
[1] "indclass will be fitted as a factor variable; there are non-zero counts for all levels"
```

```
summary(salsa1dOutput$bestModel)
```

```
Call:
gamMRSea(formula = response ~ as.factor(indclass) + bs(year,
```

```
    knots = splineParams[[2]]$knots, degree = splineParams[[2]]$degree,
    Boundary.knots = splineParams[[2]]$bd) + bs(assets, knots = splineParams[[3]]$knots,
    degree = splineParams[[3]]$degree, Boundary.knots = splineParams[[3]]$bd) +
    bs(capex, knots = splineParams[[4]]$knots, degree = splineParams[[4]]$degree,
        Boundary.knots = splineParams[[4]]$bd) + bs(ltd, knots = splineParams[[5]]$knots,
    degree = splineParams[[5]]$degree, Boundary.knots = splineParams[[5]]$bd) +
    bs(ebitda, knots = splineParams[[6]]$knots, degree = splineParams[[6]]$degree,
        Boundary.knots = splineParams[[6]]$bd) + bs(ppe, knots = splineParams[[7]]$knots,
    degree = splineParams[[7]]$degree, Boundary.knots = splineParams[[7]]$bd) +
    bs(sales, knots = splineParams[[8]]$knots, degree = splineParams[[8]]$degree,
        Boundary.knots = splineParams[[8]]$bd) + bs(ads, knots = splineParams[[9]]$knots,
    degree = splineParams[[9]]$degree, Boundary.knots = splineParams[[9]]$bd) +
    bs(rd, knots = splineParams[[10]]$knots, degree = splineParams[[10]]$degree,
        Boundary.knots = splineParams[[10]]$bd) + bs(bookval,
    knots = splineParams[[11]]$knots, degree = splineParams[[11]]$degree,
    Boundary.knots = splineParams[[11]]$bd) + bs(mv, knots = splineParams[[12]]$knots,
    degree = splineParams[[12]]$degree, Boundary.knots = splineParams[[12]]$bd),
    family = gaussian(link = identity), data = newdat, splineParams = splineParams)

Deviance Residuals:
    Min       1Q   Median       3Q      Max
-35.438   -1.117   -0.317    0.635  161.504

Coefficients:
                      Estimate Std. Error Robust S.E. t value Pr(>|t|)
(Intercept)            34.8726     5.3144      5.3144   6.562 5.51e-11 ***
as.factor(indclass)2    0.6059     0.8376      0.8376   0.723  0.46944
as.factor(indclass)3    2.2117     1.3387      1.3387   1.652  0.09852 .
as.factor(indclass)4    2.0359     0.9883      0.9883   2.060  0.03941 *
as.factor(indclass)5    1.7251     1.3260      1.3260   1.301  0.19330
as.factor(indclass)6    0.7728     0.8370      0.8370   0.923  0.35582
as.factor(indclass)7    1.3570     0.8636      0.8636   1.571  0.11612
as.factor(indclass)8    0.6019     1.0102      1.0102   0.596  0.55129
as.factor(indclass)9    0.9434     0.8304      0.8304   1.136  0.25592
as.factor(indclass)10   0.6547     0.8590      0.8590   0.762  0.44600
as.factor(indclass)11   0.6237     0.8802      0.8802   0.709  0.47856
as.factor(indclass)12   0.6203     0.8149      0.8149   0.761  0.44656
as.factor(indclass)13   1.1521     0.8137      0.8137   1.416  0.15686
as.factor(indclass)14   0.5902     0.8431      0.8431   0.700  0.48388
as.factor(indclass)15   0.7496     0.9097      0.9097   0.824  0.40999
as.factor(indclass)16   2.2406     1.5127      1.5127   1.481  0.13857
as.factor(indclass)17   0.6764     0.8438      0.8438   0.802  0.42276
as.factor(indclass)18   1.7113     1.2096      1.2096   1.415  0.15716
as.factor(indclass)19   0.8201     0.9879      0.9879   0.830  0.40646
as.factor(indclass)20   1.3694     1.5791      1.5791   0.867  0.38586
as.factor(indclass)21   0.9312     0.8193      0.8193   1.137  0.25575
as.factor(indclass)22   0.8394     0.8246      0.8246   1.018  0.30876
as.factor(indclass)23   0.9160     0.8402      0.8402   1.090  0.27562
as.factor(indclass)24   0.5328     1.3072      1.3072   0.408  0.68358
as.factor(indclass)25   0.5098     1.3786      1.3786   0.370  0.71153
as.factor(indclass)26   0.2941     0.9639      0.9639   0.305  0.76028
as.factor(indclass)28   1.1493     1.1362      1.1362   1.012  0.31174
as.factor(indclass)30   0.1339     1.7679      1.7679   0.076  0.93961
as.factor(indclass)32   1.0783     0.8572      0.8572   1.258  0.20843
```

as.factor(indclass)33	1.1505	0.9593	0.9593	1.199	0.23045	
as.factor(indclass)34	0.8740	0.8382	0.8382	1.043	0.29712	
as.factor(indclass)35	1.0941	0.8182	0.8182	1.337	0.18120	
as.factor(indclass)36	1.0477	0.8067	0.8067	1.299	0.19404	
as.factor(indclass)37	1.0059	0.8105	0.8105	1.241	0.21460	
as.factor(indclass)38	0.9199	0.8196	0.8196	1.122	0.26167	
as.factor(indclass)39	0.1372	0.8843	0.8843	0.155	0.87670	
as.factor(indclass)41	1.7520	1.4086	1.4086	1.244	0.21361	
as.factor(indclass)42	0.7761	0.8346	0.8346	0.930	0.35242	
as.factor(indclass)43	0.7622	0.8173	0.8173	0.933	0.35108	
as.factor(indclass)44	0.3681	0.8229	0.8229	0.447	0.65467	
as.factor(indclass)49	2.3242	1.2765	1.2765	1.821	0.06866	.
s(year)1	0.6444	0.2389	0.2389	2.697	0.00700	**
s(year)2	0.1052	0.1721	0.1721	0.611	0.54099	
s(year)3	0.5610	0.2013	0.2013	2.786	0.00534	**
s(assets)1	13.9326	1.8062	1.8062	7.714	1.31e-14	***
s(assets)2	17.2687	1.0623	1.0623	16.256	< 2e-16	***
s(assets)3	15.3595	1.1601	1.1601	13.240	< 2e-16	***
s(assets)4	21.1744	1.2389	1.2389	17.091	< 2e-16	***
s(assets)5	17.4755	1.5150	1.5150	11.535	< 2e-16	***
s(assets)6	39.5105	3.6351	3.6351	10.869	< 2e-16	***
s(assets)7	-8.1529	5.9643	5.9643	-1.367	0.17167	
s(capex)1	24.3226	13.2591	13.2591	1.834	0.06662	.
s(capex)2	-1.1946	3.8567	3.8567	-0.310	0.75675	
s(capex)3	-0.5022	3.8538	3.8538	-0.130	0.89632	
s(capex)4	-1.8042	4.2166	4.2166	-0.428	0.66875	
s(capex)5	3.3299	5.0207	5.0207	0.663	0.50719	
s(ltd)1	0.1603	0.1728	0.1728	0.928	0.35351	
s(ltd)2	-0.1119	0.1032	0.1032	-1.085	0.27800	
s(ltd)3	1.0771	0.2006	0.2006	5.369	8.04e-08	***
s(ltd)4	4.1628	1.7940	1.7940	2.320	0.02033	*
s(ltd)5	0.5213	3.3633	3.3633	0.155	0.87682	
s(ebitda)1	9.7646	4.2872	4.2872	2.278	0.02277	*
s(ebitda)2	6.3865	3.0145	3.0145	2.119	0.03414	*
s(ebitda)3	5.7441	3.0351	3.0351	1.893	0.05844	.
s(ebitda)4	-4.0144	3.1131	3.1131	-1.290	0.19724	
s(ebitda)5	2.2214	3.4795	3.4795	0.638	0.52320	
s(ppe)1	0.5202	0.4121	0.4121	1.262	0.20682	
s(ppe)2	-0.5795	0.4516	0.4516	-1.283	0.19944	
s(ppe)3	8.2825	1.9463	1.9463	4.255	2.10e-05	***
s(ppe)4	-2.3235	2.6043	2.6043	-0.892	0.37231	
s(sales)1	-0.7546	0.2932	0.2932	-2.574	0.01007	*
s(sales)2	0.5574	2.1232	2.1232	0.263	0.79294	
s(sales)3	-12.5262	2.1583	2.1583	-5.804	6.63e-09	***
s(ads)1	0.5549	0.1388	0.1388	3.997	6.46e-05	***
s(ads)2	-1.2768	0.9526	0.9526	-1.340	0.18014	
s(ads)3	-2.3815	1.7117	1.7117	-1.391	0.16414	
s(rd)1	0.9831	0.3125	0.3125	3.146	0.00166	**
s(rd)2	-0.2182	0.1595	0.1595	-1.368	0.17130	
s(rd)3	-4.0810	1.0401	1.0401	-3.924	8.77e-05	***
s(rd)4	5.6935	2.0009	2.0009	2.845	0.00444	**
s(bookval)1	-50.5226	2.1582	2.1582	-23.409	< 2e-16	***
s(bookval)2	-49.7107	1.6693	1.6693	-29.779	< 2e-16	***
s(bookval)3	-65.2587	1.7032	1.7032	-38.316	< 2e-16	***

```
s(bookval)4            -76.3912     1.7316      1.7316 -44.117  < 2e-16 ***
s(bookval)5            -83.3197     1.7365      1.7365 -47.982  < 2e-16 ***
s(bookval)6           -138.0833     3.2866      3.2866 -42.013  < 2e-16 ***
s(bookval)7            -64.4314     4.8969      4.8969 -13.158  < 2e-16 ***
s(mv)1                   9.4423     0.5859      0.5859  16.116  < 2e-16 ***
s(mv)2                  15.4950     0.5534      0.5534  28.001  < 2e-16 ***
s(mv)3                  19.0301     0.6122      0.6122  31.087  < 2e-16 ***
s(mv)4                  21.0754     0.5765      0.5765  36.560  < 2e-16 ***
s(mv)5                  27.2288     0.5959      0.5959  45.696  < 2e-16 ***
s(mv)6                  54.7190     1.0047      1.0047  54.464  < 2e-16 ***
s(mv)7                  40.5590     1.2644      1.2644  32.078  < 2e-16 ***
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

(Dispersion parameter for gaussian family taken to be 14.62874)

    Null deviance: 375420  on 13524  degrees of freedom
Residual deviance: 196479  on 13431  degrees of freedom
AIC:  74765

Max Panel Size = 1 (independence assumed); Number of panels = 13525
Number of Fisher Scoring iterations: 2
```

```
anova(salsa1dOutput$bestModel, test = "F")
```

```
Analysis of Deviance Table (Type II tests)
Marginal Testing

Response: response
Error estimate based on Pearson residuals

                        SS    Df        F    Pr(>F)
as.factor(indclass)    700    40   1.1959  0.185054
s(year)                132     3   3.0181  0.028612 *
s(assets)            10091     7  98.5473 < 2.2e-16 ***
s(capex)               319     5   4.3586  0.000577 ***
s(ltd)                 499     5   6.8180 2.326e-06 ***
s(ebitda)             1513     5  20.6878 < 2.2e-16 ***
s(ppe)                 667     4  11.3934 3.130e-09 ***
s(sales)               548     3  12.4887 3.758e-08 ***
s(ads)                 371     3   8.4628 1.295e-05 ***
s(rd)                  626     4  10.7062 1.161e-08 ***
s(bookval)           85399     7 833.9674 < 2.2e-16 ***
s(mv)                97755     7 954.6296 < 2.2e-16 ***
Residuals           196479 13431
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

```
BIC(salsa1dOutput$bestModel)
```

