

Solutions Manual for `sabreR` (Sabre in R) Exercises

Version 2 (Draft)

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Abstract

Many users will have undertaken the exercises in interactive sessions. In this solutions manual we present the batch scripts that could be used to obtain the answers to the exercises. Sometimes the batch scripts are limited to the commands needed to obtain the last answer of the iterative model building and checking parts of the exercises, i.e. they do not include all the steps. Both the batch scripts, e.g. `C1.R` and their associated log files, e.g. `C1.log` are available from the Sabre site. Unless its otherwise made explicit in the text, when we use the term significant, we mean at the 95% level. It is also possible that we have failed to appreciate some of the complexities present in the data and covariates that are manifest in the many substantive fields from which these exercises are drawn, our apologies if this is the case

Contents

1	Exercise C1. Linear Model of Essay Grading	5
1.1	Relevant Results from <code>C1.log</code> and Discussion	5
1.2	Batch Script: <code>C1.R</code>	6
2	Exercise C2. Linear Model of Educational Attainment	8
2.1	Relevant Results from <code>C2.log</code> and Discussion	8
2.2	Batch Script: <code>C2.R</code>	12
3	Exercise C3. Binary Response Model of Essay Grades	14
3.1	Relevant Results from <code>C3.log</code> and Discussion	14
3.2	Batch Script: <code>C3.R</code>	16
4	Exercise C4. Ordered Response Model of Essay Grades	18
4.1	Relevant Results from <code>C4.log</code> and Discussion	18
4.2	Batch Script: <code>C4.R</code>	21
5	Exercise C5. Poison Model of Headaches	24
5.1	Relevant Results from <code>C5.log</code> and Discussion	24
5.2	Batch Script: <code>C5.R</code>	25

6	Exercise L1. Linear Model of Psychological Distress	26
6.1	Relevant Results from L1.log and Discussion	26
6.2	Batch Script: L1.R	27
7	Exercise L2. Linear Model of log Wages	28
7.1	Relevant Results from L2.log and Discussion	28
7.2	Batch Script: L2.R	30
8	Exercise L3. Linear Growth Model of log of Unemployment Claims	32
8.1	Relevant Results from L3.log and Discussion	32
8.2	Batch Script: L3.R	34
9	Exercise L4. Binary Model of Trade Union Membership	35
9.1	Relevant Results from L4.log and Discussion	35
9.2	Batch Script: L4.R	38
10	Exercise L5. Ordered Response Model of Attitudes to Abortion	40
10.1	Relevant Results from L5.log and Discussion	40
10.2	Batch Script: L5.do	43
11	Exercise L6. Ordered Response Model of Respiratory Status	45
11.1	Relevant Results from L6.log and Discussion	45
11.2	Batch Script: L6.R	47
12	Exercise L8. Poisson Model of Epileptic Seizures	49
12.1	Relevant Results from L8.log and Discussion	49
12.2	Batch Script: L8.R	51
13	Exercise L9. Bivariate Linear Model of Expiratory Flow Rates	53
13.1	Relevant Results from L9.log and Discussion	53
13.1.1	Standard Wright Meter: data set <code>pefr.tab</code>	53
13.1.2	Mini Wright Meter: data set <code>pefr.tab</code>	53
13.1.3	Joint Model: data set <code>pefr.tab</code>	54
13.2	Batch Script: L9.R	54
14	Exercise L10. Bivariate Model, Linear (Wages) and Binary (Trade Union Membership)	56
14.1	Relevant Results from L10.log and Discussion	56
14.1.1	Univariate models	56
14.1.2	Wage equation: data <code>wagepan.tab</code>	56
14.1.3	Trade union membership: data <code>wagepan.tab</code>	56
14.1.4	Joint model: data <code>wagepan.tab</code>	57
14.2	Batch Script: L10.R	58
15	Exercise L11. Renewal Model of Angina Pectoris (Chest Pain)	60
15.1	Relevant Results from L11.log and Discussion	60
15.2	Batch Script: L11.R	62