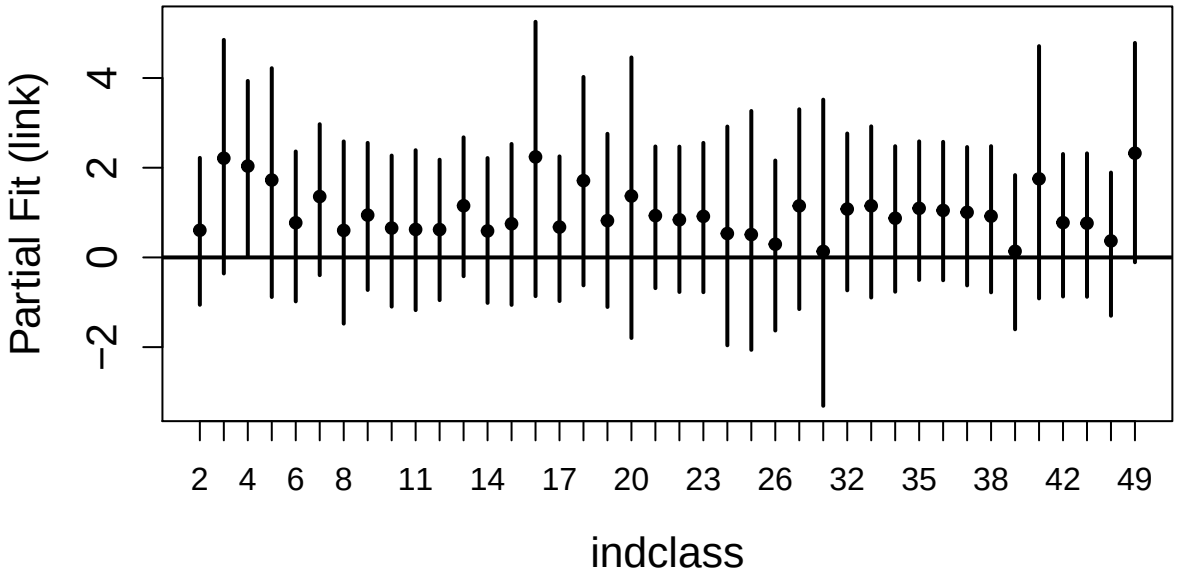
```
[1] 75479.04
```

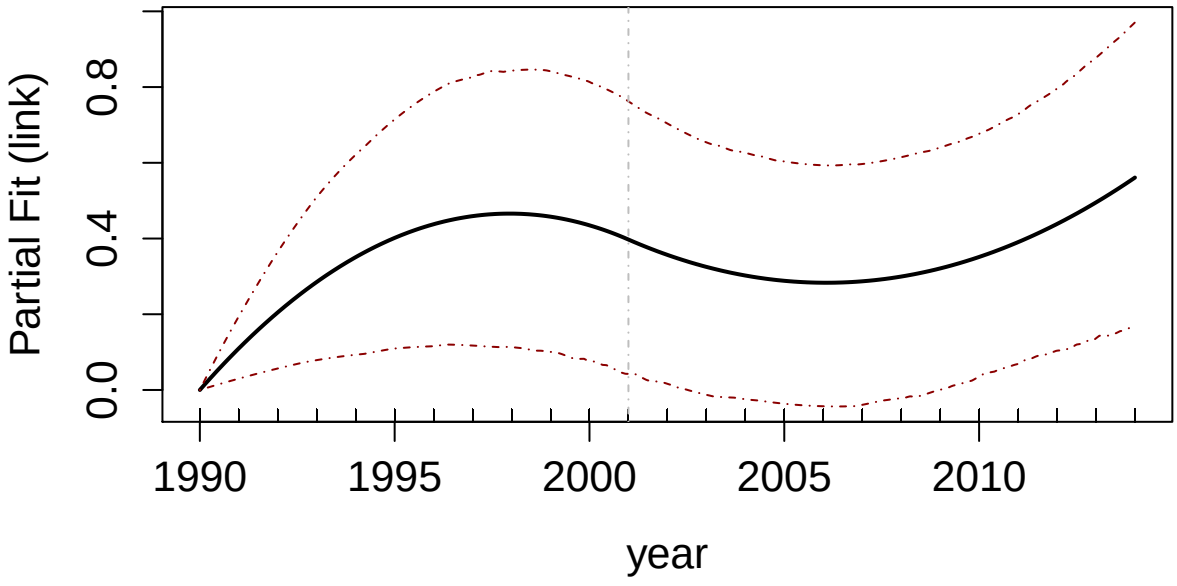
```
set.seed(123)
cv.gamMRSea(data = newdat, modelobject = salsa1dOutput$bestModel, K = 5)$delta[2]
```

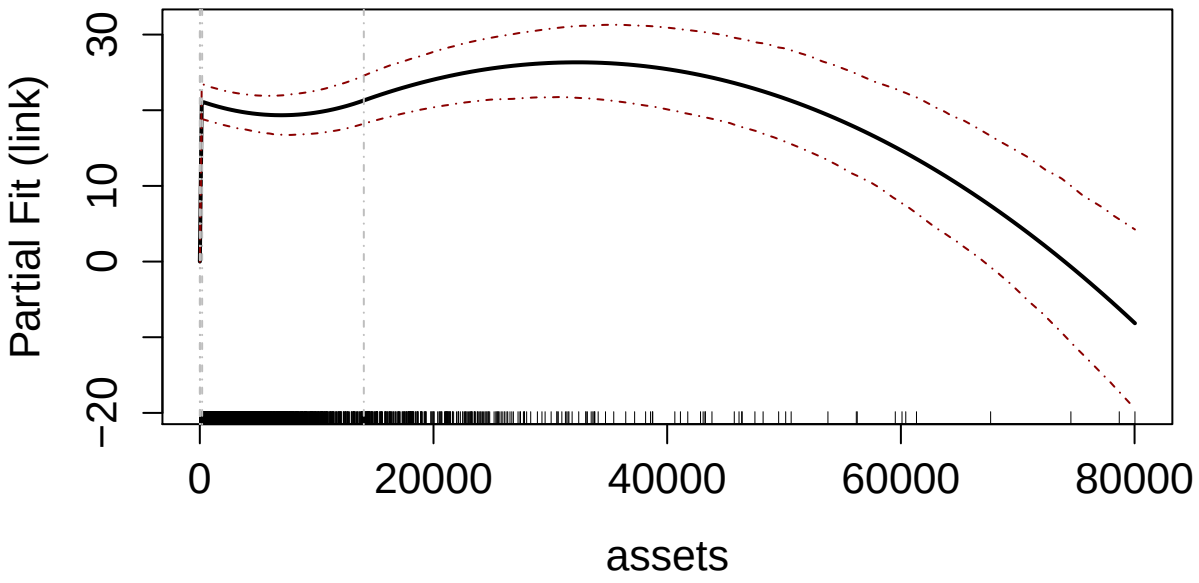
```
[1] 15.2088
```

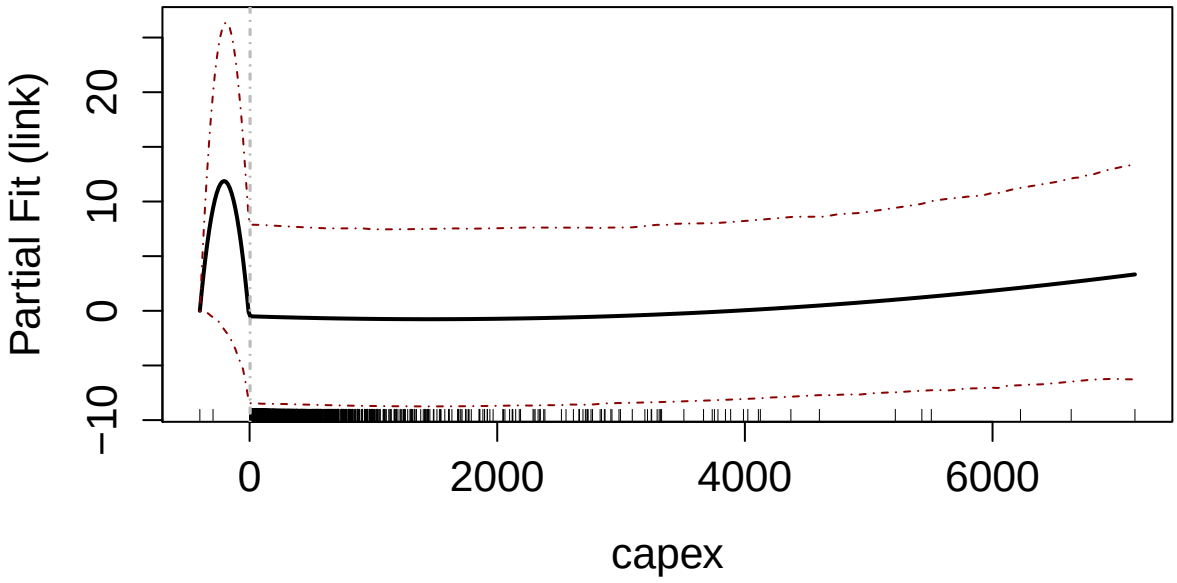
```
par(mfrow = c(1, 1))
runPartialPlots(salsa1dOutput$bestModel, varlist.in = varlist, factorlist.in = factorlist,
    data = newdat, showKnots = TRUE, type = "link")
```

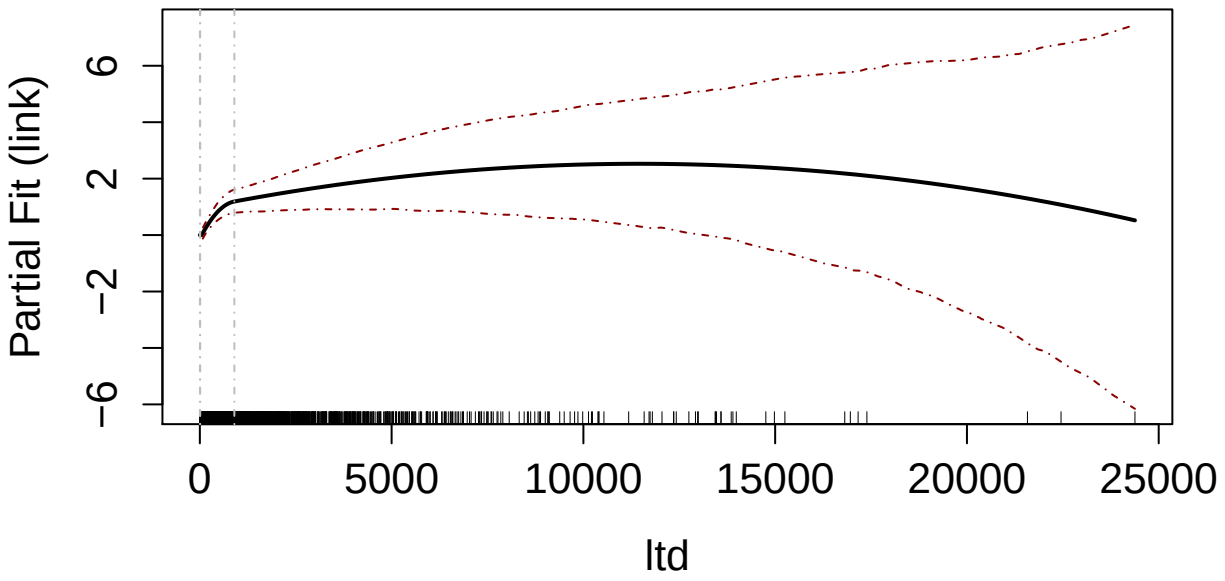
```
[1] "Making partial plots"
```

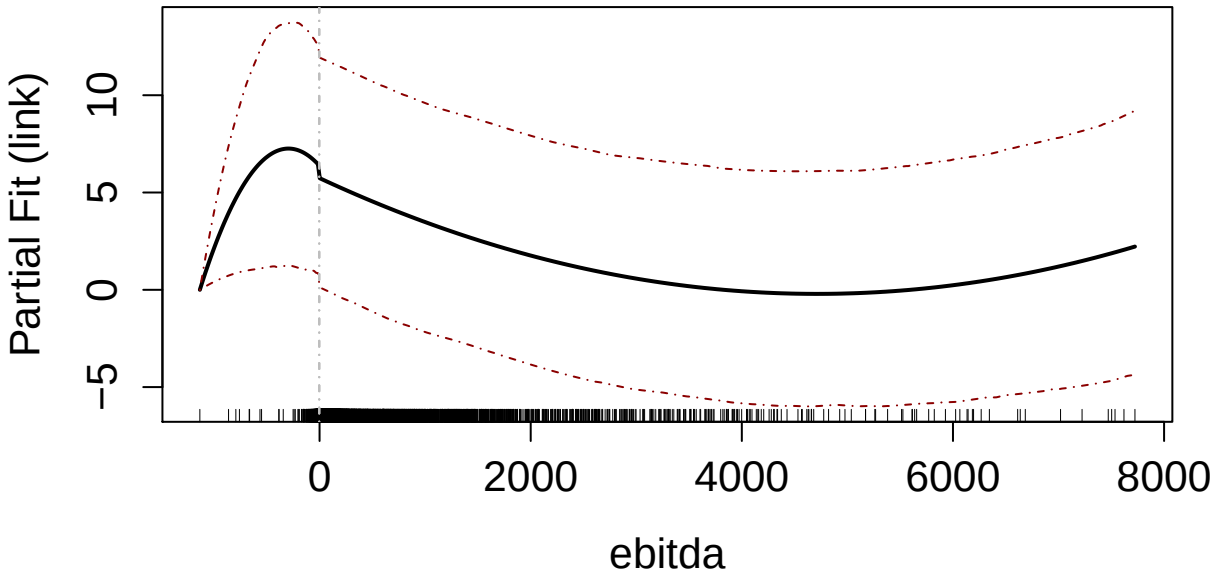


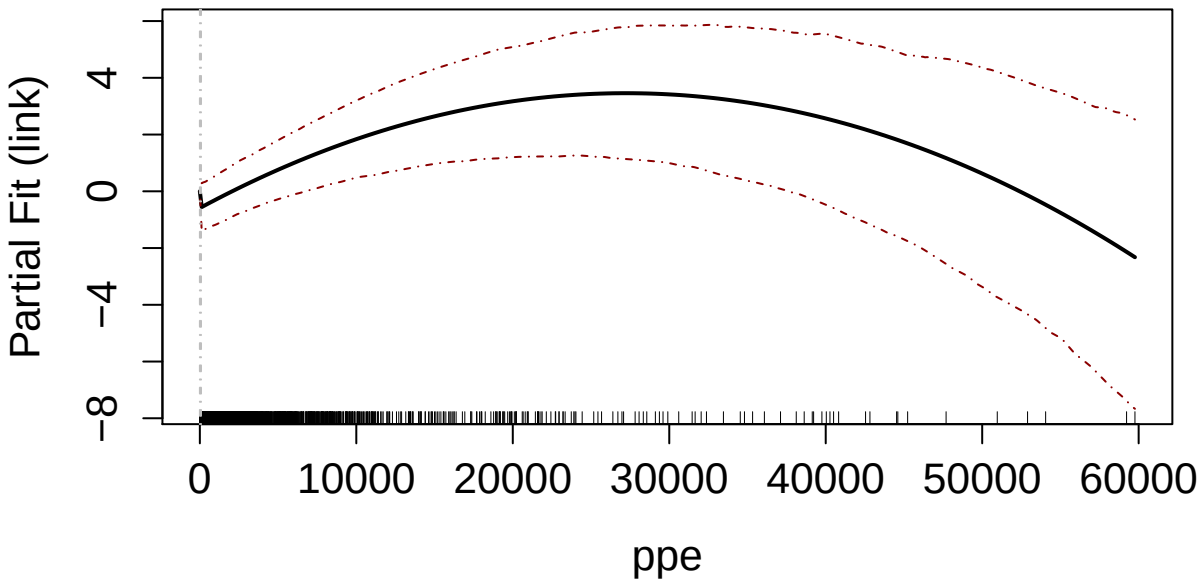


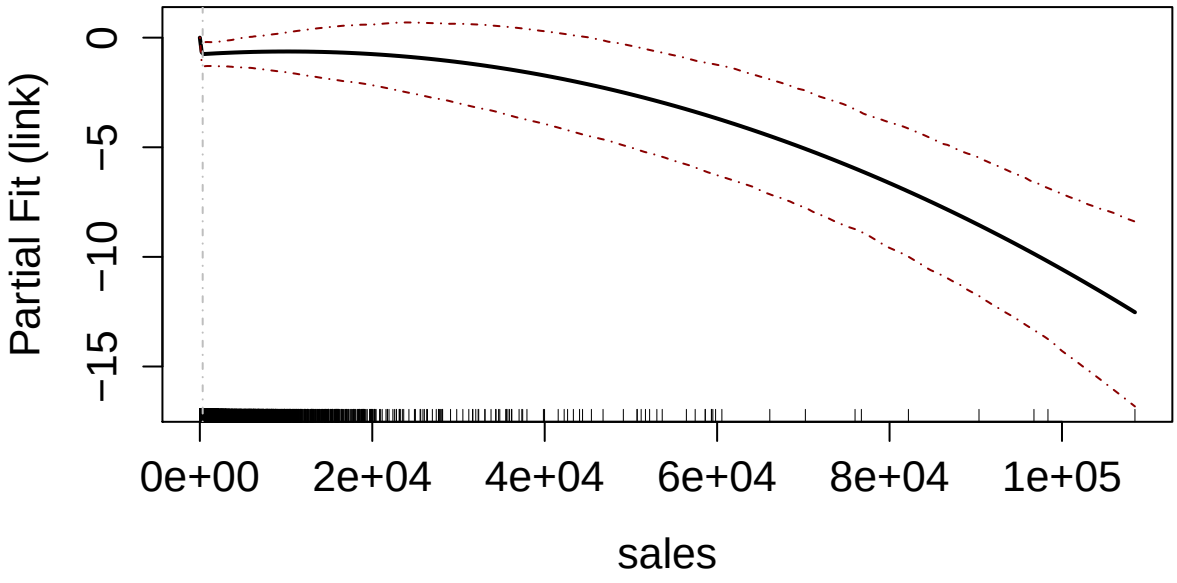

Partial Fit (link)
30
10
0
−20
0
20000
40000
60000
80000
assets

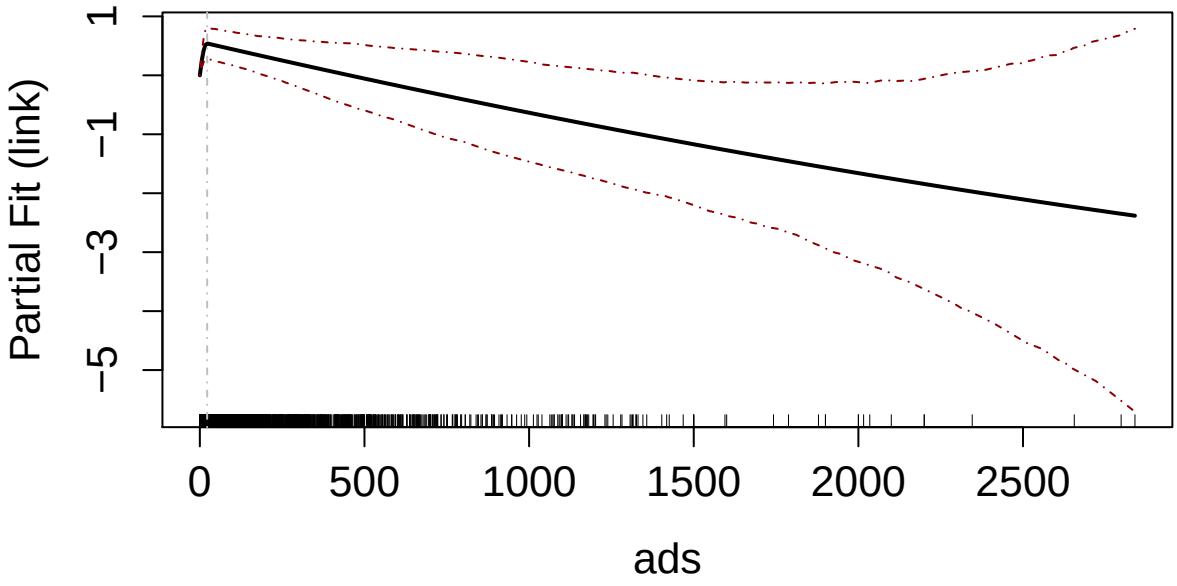

Partial Fit (link)
20
10
0
−10
0
2000
4000
6000
capex

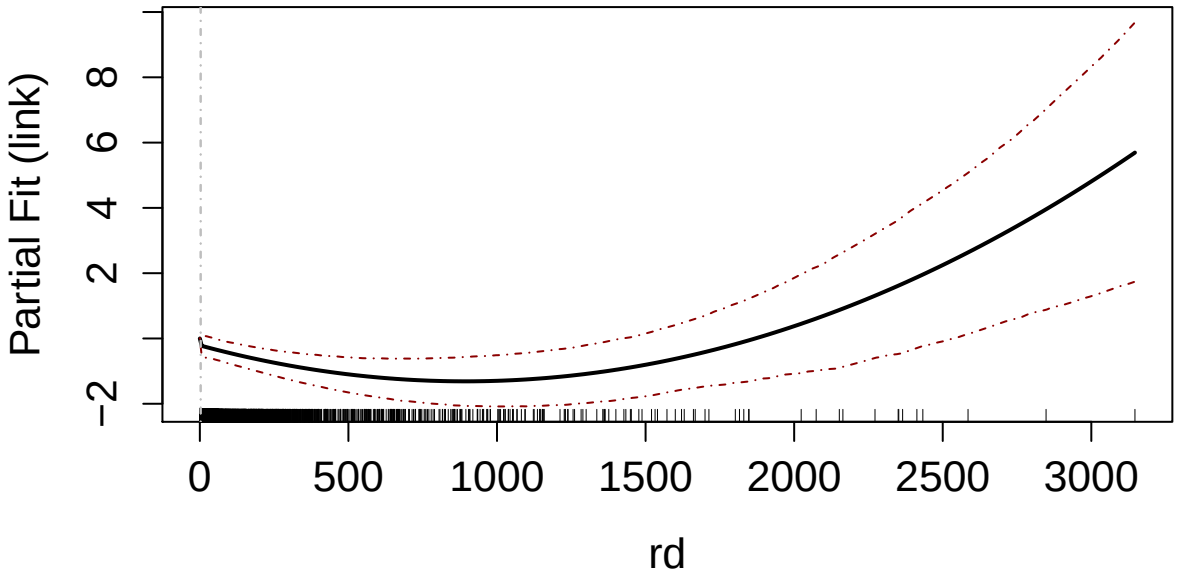

Partial Fit (link)
6
2
−2
−6
0
5000
10000
15000
20000
25000
ltd

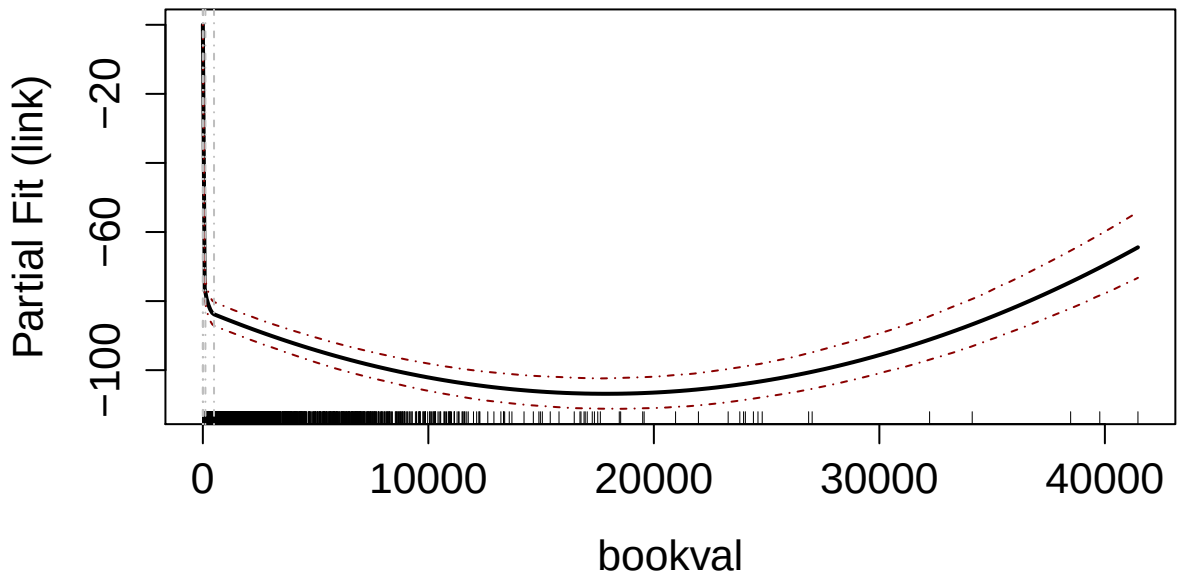

Partial Fit (link)
10
5
0
−5
0
2000
4000
6000
8000
ebitda

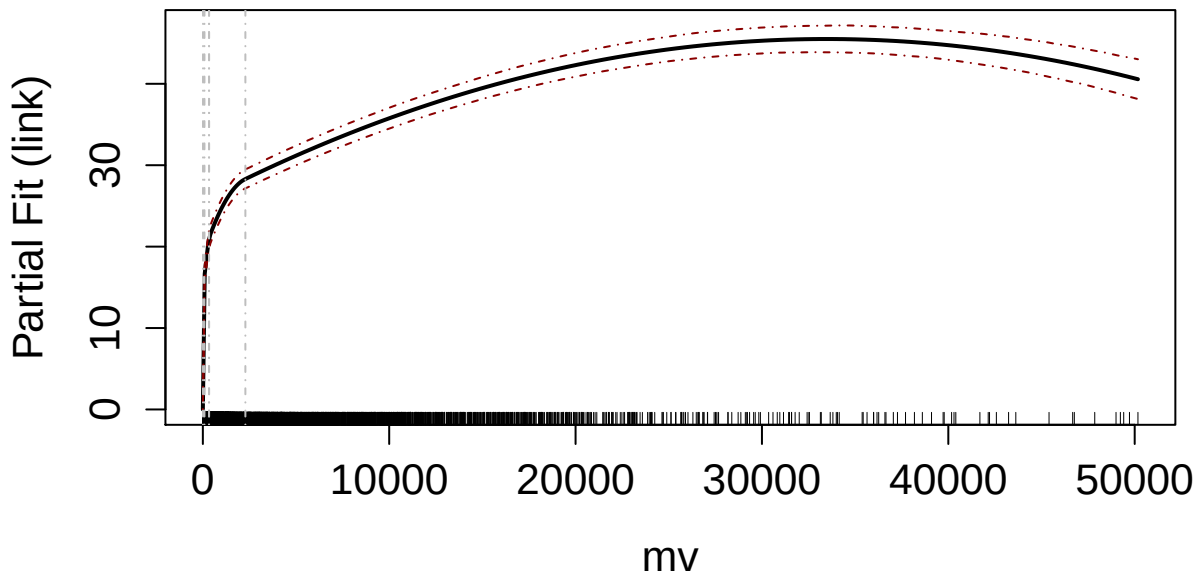

Partial Fit (link)
4
0
−4
−8
0
10000
20000
30000
40000
50000
60000
ppe


Partial Fit (link)
0
−5
−10
−15
0e+00
2e+04
4e+04
6e+04
8e+04
1e+05
sales


Partial Fit (link)
1
−1
−3
−5
0
500
1000
1500
2000
2500
ads


Partial Fit (link)
8
6
4
2
−2
0
500
1000
1500
2000
2500
3000
rd






```
salsa1dOutput$keptvarlist
```

```
 [1] "year"    "assets"  "capex"   "ltd"     "ebitda"  "ppe"     "sales"
 [8] "ads"     "rd"      "bookval" "mv"
```

```
salsa1dOutput$modelFits1D
```

```
[[1]]
[[1]]$term
[1] "startmodel"

[[1]]$kept
NULL

[[1]]$basemodelformula
glm(formula = response ~ as.factor(indclass) + bs(year, knots = splineParams[[2]]$knots,
    degree = splineParams[[2]]$degree, Boundary.knots = splineParams[[2]]$bd) +
    bs(assets, knots = splineParams[[3]]$knots, degree = splineParams[[3]]$degree,
        Boundary.knots = splineParams[[3]]$bd) + bs(capex, knots = splineParams[[4]]$knots,
    degree = splineParams[[4]]$degree, Boundary.knots = splineParams[[4]]$bd) +
    bs(ltd, knots = splineParams[[5]]$knots, degree = splineParams[[5]]$degree,
        Boundary.knots = splineParams[[5]]$bd) + bs(ebitda, knots = splineParams[[6]]$knots,
    degree = splineParams[[6]]$degree, Boundary.knots = splineParams[[6]]$bd) +
    bs(ppe, knots = splineParams[[7]]$knots, degree = splineParams[[7]]$degree,
        Boundary.knots = splineParams[[7]]$bd) + bs(sales, knots = splineParams[[8]]$knots,
    degree = splineParams[[8]]$degree, Boundary.knots = splineParams[[8]]$bd) +
    bs(ads, knots = splineParams[[9]]$knots, degree = splineParams[[9]]$degree,
        Boundary.knots = splineParams[[9]]$bd) + bs(rd, knots = splineParams[[10]]$knots,
    degree = splineParams[[10]]$degree, Boundary.knots = splineParams[[10]]$bd) +
    bs(bookval, knots = splineParams[[11]]$knots, degree = splineParams[[11]]$degree,
        Boundary.knots = splineParams[[11]]$bd) + bs(mv, knots = splineParams[[12]]$knots,
    degree = splineParams[[12]]$degree, Boundary.knots = splineParams[[12]]$bd),
    family = gaussian(link = identity), data = data)

[[1]]$knotsSelected
NULL

[[1]]$tempfits
 fitStat
79214.52


[[2]]
[[2]]$term
[1] "bs(year, knots = splineParams[[2]]$knots, degree=splineParams[[2]]$degree, Boundary.knots=splinePa

[[2]]$kept
[1] "YES - new knots"

[[2]]$basemodelformula
glm(formula = response ~ as.factor(indclass) + bs(assets, knots = splineParams[[3]]$knots,
    degree = splineParams[[3]]$degree, Boundary.knots = splineParams[[3]]$bd) +
    bs(capex, knots = splineParams[[4]]$knots, degree = splineParams[[4]]$degree,
        Boundary.knots = splineParams[[4]]$bd) + bs(ltd, knots = splineParams[[5]]$knots,
    degree = splineParams[[5]]$degree, Boundary.knots = splineParams[[5]]$bd) +
    bs(ebitda, knots = splineParams[[6]]$knots, degree = splineParams[[6]]$degree,
        Boundary.knots = splineParams[[6]]$bd) + bs(ppe, knots = splineParams[[7]]$knots,
    degree = splineParams[[7]]$degree, Boundary.knots = splineParams[[7]]$bd) +
    bs(sales, knots = splineParams[[8]]$knots, degree = splineParams[[8]]$degree,
```

```
        Boundary.knots = splineParams[[8]]$bd) + bs(ads, knots = splineParams[[9]]$knots,
    degree = splineParams[[9]]$degree, Boundary.knots = splineParams[[9]]$bd) +
    bs(rd, knots = splineParams[[10]]$knots, degree = splineParams[[10]]$degree,
        Boundary.knots = splineParams[[10]]$bd) + bs(bookval,
    knots = splineParams[[11]]$knots, degree = splineParams[[11]]$degree,
    Boundary.knots = splineParams[[11]]$bd) + bs(mv, knots = splineParams[[12]]$knots,
    degree = splineParams[[12]]$degree, Boundary.knots = splineParams[[12]]$bd) +
    bs(year, knots = splineParams[[2]]$knots, degree = splineParams[[2]]$degree,
        Boundary.knots = splineParams[[2]]$bd), family = gaussian(link = identity),
    data = data)

[[2]]$knotsSelected
[1] 2001

[[2]]$baseModelFits
 fitStat
79206.97

[[2]]$modelfits
 fitStat
79206.97


[[3]]
[[3]]$term
[1] "bs(assets, knots = splineParams[[3]]$knots, degree=splineParams[[3]]$degree, Boundary.knots=splinel

[[3]]$kept
[1] "YES - new knots"

[[3]]$basemodelformula
glm(formula = response ~ as.factor(indclass) + bs(capex, knots = splineParams[[4]]$knots,
    degree = splineParams[[4]]$degree, Boundary.knots = splineParams[[4]]$bd) +
    bs(ltd, knots = splineParams[[5]]$knots, degree = splineParams[[5]]$degree,
        Boundary.knots = splineParams[[5]]$bd) + bs(ebitda, knots = splineParams[[6]]$knots,
    degree = splineParams[[6]]$degree, Boundary.knots = splineParams[[6]]$bd) +
    bs(ppe, knots = splineParams[[7]]$knots, degree = splineParams[[7]]$degree,
        Boundary.knots = splineParams[[7]]$bd) + bs(sales, knots = splineParams[[8]]$knots,
    degree = splineParams[[8]]$degree, Boundary.knots = splineParams[[8]]$bd) +
    bs(ads, knots = splineParams[[9]]$knots, degree = splineParams[[9]]$degree,
        Boundary.knots = splineParams[[9]]$bd) + bs(rd, knots = splineParams[[10]]$knots,
    degree = splineParams[[10]]$degree, Boundary.knots = splineParams[[10]]$bd) +
    bs(bookval, knots = splineParams[[11]]$knots, degree = splineParams[[11]]$degree,
        Boundary.knots = splineParams[[11]]$bd) + bs(mv, knots = splineParams[[12]]$knots,
    degree = splineParams[[12]]$degree, Boundary.knots = splineParams[[12]]$bd) +
    bs(year, knots = splineParams[[2]]$knots, degree = splineParams[[2]]$degree,
        Boundary.knots = splineParams[[2]]$bd) + bs(assets, knots = splineParams[[3]]$knots,
    degree = splineParams[[3]]$degree, Boundary.knots = splineParams[[3]]$bd),
    family = gaussian(link = identity), data = data)

[[3]]$knotsSelected
[1]     7.974     8.584     9.623   198.588 14036.000

[[3]]$baseModelFits
```

```
 fitStat
78972.28

[[3]]$modelfits
 fitStat
78972.28


[[4]]
[[4]]$term
[1] "bs(capex, knots = splineParams[[4]]$knots, degree=splineParams[[4]]$degree, Boundary.knots=splinePa

[[4]]$kept
[1] "YES - new knots"

[[4]]$basemodelformula
glm(formula = response ~ as.factor(indclass) + bs(ltd, knots = splineParams[[5]]$knots,
    degree = splineParams[[5]]$degree, Boundary.knots = splineParams[[5]]$bd) +
    bs(ebitda, knots = splineParams[[6]]$knots, degree = splineParams[[6]]$degree,
        Boundary.knots = splineParams[[6]]$bd) + bs(ppe, knots = splineParams[[7]]$knots,
    degree = splineParams[[7]]$degree, Boundary.knots = splineParams[[7]]$bd) +
    bs(sales, knots = splineParams[[8]]$knots, degree = splineParams[[8]]$degree,
        Boundary.knots = splineParams[[8]]$bd) + bs(ads, knots = splineParams[[9]]$knots,
    degree = splineParams[[9]]$degree, Boundary.knots = splineParams[[9]]$bd) +
    bs(rd, knots = splineParams[[10]]$knots, degree = splineParams[[10]]$degree,
        Boundary.knots = splineParams[[10]]$bd) + bs(bookval,
    knots = splineParams[[11]]$knots, degree = splineParams[[11]]$degree,
    Boundary.knots = splineParams[[11]]$bd) + bs(mv, knots = splineParams[[12]]$knots,
    degree = splineParams[[12]]$degree, Boundary.knots = splineParams[[12]]$bd) +
    bs(year, knots = splineParams[[2]]$knots, degree = splineParams[[2]]$degree,
        Boundary.knots = splineParams[[2]]$bd) + bs(assets, knots = splineParams[[3]]$knots,
    degree = splineParams[[3]]$degree, Boundary.knots = splineParams[[3]]$bd) +
    bs(capex, knots = splineParams[[4]]$knots, degree = splineParams[[4]]$degree,
        Boundary.knots = splineParams[[4]]$bd), family = gaussian(link = identity),
    data = data)

[[4]]$knotsSelected
[1] 0.475 0.872 9.097

[[4]]$baseModelFits
 fitStat
78973.01

[[4]]$modelfits
 fitStat
78973.01


[[5]]
[[5]]$term
[1] "bs(ltd, knots = splineParams[[5]]$knots, degree=splineParams[[5]]$degree, Boundary.knots=splinePara

[[5]]$kept
[1] "YES - new knots"
```

```
[[5]]$basemodelformula
glm(formula = response ~ as.factor(indclass) + bs(ebitda, knots = splineParams[[6]]$knots,
    degree = splineParams[[6]]$degree, Boundary.knots = splineParams[[6]]$bd) +
    bs(ppe, knots = splineParams[[7]]$knots, degree = splineParams[[7]]$degree,
        Boundary.knots = splineParams[[7]]$bd) + bs(sales, knots = splineParams[[8]]$knots,
    degree = splineParams[[8]]$degree, Boundary.knots = splineParams[[8]]$bd) +
    bs(ads, knots = splineParams[[9]]$knots, degree = splineParams[[9]]$degree,
        Boundary.knots = splineParams[[9]]$bd) + bs(rd, knots = splineParams[[10]]$knots,
    degree = splineParams[[10]]$degree, Boundary.knots = splineParams[[10]]$bd) +
    bs(bookval, knots = splineParams[[11]]$knots, degree = splineParams[[11]]$degree,
        Boundary.knots = splineParams[[11]]$bd) + bs(mv, knots = splineParams[[12]]$knots,
    degree = splineParams[[12]]$degree, Boundary.knots = splineParams[[12]]$bd) +
    bs(year, knots = splineParams[[2]]$knots, degree = splineParams[[2]]$degree,
        Boundary.knots = splineParams[[2]]$bd) + bs(assets, knots = splineParams[[3]]$knots,
    degree = splineParams[[3]]$degree, Boundary.knots = splineParams[[3]]$bd) +
    bs(capex, knots = splineParams[[4]]$knots, degree = splineParams[[4]]$degree,
        Boundary.knots = splineParams[[4]]$bd) + bs(ltd, knots = splineParams[[5]]$knots,
    degree = splineParams[[5]]$degree, Boundary.knots = splineParams[[5]]$bd),
    family = gaussian(link = identity), data = data)

[[5]]$knotsSelected
[1]   2.431   9.205 899.955

[[5]]$baseModelFits
 fitStat
78964.83

[[5]]$modelfits
 fitStat
78964.83


[[6]]
[[6]]$term
[1] "bs(ebitda, knots = splineParams[[6]]$knots, degree=splineParams[[6]]$degree, Boundary.knots=splineP

[[6]]$kept
[1] "YES - new knots"

[[6]]$basemodelformula
glm(formula = response ~ as.factor(indclass) + bs(ppe, knots = splineParams[[7]]$knots,
    degree = splineParams[[7]]$degree, Boundary.knots = splineParams[[7]]$bd) +
    bs(sales, knots = splineParams[[8]]$knots, degree = splineParams[[8]]$degree,
        Boundary.knots = splineParams[[8]]$bd) + bs(ads, knots = splineParams[[9]]$knots,
    degree = splineParams[[9]]$degree, Boundary.knots = splineParams[[9]]$bd) +
    bs(rd, knots = splineParams[[10]]$knots, degree = splineParams[[10]]$degree,
        Boundary.knots = splineParams[[10]]$bd) + bs(bookval,
    knots = splineParams[[11]]$knots, degree = splineParams[[11]]$degree,
    Boundary.knots = splineParams[[11]]$bd) + bs(mv, knots = splineParams[[12]]$knots,
    degree = splineParams[[12]]$degree, Boundary.knots = splineParams[[12]]$bd) +
    bs(year, knots = splineParams[[2]]$knots, degree = splineParams[[2]]$degree,
        Boundary.knots = splineParams[[2]]$bd) + bs(assets, knots = splineParams[[3]]$knots,
    degree = splineParams[[3]]$degree, Boundary.knots = splineParams[[3]]$bd) +
```

```
    bs(capex, knots = splineParams[[4]]$knots, degree = splineParams[[4]]$degree,
        Boundary.knots = splineParams[[4]]$bd) + bs(ltd, knots = splineParams[[5]]$knots,
    degree = splineParams[[5]]$degree, Boundary.knots = splineParams[[5]]$bd) +
    bs(ebitda, knots = splineParams[[6]]$knots, degree = splineParams[[6]]$degree,
        Boundary.knots = splineParams[[6]]$bd), family = gaussian(link = identity),
    data = data)

[[6]]$knotsSelected
[1] -4.384 -2.195 -2.016

[[6]]$baseModelFits
 fitStat
78942.19

[[6]]$modelfits
 fitStat
78942.19


[[7]]
[[7]]$term
[1] "bs(ppe, knots = splineParams[[7]]$knots, degree=splineParams[[7]]$degree, Boundary.knots=splinePara

[[7]]$kept
[1] "YES - new knots"

[[7]]$basemodelformula
glm(formula = response ~ as.factor(indclass) + bs(sales, knots = splineParams[[8]]$knots,
    degree = splineParams[[8]]$degree, Boundary.knots = splineParams[[8]]$bd) +
    bs(ads, knots = splineParams[[9]]$knots, degree = splineParams[[9]]$degree,
        Boundary.knots = splineParams[[9]]$bd) + bs(rd, knots = splineParams[[10]]$knots,
    degree = splineParams[[10]]$degree, Boundary.knots = splineParams[[10]]$bd) +
    bs(bookval, knots = splineParams[[11]]$knots, degree = splineParams[[11]]$degree,
        Boundary.knots = splineParams[[11]]$bd) + bs(mv, knots = splineParams[[12]]$knots,
    degree = splineParams[[12]]$degree, Boundary.knots = splineParams[[12]]$bd) +
    bs(year, knots = splineParams[[2]]$knots, degree = splineParams[[2]]$degree,
        Boundary.knots = splineParams[[2]]$bd) + bs(assets, knots = splineParams[[3]]$knots,
    degree = splineParams[[3]]$degree, Boundary.knots = splineParams[[3]]$bd) +
    bs(capex, knots = splineParams[[4]]$knots, degree = splineParams[[4]]$degree,
        Boundary.knots = splineParams[[4]]$bd) + bs(ltd, knots = splineParams[[5]]$knots,
    degree = splineParams[[5]]$degree, Boundary.knots = splineParams[[5]]$bd) +
    bs(ebitda, knots = splineParams[[6]]$knots, degree = splineParams[[6]]$degree,
        Boundary.knots = splineParams[[6]]$bd) + bs(ppe, knots = splineParams[[7]]$knots,
    degree = splineParams[[7]]$degree, Boundary.knots = splineParams[[7]]$bd),
    family = gaussian(link = identity), data = data)

[[7]]$knotsSelected
[1]  3.657 74.333

[[7]]$baseModelFits
 fitStat
78939.68

[[7]]$modelfits
```

```
 fitStat
78939.68


[[8]]
[[8]]$term
[1] "bs(sales, knots = splineParams[[8]]$knots, degree=splineParams[[8]]$degree, Boundary.knots=splinePa

[[8]]$kept
[1] "YES - new knots"

[[8]]$basemodelformula
glm(formula = response ~ as.factor(indclass) + bs(ads, knots = splineParams[[9]]$knots,
    degree = splineParams[[9]]$degree, Boundary.knots = splineParams[[9]]$bd) +
    bs(rd, knots = splineParams[[10]]$knots, degree = splineParams[[10]]$degree,
        Boundary.knots = splineParams[[10]]$bd) + bs(bookval,
    knots = splineParams[[11]]$knots, degree = splineParams[[11]]$degree,
    Boundary.knots = splineParams[[11]]$bd) + bs(mv, knots = splineParams[[12]]$knots,
    degree = splineParams[[12]]$degree, Boundary.knots = splineParams[[12]]$bd) +
    bs(year, knots = splineParams[[2]]$knots, degree = splineParams[[2]]$degree,
        Boundary.knots = splineParams[[2]]$bd) + bs(assets, knots = splineParams[[3]]$knots,
    degree = splineParams[[3]]$degree, Boundary.knots = splineParams[[3]]$bd) +
    bs(capex, knots = splineParams[[4]]$knots, degree = splineParams[[4]]$degree,
        Boundary.knots = splineParams[[4]]$bd) + bs(ltd, knots = splineParams[[5]]$knots,
    degree = splineParams[[5]]$degree, Boundary.knots = splineParams[[5]]$bd) +
    bs(ebitda, knots = splineParams[[6]]$knots, degree = splineParams[[6]]$degree,
        Boundary.knots = splineParams[[6]]$bd) + bs(ppe, knots = splineParams[[7]]$knots,
    degree = splineParams[[7]]$degree, Boundary.knots = splineParams[[7]]$bd) +
    bs(sales, knots = splineParams[[8]]$knots, degree = splineParams[[8]]$degree,
        Boundary.knots = splineParams[[8]]$bd), family = gaussian(link = identity),
    data = data)

[[8]]$knotsSelected
[1] 328.882

[[8]]$baseModelFits
 fitStat
78938.62

[[8]]$modelfits
 fitStat
78938.62


[[9]]
[[9]]$term
[1] "bs(ads, knots = splineParams[[9]]$knots, degree=splineParams[[9]]$degree, Boundary.knots=splinePara

[[9]]$kept
[1] "YES - new knots"

[[9]]$basemodelformula
glm(formula = response ~ as.factor(indclass) + bs(rd, knots = splineParams[[10]]$knots,
    degree = splineParams[[10]]$degree, Boundary.knots = splineParams[[10]]$bd) +
```

```
    bs(bookval, knots = splineParams[[11]]$knots, degree = splineParams[[11]]$degree,
        Boundary.knots = splineParams[[11]]$bd) + bs(mv, knots = splineParams[[12]]$knots,
    degree = splineParams[[12]]$degree, Boundary.knots = splineParams[[12]]$bd) +
    bs(year, knots = splineParams[[2]]$knots, degree = splineParams[[2]]$degree,
        Boundary.knots = splineParams[[2]]$bd) + bs(assets, knots = splineParams[[3]]$knots,
    degree = splineParams[[3]]$degree, Boundary.knots = splineParams[[3]]$bd) +
    bs(capex, knots = splineParams[[4]]$knots, degree = splineParams[[4]]$degree,
        Boundary.knots = splineParams[[4]]$bd) + bs(ltd, knots = splineParams[[5]]$knots,
    degree = splineParams[[5]]$degree, Boundary.knots = splineParams[[5]]$bd) +
    bs(ebitda, knots = splineParams[[6]]$knots, degree = splineParams[[6]]$degree,
        Boundary.knots = splineParams[[6]]$bd) + bs(ppe, knots = splineParams[[7]]$knots,
    degree = splineParams[[7]]$degree, Boundary.knots = splineParams[[7]]$bd) +
    bs(sales, knots = splineParams[[8]]$knots, degree = splineParams[[8]]$degree,
        Boundary.knots = splineParams[[8]]$bd) + bs(ads, knots = splineParams[[9]]$knots,
    degree = splineParams[[9]]$degree, Boundary.knots = splineParams[[9]]$bd),
    family = gaussian(link = identity), data = data)

[[9]]$knotsSelected
[1] 22.209

[[9]]$baseModelFits
 fitStat
78928.86

[[9]]$modelfits
 fitStat
78928.86


[[10]]
[[10]]$term
[1] "bs(rd, knots = splineParams[[10]]$knots, degree=splineParams[[10]]$degree, Boundary.knots=splinePa

[[10]]$kept
[1] "YES - new knots"

[[10]]$basemodelformula
glm(formula = response ~ as.factor(indclass) + bs(bookval, knots = splineParams[[11]]$knots,
    degree = splineParams[[11]]$degree, Boundary.knots = splineParams[[11]]$bd) +
    bs(mv, knots = splineParams[[12]]$knots, degree = splineParams[[12]]$degree,
        Boundary.knots = splineParams[[12]]$bd) + bs(year, knots = splineParams[[2]]$knots,
    degree = splineParams[[2]]$degree, Boundary.knots = splineParams[[2]]$bd) +
    bs(assets, knots = splineParams[[3]]$knots, degree = splineParams[[3]]$degree,
        Boundary.knots = splineParams[[3]]$bd) + bs(capex, knots = splineParams[[4]]$knots,
    degree = splineParams[[4]]$degree, Boundary.knots = splineParams[[4]]$bd) +
    bs(ltd, knots = splineParams[[5]]$knots, degree = splineParams[[5]]$degree,
        Boundary.knots = splineParams[[5]]$bd) + bs(ebitda, knots = splineParams[[6]]$knots,
    degree = splineParams[[6]]$degree, Boundary.knots = splineParams[[6]]$bd) +
    bs(ppe, knots = splineParams[[7]]$knots, degree = splineParams[[7]]$degree,
        Boundary.knots = splineParams[[7]]$bd) + bs(sales, knots = splineParams[[8]]$knots,
    degree = splineParams[[8]]$degree, Boundary.knots = splineParams[[8]]$bd) +
    bs(ads, knots = splineParams[[9]]$knots, degree = splineParams[[9]]$degree,
        Boundary.knots = splineParams[[9]]$bd) + bs(rd, knots = splineParams[[10]]$knots,
    degree = splineParams[[10]]$degree, Boundary.knots = splineParams[[10]]$bd),
```

```
    family = gaussian(link = identity), data = data)

[[10]]$knotsSelected
[1] 2.531 2.990

[[10]]$baseModelFits
 fitStat
78915.92

[[10]]$modelfits
 fitStat
78915.92


[[11]]
[[11]]$term
[1] "bs(bookval, knots = splineParams[[11]]$knots, degree=splineParams[[11]]$degree, Boundary.knots=spli

[[11]]$kept
[1] "YES - new knots"

[[11]]$basemodelformula
glm(formula = response ~ as.factor(indclass) + bs(mv, knots = splineParams[[12]]$knots,
    degree = splineParams[[12]]$degree, Boundary.knots = splineParams[[12]]$bd) +
    bs(year, knots = splineParams[[2]]$knots, degree = splineParams[[2]]$degree,
        Boundary.knots = splineParams[[2]]$bd) + bs(assets, knots = splineParams[[3]]$knots,
    degree = splineParams[[3]]$degree, Boundary.knots = splineParams[[3]]$bd) +
    bs(capex, knots = splineParams[[4]]$knots, degree = splineParams[[4]]$degree,
        Boundary.knots = splineParams[[4]]$bd) + bs(ltd, knots = splineParams[[5]]$knots,
    degree = splineParams[[5]]$degree, Boundary.knots = splineParams[[5]]$bd) +
    bs(ebitda, knots = splineParams[[6]]$knots, degree = splineParams[[6]]$degree,
        Boundary.knots = splineParams[[6]]$bd) + bs(ppe, knots = splineParams[[7]]$knots,
    degree = splineParams[[7]]$degree, Boundary.knots = splineParams[[7]]$bd) +
    bs(sales, knots = splineParams[[8]]$knots, degree = splineParams[[8]]$degree,
        Boundary.knots = splineParams[[8]]$bd) + bs(ads, knots = splineParams[[9]]$knots,
    degree = splineParams[[9]]$degree, Boundary.knots = splineParams[[9]]$bd) +
    bs(rd, knots = splineParams[[10]]$knots, degree = splineParams[[10]]$degree,
        Boundary.knots = splineParams[[10]]$bd) + bs(bookval,
    knots = splineParams[[11]]$knots, degree = splineParams[[11]]$degree,
    Boundary.knots = splineParams[[11]]$bd), family = gaussian(link = identity),
    data = data)

[[11]]$knotsSelected
[1]   0.96   2.31   6.09 114.24 496.19

[[11]]$baseModelFits
 fitStat
76935.23

[[11]]$modelfits
 fitStat
76935.23
```

```
[[12]]
[[12]]$term
[1] "bs(mv, knots = splineParams[[12]]$knots, degree=splineParams[[12]]$degree, Boundary.knots=splinePa

[[12]]$kept
[1] "YES - new knots"

[[12]]$basemodelformula
glm(formula = response ~ as.factor(indclass) + bs(year, knots = splineParams[[2]]$knots,
    degree = splineParams[[2]]$degree, Boundary.knots = splineParams[[2]]$bd) +
    bs(assets, knots = splineParams[[3]]$knots, degree = splineParams[[3]]$degree,
        Boundary.knots = splineParams[[3]]$bd) + bs(capex, knots = splineParams[[4]]$knots,
    degree = splineParams[[4]]$degree, Boundary.knots = splineParams[[4]]$bd) +
    bs(ltd, knots = splineParams[[5]]$knots, degree = splineParams[[5]]$degree,
        Boundary.knots = splineParams[[5]]$bd) + bs(ebitda, knots = splineParams[[6]]$knots,
    degree = splineParams[[6]]$degree, Boundary.knots = splineParams[[6]]$bd) +
    bs(ppe, knots = splineParams[[7]]$knots, degree = splineParams[[7]]$degree,
        Boundary.knots = splineParams[[7]]$bd) + bs(sales, knots = splineParams[[8]]$knots,
    degree = splineParams[[8]]$degree, Boundary.knots = splineParams[[8]]$bd) +
    bs(ads, knots = splineParams[[9]]$knots, degree = splineParams[[9]]$degree,
        Boundary.knots = splineParams[[9]]$bd) + bs(rd, knots = splineParams[[10]]$knots,
    degree = splineParams[[10]]$degree, Boundary.knots = splineParams[[10]]$bd) +
    bs(bookval, knots = splineParams[[11]]$knots, degree = splineParams[[11]]$degree,
        Boundary.knots = splineParams[[11]]$bd) + bs(mv, knots = splineParams[[12]]$knots,
    degree = splineParams[[12]]$degree, Boundary.knots = splineParams[[12]]$bd),
    family = gaussian(link = identity), data = data)

[[12]]$knotsSelected
[1]    9.35   86.89  332.56  334.21 2282.55

[[12]]$baseModelFits
 fitStat
75479.04

[[12]]$modelfits
 fitStat
75479.04
```

```
require(lawstat)
runs.test(residuals(salsa1dOutput$bestModel))
```

```
    Runs Test - Two sided

data:  residuals(salsa1dOutput$bestModel)
Standardized Runs Statistic = -50.657, p-value < 2.2e-16
```

大P没有correlation问题
这里小，有问题

```
salsa1dOutputRemoval <- runSALSA1D(initialModel, salsa1dlist, varlist = varlist,
    factorlist = factorlist, newdat, splineParams = NULL, suppress.printout = TRUE,
    datain = newdat, removal = TRUE)
```

```
[1] "indclass will be fitted as a factor variable; there are non-zero counts for all levels"
```

```
BIC(salsa1dOutputRemoval$bestModel)
```

```
[1] 76334.37
```

```
cv.gamMRSea(data = newdat, modelobject = salsa1dOutputRemoval$bestModel, K = 5)$delta[2]
```

```
[1] 15.9662
```

```
salsa1dOutputRemoval$keptvarlist
```

```
 [1] "year"    "assets"  "ltd"     "ebitda"  "ppe"     "sales"   "ads"
 [8] "rd"      "bookval" "mv"
```

```
salsa1dOutputRemoval$modelFits1D
```

```
[[1]]
[[1]]$term
[1] "startmodel"

[[1]]$kept
NULL

[[1]]$basemodelformula
glm(formula = response ~ as.factor(indclass) + bs(year, knots = splineParams[[2]]$knots,
    degree = splineParams[[2]]$degree, Boundary.knots = splineParams[[2]]$bd) +
    bs(assets, knots = splineParams[[3]]$knots, degree = splineParams[[3]]$degree,
        Boundary.knots = splineParams[[3]]$bd) + bs(capex, knots = splineParams[[4]]$knots,
    degree = splineParams[[4]]$degree, Boundary.knots = splineParams[[4]]$bd) +
    bs(ltd, knots = splineParams[[5]]$knots, degree = splineParams[[5]]$degree,
        Boundary.knots = splineParams[[5]]$bd) + bs(ebitda, knots = splineParams[[6]]$knots,
    degree = splineParams[[6]]$degree, Boundary.knots = splineParams[[6]]$bd) +
    bs(ppe, knots = splineParams[[7]]$knots, degree = splineParams[[7]]$degree,
        Boundary.knots = splineParams[[7]]$bd) + bs(sales, knots = splineParams[[8]]$knots,
    degree = splineParams[[8]]$degree, Boundary.knots = splineParams[[8]]$bd) +
    bs(ads, knots = splineParams[[9]]$knots, degree = splineParams[[9]]$degree,
        Boundary.knots = splineParams[[9]]$bd) + bs(rd, knots = splineParams[[10]]$knots,
    degree = splineParams[[10]]$degree, Boundary.knots = splineParams[[10]]$bd) +
    bs(bookval, knots = splineParams[[11]]$knots, degree = splineParams[[11]]$degree,
        Boundary.knots = splineParams[[11]]$bd) + bs(mv, knots = splineParams[[12]]$knots,
    degree = splineParams[[12]]$degree, Boundary.knots = splineParams[[12]]$bd),
    family = gaussian(link = identity), data = data)

[[1]]$knotsSelected
NULL

[[1]]$tempfits
         CV     fitStat
   19.74967 79214.51575


[[2]]
[[2]]$term
[1] "bs(year, knots = splineParams[[2]]$knots, degree=splineParams[[2]]$degree, Boundary.knots=splinePa

[[2]]$kept
[1] "YES - new knots"

[[2]]$basemodelformula
glm(formula = response ~ as.factor(indclass) + bs(assets, knots = splineParams[[3]]$knots,
```

```
    degree = splineParams[[3]]$degree, Boundary.knots = splineParams[[3]]$bd) +
    bs(capex, knots = splineParams[[4]]$knots, degree = splineParams[[4]]$degree,
        Boundary.knots = splineParams[[4]]$bd) + bs(ltd, knots = splineParams[[5]]$knots,
    degree = splineParams[[5]]$degree, Boundary.knots = splineParams[[5]]$bd) +
    bs(ebitda, knots = splineParams[[6]]$knots, degree = splineParams[[6]]$degree,
        Boundary.knots = splineParams[[6]]$bd) + bs(ppe, knots = splineParams[[7]]$knots,
    degree = splineParams[[7]]$degree, Boundary.knots = splineParams[[7]]$bd) +
    bs(sales, knots = splineParams[[8]]$knots, degree = splineParams[[8]]$degree,
        Boundary.knots = splineParams[[8]]$bd) + bs(ads, knots = splineParams[[9]]$knots,
    degree = splineParams[[9]]$degree, Boundary.knots = splineParams[[9]]$bd) +
    bs(rd, knots = splineParams[[10]]$knots, degree = splineParams[[10]]$degree,
        Boundary.knots = splineParams[[10]]$bd) + bs(bookval,
    knots = splineParams[[11]]$knots, degree = splineParams[[11]]$degree,
    Boundary.knots = splineParams[[11]]$bd) + bs(mv, knots = splineParams[[12]]$knots,
    degree = splineParams[[12]]$degree, Boundary.knots = splineParams[[12]]$bd) +
    bs(year, knots = splineParams[[2]]$knots, degree = splineParams[[2]]$degree,
        Boundary.knots = splineParams[[2]]$bd), family = gaussian(link = identity),
    data = data)

[[2]]$knotsSelected
[1] 2001

[[2]]$baseModelFits
         CV     fitStat
   19.73821 79206.97160

[[2]]$modelfits
         CV     fitStat
   19.73821 79206.97160


[[3]]
[[3]]$term
[1] "bs(assets, knots = splineParams[[3]]$knots, degree=splineParams[[3]]$degree, Boundary.knots=splinel

[[3]]$kept
[1] "YES - new knots"

[[3]]$basemodelformula
glm(formula = response ~ as.factor(indclass) + bs(capex, knots = splineParams[[4]]$knots,
    degree = splineParams[[4]]$degree, Boundary.knots = splineParams[[4]]$bd) +
    bs(ltd, knots = splineParams[[5]]$knots, degree = splineParams[[5]]$degree,
        Boundary.knots = splineParams[[5]]$bd) + bs(ebitda, knots = splineParams[[6]]$knots,
    degree = splineParams[[6]]$degree, Boundary.knots = splineParams[[6]]$bd) +
    bs(ppe, knots = splineParams[[7]]$knots, degree = splineParams[[7]]$degree,
        Boundary.knots = splineParams[[7]]$bd) + bs(sales, knots = splineParams[[8]]$knots,
    degree = splineParams[[8]]$degree, Boundary.knots = splineParams[[8]]$bd) +
    bs(ads, knots = splineParams[[9]]$knots, degree = splineParams[[9]]$degree,
        Boundary.knots = splineParams[[9]]$bd) + bs(rd, knots = splineParams[[10]]$knots,
    degree = splineParams[[10]]$degree, Boundary.knots = splineParams[[10]]$bd) +
    bs(bookval, knots = splineParams[[11]]$knots, degree = splineParams[[11]]$degree,
        Boundary.knots = splineParams[[11]]$bd) + bs(mv, knots = splineParams[[12]]$knots,
    degree = splineParams[[12]]$degree, Boundary.knots = splineParams[[12]]$bd) +
    bs(year, knots = splineParams[[2]]$knots, degree = splineParams[[2]]$degree,
```

```
        Boundary.knots = splineParams[[2]]$bd) + bs(assets, knots = splineParams[[3]]$knots,
    degree = splineParams[[3]]$degree, Boundary.knots = splineParams[[3]]$bd),
    family = gaussian(link = identity), data = data)

[[3]]$knotsSelected
[1]    22.216   189.841 14651.000

[[3]]$baseModelFits
         CV     fitStat
   19.38993 78964.01412

[[3]]$modelfits
         CV     fitStat
   19.38993 78964.01412


[[4]]
[[4]]$term
[1] "bs(capex, knots = splineParams[[4]]$knots, degree=splineParams[[4]]$degree, Boundary.knots=splineP

[[4]]$kept
[1] "NO"

[[4]]$basemodelformula
glm(formula = response ~ as.factor(indclass) + bs(ltd, knots = splineParams[[5]]$knots,
    degree = splineParams[[5]]$degree, Boundary.knots = splineParams[[5]]$bd) +
    bs(ebitda, knots = splineParams[[6]]$knots, degree = splineParams[[6]]$degree,
        Boundary.knots = splineParams[[6]]$bd) + bs(ppe, knots = splineParams[[7]]$knots,
    degree = splineParams[[7]]$degree, Boundary.knots = splineParams[[7]]$bd) +
    bs(sales, knots = splineParams[[8]]$knots, degree = splineParams[[8]]$degree,
        Boundary.knots = splineParams[[8]]$bd) + bs(ads, knots = splineParams[[9]]$knots,
    degree = splineParams[[9]]$degree, Boundary.knots = splineParams[[9]]$bd) +
    bs(rd, knots = splineParams[[10]]$knots, degree = splineParams[[10]]$degree,
        Boundary.knots = splineParams[[10]]$bd) + bs(bookval,
    knots = splineParams[[11]]$knots, degree = splineParams[[11]]$degree,
    Boundary.knots = splineParams[[11]]$bd) + bs(mv, knots = splineParams[[12]]$knots,
    degree = splineParams[[12]]$degree, Boundary.knots = splineParams[[12]]$bd) +
    bs(year, knots = splineParams[[2]]$knots, degree = splineParams[[2]]$degree,
        Boundary.knots = splineParams[[2]]$bd) + bs(assets, knots = splineParams[[3]]$knots,
    degree = splineParams[[3]]$degree, Boundary.knots = splineParams[[3]]$bd),
    family = gaussian(link = identity), data = data)

[[4]]$knotsSelected
[1] "NA"

[[4]]$baseModelFits
         CV     fitStat
   19.35789 78938.14210

[[4]]$modelfits
         CV     fitStat
   19.44358 78965.54836
```

```
[[5]]
[[5]]$term
[1] "bs(ltd, knots = splineParams[[5]]$knots, degree=splineParams[[5]]$degree, Boundary.knots=splinePara

[[5]]$kept
[1] "YES - linear"

[[5]]$basemodelformula
glm(formula = response ~ as.factor(indclass) + bs(ebitda, knots = splineParams[[6]]$knots,
    degree = splineParams[[6]]$degree, Boundary.knots = splineParams[[6]]$bd) +
    bs(ppe, knots = splineParams[[7]]$knots, degree = splineParams[[7]]$degree,
        Boundary.knots = splineParams[[7]]$bd) + bs(sales, knots = splineParams[[8]]$knots,
    degree = splineParams[[8]]$degree, Boundary.knots = splineParams[[8]]$bd) +
    bs(ads, knots = splineParams[[9]]$knots, degree = splineParams[[9]]$degree,
        Boundary.knots = splineParams[[9]]$bd) + bs(rd, knots = splineParams[[10]]$knots,
    degree = splineParams[[10]]$degree, Boundary.knots = splineParams[[10]]$bd) +
    bs(bookval, knots = splineParams[[11]]$knots, degree = splineParams[[11]]$degree,
        Boundary.knots = splineParams[[11]]$bd) + bs(mv, knots = splineParams[[12]]$knots,
    degree = splineParams[[12]]$degree, Boundary.knots = splineParams[[12]]$bd) +
    bs(year, knots = splineParams[[2]]$knots, degree = splineParams[[2]]$degree,
        Boundary.knots = splineParams[[2]]$bd) + bs(assets, knots = splineParams[[3]]$knots,
    degree = splineParams[[3]]$degree, Boundary.knots = splineParams[[3]]$bd) +
    ltd, family = gaussian(link = identity), data = data)

[[5]]$knotsSelected
[1] "NA"

[[5]]$baseModelFits
         CV     fitStat
   19.32935 78926.75106

[[5]]$modelfits
         CV     fitStat
   19.34031 78931.28811


[[6]]
[[6]]$term
[1] "bs(ebitda, knots = splineParams[[6]]$knots, degree=splineParams[[6]]$degree, Boundary.knots=spline

[[6]]$kept
[1] "YES - new knots"

[[6]]$basemodelformula
glm(formula = response ~ as.factor(indclass) + bs(ppe, knots = splineParams[[7]]$knots,
    degree = splineParams[[7]]$degree, Boundary.knots = splineParams[[7]]$bd) +
    bs(sales, knots = splineParams[[8]]$knots, degree = splineParams[[8]]$degree,
        Boundary.knots = splineParams[[8]]$bd) + bs(ads, knots = splineParams[[9]]$knots,
    degree = splineParams[[9]]$degree, Boundary.knots = splineParams[[9]]$bd) +
    bs(rd, knots = splineParams[[10]]$knots, degree = splineParams[[10]]$degree,
        Boundary.knots = splineParams[[10]]$bd) + bs(bookval,
    knots = splineParams[[11]]$knots, degree = splineParams[[11]]$degree,
    Boundary.knots = splineParams[[11]]$bd) + bs(mv, knots = splineParams[[12]]$knots,
    degree = splineParams[[12]]$degree, Boundary.knots = splineParams[[12]]$bd) +
```

```
    bs(year, knots = splineParams[[2]]$knots, degree = splineParams[[2]]$degree,
        Boundary.knots = splineParams[[2]]$bd) + bs(assets, knots = splineParams[[3]]$knots,
    degree = splineParams[[3]]$degree, Boundary.knots = splineParams[[3]]$bd) +
    ltd + bs(ebitda, knots = splineParams[[6]]$knots, degree = splineParams[[6]]$degree,
    Boundary.knots = splineParams[[6]]$bd), family = gaussian(link = identity),
    data = data)

[[6]]$knotsSelected
[1] -3.523 -3.394 -1.661

[[6]]$baseModelFits
         CV     fitStat
   19.27726 78901.67152

[[6]]$modelfits
         CV     fitStat
   19.27726 78901.67152


[[7]]
[[7]]$term
[1] "bs(ppe, knots = splineParams[[7]]$knots, degree=splineParams[[7]]$degree, Boundary.knots=splinePara

[[7]]$kept
[1] "YES - new knots"

[[7]]$basemodelformula
glm(formula = response ~ as.factor(indclass) + bs(sales, knots = splineParams[[8]]$knots,
    degree = splineParams[[8]]$degree, Boundary.knots = splineParams[[8]]$bd) +
    bs(ads, knots = splineParams[[9]]$knots, degree = splineParams[[9]]$degree,
        Boundary.knots = splineParams[[9]]$bd) + bs(rd, knots = splineParams[[10]]$knots,
    degree = splineParams[[10]]$degree, Boundary.knots = splineParams[[10]]$bd) +
    bs(bookval, knots = splineParams[[11]]$knots, degree = splineParams[[11]]$degree,
        Boundary.knots = splineParams[[11]]$bd) + bs(mv, knots = splineParams[[12]]$knots,
    degree = splineParams[[12]]$degree, Boundary.knots = splineParams[[12]]$bd) +
    bs(year, knots = splineParams[[2]]$knots, degree = splineParams[[2]]$degree,
        Boundary.knots = splineParams[[2]]$bd) + bs(assets, knots = splineParams[[3]]$knots,
    degree = splineParams[[3]]$degree, Boundary.knots = splineParams[[3]]$bd) +
    ltd + bs(ebitda, knots = splineParams[[6]]$knots, degree = splineParams[[6]]$degree,
    Boundary.knots = splineParams[[6]]$bd) + bs(ppe, knots = splineParams[[7]]$knots,
    degree = splineParams[[7]]$degree, Boundary.knots = splineParams[[7]]$bd),
    family = gaussian(link = identity), data = data)

[[7]]$knotsSelected
[1]  4.121 70.987

[[7]]$baseModelFits
         CV     fitStat
   19.26229 78897.77483

[[7]]$modelfits
         CV     fitStat
   19.26229 78897.77483
```

```
[[8]]
[[8]]$term
[1] "bs(sales, knots = splineParams[[8]]$knots, degree=splineParams[[8]]$degree, Boundary.knots=splinePa

[[8]]$kept
[1] "YES - new knots"

[[8]]$basemodelformula
glm(formula = response ~ as.factor(indclass) + bs(ads, knots = splineParams[[9]]$knots,
    degree = splineParams[[9]]$degree, Boundary.knots = splineParams[[9]]$bd) +
    bs(rd, knots = splineParams[[10]]$knots, degree = splineParams[[10]]$degree,
        Boundary.knots = splineParams[[10]]$bd) + bs(bookval,
    knots = splineParams[[11]]$knots, degree = splineParams[[11]]$degree,
    Boundary.knots = splineParams[[11]]$bd) + bs(mv, knots = splineParams[[12]]$knots,
    degree = splineParams[[12]]$degree, Boundary.knots = splineParams[[12]]$bd) +
    bs(year, knots = splineParams[[2]]$knots, degree = splineParams[[2]]$degree,
        Boundary.knots = splineParams[[2]]$bd) + bs(assets, knots = splineParams[[3]]$knots,
    degree = splineParams[[3]]$degree, Boundary.knots = splineParams[[3]]$bd) +
    ltd + bs(ebitda, knots = splineParams[[6]]$knots, degree = splineParams[[6]]$degree,
    Boundary.knots = splineParams[[6]]$bd) + bs(ppe, knots = splineParams[[7]]$knots,
    degree = splineParams[[7]]$degree, Boundary.knots = splineParams[[7]]$bd) +
    bs(sales, knots = splineParams[[8]]$knots, degree = splineParams[[8]]$degree,
        Boundary.knots = splineParams[[8]]$bd), family = gaussian(link = identity),
    data = data)

[[8]]$knotsSelected
[1] 264.159

[[8]]$baseModelFits
         CV     fitStat
   19.26172 78897.62097

[[8]]$modelfits
         CV     fitStat
   19.26172 78897.62097


[[9]]
[[9]]$term
[1] "bs(ads, knots = splineParams[[9]]$knots, degree=splineParams[[9]]$degree, Boundary.knots=splinePara

[[9]]$kept
[1] "YES - new knots"

[[9]]$basemodelformula
glm(formula = response ~ as.factor(indclass) + bs(rd, knots = splineParams[[10]]$knots,
    degree = splineParams[[10]]$degree, Boundary.knots = splineParams[[10]]$bd) +
    bs(bookval, knots = splineParams[[11]]$knots, degree = splineParams[[11]]$degree,
        Boundary.knots = splineParams[[11]]$bd) + bs(mv, knots = splineParams[[12]]$knots,
    degree = splineParams[[12]]$degree, Boundary.knots = splineParams[[12]]$bd) +
    bs(year, knots = splineParams[[2]]$knots, degree = splineParams[[2]]$degree,
        Boundary.knots = splineParams[[2]]$bd) + bs(assets, knots = splineParams[[3]]$knots,
    degree = splineParams[[3]]$degree, Boundary.knots = splineParams[[3]]$bd) +
```

```
    ltd + bs(ebitda, knots = splineParams[[6]]$knots, degree = splineParams[[6]]$degree,
    Boundary.knots = splineParams[[6]]$bd) + bs(ppe, knots = splineParams[[7]]$knots,
    degree = splineParams[[7]]$degree, Boundary.knots = splineParams[[7]]$bd) +
    bs(sales, knots = splineParams[[8]]$knots, degree = splineParams[[8]]$degree,
        Boundary.knots = splineParams[[8]]$bd) + bs(ads, knots = splineParams[[9]]$knots,
    degree = splineParams[[9]]$degree, Boundary.knots = splineParams[[9]]$bd),
    family = gaussian(link = identity), data = data)

[[9]]$knotsSelected
[1] 20.071

[[9]]$baseModelFits
         CV     fitStat
   19.24871 78887.24001

[[9]]$modelfits
         CV     fitStat
   19.24871 78887.24001


[[10]]
[[10]]$term
[1] "bs(rd, knots = splineParams[[10]]$knots, degree=splineParams[[10]]$degree, Boundary.knots=splinePa

[[10]]$kept
[1] "YES - new knots"

[[10]]$basemodelformula
glm(formula = response ~ as.factor(indclass) + bs(bookval, knots = splineParams[[11]]$knots,
    degree = splineParams[[11]]$degree, Boundary.knots = splineParams[[11]]$bd) +
    bs(mv, knots = splineParams[[12]]$knots, degree = splineParams[[12]]$degree,
        Boundary.knots = splineParams[[12]]$bd) + bs(year, knots = splineParams[[2]]$knots,
    degree = splineParams[[2]]$degree, Boundary.knots = splineParams[[2]]$bd) +
    bs(assets, knots = splineParams[[3]]$knots, degree = splineParams[[3]]$degree,
        Boundary.knots = splineParams[[3]]$bd) + ltd + bs(ebitda,
    knots = splineParams[[6]]$knots, degree = splineParams[[6]]$degree,
    Boundary.knots = splineParams[[6]]$bd) + bs(ppe, knots = splineParams[[7]]$knots,
    degree = splineParams[[7]]$degree, Boundary.knots = splineParams[[7]]$bd) +
    bs(sales, knots = splineParams[[8]]$knots, degree = splineParams[[8]]$degree,
        Boundary.knots = splineParams[[8]]$bd) + bs(ads, knots = splineParams[[9]]$knots,
    degree = splineParams[[9]]$degree, Boundary.knots = splineParams[[9]]$bd) +
    bs(rd, knots = splineParams[[10]]$knots, degree = splineParams[[10]]$degree,
        Boundary.knots = splineParams[[10]]$bd), family = gaussian(link = identity),
    data = data)

[[10]]$knotsSelected
[1] 2.584 2.946

[[10]]$baseModelFits
        CV    fitStat
   19.2201 78876.8446

[[10]]$modelfits
        CV    fitStat
```

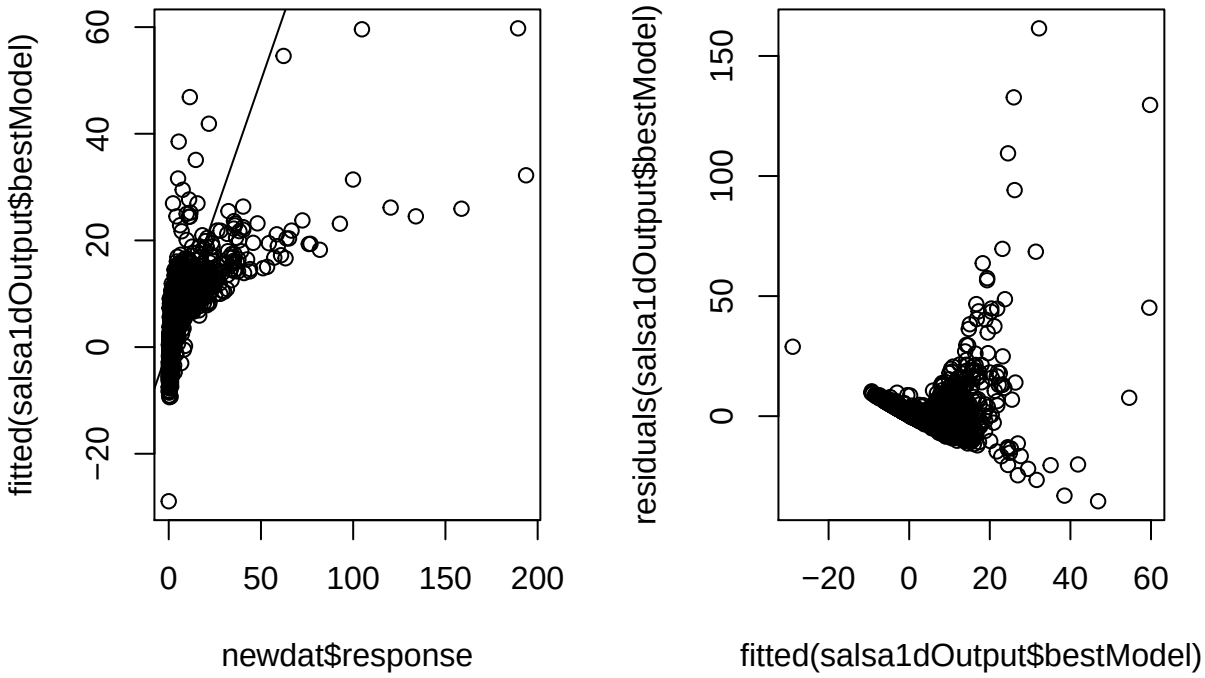
```
   19.2201 78876.8446


[[11]]
[[11]]$term
[1] "bs(bookval, knots = splineParams[[11]]$knots, degree=splineParams[[11]]$degree, Boundary.knots=spli

[[11]]$kept
[1] "YES - new knots"

[[11]]$basemodelformula
glm(formula = response ~ as.factor(indclass) + bs(mv, knots = splineParams[[12]]$knots,
    degree = splineParams[[12]]$degree, Boundary.knots = splineParams[[12]]$bd) +
    bs(year, knots = splineParams[[2]]$knots, degree = splineParams[[2]]$degree,
        Boundary.knots = splineParams[[2]]$bd) + bs(assets, knots = splineParams[[3]]$knots,
    degree = splineParams[[3]]$degree, Boundary.knots = splineParams[[3]]$bd) +
    ltd + bs(ebitda, knots = splineParams[[6]]$knots, degree = splineParams[[6]]$degree,
    Boundary.knots = splineParams[[6]]$bd) + bs(ppe, knots = splineParams[[7]]$knots,
    degree = splineParams[[7]]$degree, Boundary.knots = splineParams[[7]]$bd) +
    bs(sales, knots = splineParams[[8]]$knots, degree = splineParams[[8]]$degree,
        Boundary.knots = splineParams[[8]]$bd) + bs(ads, knots = splineParams[[9]]$knots,
    degree = splineParams[[9]]$degree, Boundary.knots = splineParams[[9]]$bd) +
    bs(rd, knots = splineParams[[10]]$knots, degree = splineParams[[10]]$degree,
        Boundary.knots = splineParams[[10]]$bd) + bs(bookval,
    knots = splineParams[[11]]$knots, degree = splineParams[[11]]$degree,
    Boundary.knots = splineParams[[11]]$bd), family = gaussian(link = identity),
    data = data)

[[11]]$knotsSelected
[1]   17.50   17.68   39.15  177.43 6235.00

[[11]]$baseModelFits
         CV     fitStat
   17.42967 77544.89206

[[11]]$modelfits
         CV     fitStat
   17.42967 77544.89206


[[12]]
[[12]]$term
[1] "bs(mv, knots = splineParams[[12]]$knots, degree=splineParams[[12]]$degree, Boundary.knots=splinePa

[[12]]$kept
[1] "YES - new knots"

[[12]]$basemodelformula
glm(formula = response ~ as.factor(indclass) + bs(year, knots = splineParams[[2]]$knots,
    degree = splineParams[[2]]$degree, Boundary.knots = splineParams[[2]]$bd) +
    bs(assets, knots = splineParams[[3]]$knots, degree = splineParams[[3]]$degree,
        Boundary.knots = splineParams[[3]]$bd) + ltd + bs(ebitda,
    knots = splineParams[[6]]$knots, degree = splineParams[[6]]$degree,
    Boundary.knots = splineParams[[6]]$bd) + bs(ppe, knots = splineParams[[7]]$knots,
```

```
    degree = splineParams[[7]]$degree, Boundary.knots = splineParams[[7]]$bd) +
    bs(sales, knots = splineParams[[8]]$knots, degree = splineParams[[8]]$degree,
        Boundary.knots = splineParams[[8]]$bd) + bs(ads, knots = splineParams[[9]]$knots,
    degree = splineParams[[9]]$degree, Boundary.knots = splineParams[[9]]$bd) +
    bs(rd, knots = splineParams[[10]]$knots, degree = splineParams[[10]]$degree,
        Boundary.knots = splineParams[[10]]$bd) + bs(bookval,
    knots = splineParams[[11]]$knots, degree = splineParams[[11]]$degree,
    Boundary.knots = splineParams[[11]]$bd) + bs(mv, knots = splineParams[[12]]$knots,
    degree = splineParams[[12]]$degree, Boundary.knots = splineParams[[12]]$bd),
    family = gaussian(link = identity), data = data)

[[12]]$knotsSelected
[1]   38.62  382.55 4176.47

[[12]]$baseModelFits
         CV     fitStat
   15.95179 76334.37192

[[12]]$modelfits
         CV     fitStat
   15.95179 76334.37192
```

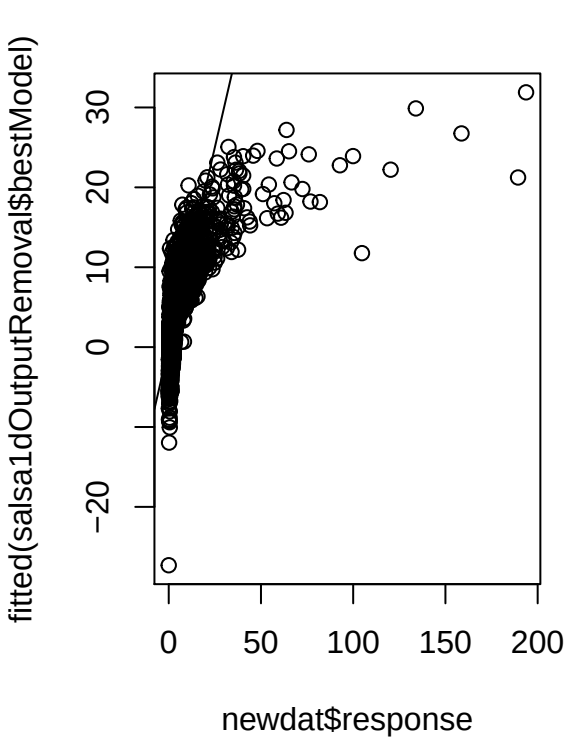
```
anova(salsa1dOutputRemoval$bestModel, test = "F")
```

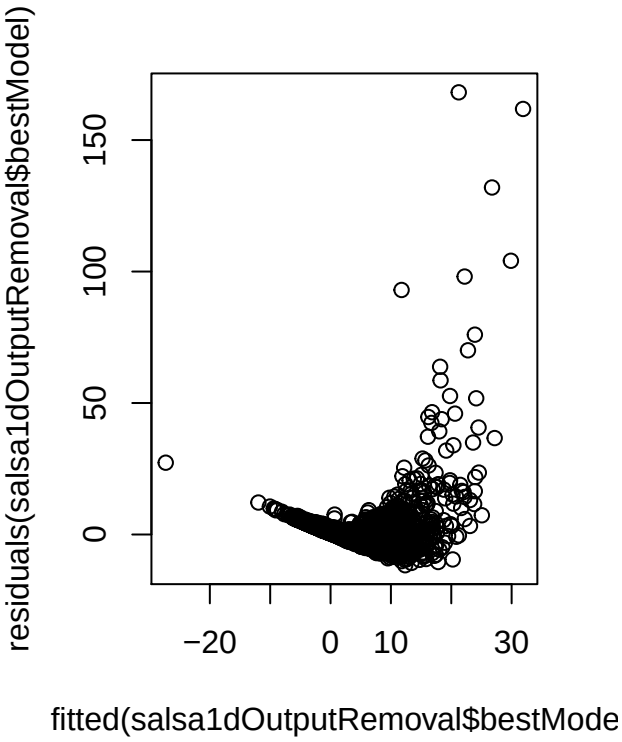
```
Analysis of Deviance Table (Type II tests)
Marginal Testing

Response: response
Error estimate based on Pearson residuals

                        SS    Df         F    Pr(>F)
as.factor(indclass)    876    40    1.3936 0.0504919 .
s(year)                173     3    3.6641 0.0117890 *
s(assets)             7421     5   94.4626 < 2.2e-16 ***
s(ltd)                 362     1   23.0546 1.592e-06 ***
s(ebitda)             1771     5   22.5454 < 2.2e-16 ***
s(ppe)                1367     4   21.7568 < 2.2e-16 ***
s(sales)               259     3    5.4961 0.0009044 ***
s(ads)                 131     3    2.7689 0.0401204 *
s(rd)                  662     4   10.5306 1.621e-08 ***
s(bookval)           75564     7  687.0573 < 2.2e-16 ***
s(mv)               103177     5 1313.3736 < 2.2e-16 ***
Residuals           211228 13444
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

```
par(mfrow = c(1, 2))
plot(newdat$response, fitted(salsa1dOutput$bestModel))
abline(0, 1)
plot(fitted(salsa1dOutput$bestModel), residuals(salsa1dOutput$bestModel))
```




```
par(mfrow = c(1, 2))
plot(newdat$response, fitted(salsa1dOutputRemoval$bestModel))
abline(0, 1)
plot(fitted(salsa1dOutputRemoval$bestModel), residuals(salsa1dOutputRemoval$bestModel))
```


fitted(salsa1dOutputRemoval$bestModel)
30
20
10
0
−20
0
50
100
150
200
newdat$response


residuals(salsa1dOutputRemoval$bestModel)
150
100
50
0
−20
0
10
30
fitted(salsa1dOutputRemoval$bestMode

Questions

1. TRUE or FALSE? The most interior knots allocated to any of the covariates in the `salsa1dOutput` model was 7 out of a maximum of 10.

2. Which of the following, regarding the `salsa1dOutput` model, is FALSE?

   (a) The variance estimate for the `salsa1dOutput` model is approximately 16
   (b) The p-value for the runs test is very small indicating that we do not have an issue with independence.
   (c) The Anova output for the `salsa1dOutput` model suggests that industry class, capital expenditure, sales and year are not significant predictors of Tobins Q. This result suggests that we should begin by removing `capex` and re-running our model.
   (d) Only industry classes 3,4 and 16 are significantly different to the baseline class, 1.
   (e) As the externally assessed market value increases, the tobins Q ratio increases.

3. Which of the following is FALSE?

   (a) The removal method used here uses five-fold cross validation to choose between 1) a covariate being removed, 2) linear, 3) with a single knot at the mean and 4) with SALSA chosen knots.
   (b) The removal method result agrees with the initial finding of the `salsa1dOutput` model in that the `capex` covariate should be removed.
   (c) Nine covariates have knots chosen by SALSA in the removal model, while this is 11 covariates in the `salsa1dOutput` model.
   (d) The Anova output for the removal model indicates that under hypothesis testing, the `indclass` covariate might be removed (at the 5% level), whereas if cross-validation is used for selection this term remains.

4. TRUE or FALSE? The removal method model is better than the non-removal model, where "best" is denoted by the BIC criterion.