16 Exercise L12. Bivariate Competing Risk Model of German Un-employment Data	63
16.1 Relevant Results from L12.log and Discussion	63
16.2 Batch Script: L12.R	65
17 Exercise 3LC1. Linear Model: Pupil Rating of School Managers (856 Pupils in 94 Schools)	67
17.1 Relevant Results from 3LC1.log and Discussion	67
17.2 Batch Script: 3LC1.R	69
18 Exercise 3LC2. Binary Response Model for the Tower of London tests (226 Individuals in 118 Families)	70
18.1 Relevant Results from 3LC2.log and Discussion	70
18.2 Batch Script: 3LC2.R	72
19 Exercise 3LC3. Binary Response Model of the Guatemalan Immunisation of Children (1595 Mothers in 161 Communities)	73
19.1 Relevant Results from 3LC3.log and Discussion	73
19.2 Batch Script: 3LC3.R	75
20 Exercise 3LC4. Poisson Model of Skin Cancer Deaths (78 Regions in 9 Nations)	77
20.1 Relevant Results from 3LC4.log and Discussion	77
20.2 Batch Script: 3LC4.R	78
21 Exercise 3LC5. Event History Cloglog Link Model of Time to Fill Vacancies (1736 Vacancies in 515 Firms)	80
21.1 Relevant Results from 3LC5.log and Discussion	80
21.2 Batch Script: 3LC5.R	83
22 Exercise EP1. Trade Union Membership with Endpoints	84
22.1 Relevant Results from EP1.log and Discussion	84
22.2 Batch Script: EP1.R	85
23 Exercise EP2. Poisson Model of the Number of Fish Caught by Visitors to a US National Park.	87
23.1 Relevant Results from EP2.log and Discussion	87
23.2 Batch Script: EP2.R	88
24 Exercise EP3. Binary Response Model of Female Employment Participation.	89
24.1 Relevant Results from EP3.log and Discussion	89
24.2 Batch Script: EP3.R	90
25 Exercise FOL1. Binary Response Model for Trade Union Membership 1980-1987 of Young Males (Wooldridge, 2005)	92
25.1 Conditional analysis: Relevant Results from FOL1.log and Discussion	92
25.2 Joint analysis of the initial condition and subsequent responses: Relevant Results from FOL1.log and Discussion	93
25.3 Batch Script: FOL1.R	96

26 Exercise FOL2. Probit Model for Trade Union Membership of Females	99
26.1 Conditional analysis: Relevant Results from FOL2.log and Discussion	99
26.2 Joint analysis of the initial condition and subsequent responses: Relevant Results from FOL2.log and Discussion	100
26.3 Batch Script: FOL2.R	103
27 Exercise FOL3. Binary Response Model for Female Labour Force Participation in the UK	105
27.1 Conditional analysis: Relevant Results from FOL3.log and Discussion	105
27.2 Joint analysis of the initial condition and subsequent responses: Relevant Results from FOL3.log and Discussion	106
27.3 Batch Script: FOL3.R	110
28 Exercise FOC4. Poisson Model of Patents and R&D Expenditure	112
28.1 Relevant Results from FOC4.log and Discussion	112
28.2 Batch Script: FOC4.do	117
29 Exercise FE1. Linear Model for the Effect of Job Training on Firm Scrap Rates	120
29.1 Relevant Results from FE1.log and Discussion	120
29.2 Batch Script: FE1.do	123
30 Exercise FE2. Linear Model to Establish if the Returns to Education Changed over Time	124
30.1 Relevant Results from FE2.log and Discussion	124
30.2 Batch Script: FE2.R	127

1 Exercise C1. Linear Model of Essay Grading

1.1 Relevant Results from C1.log and Discussion

Task 1. Estimate the linear model using Sabre on `grade`, with just a constant and no other effects.

Result/Discussion

Log likelihood = -884.88956 on 394 residual degrees of freedom

Parameter	Estimate	Std. Err.
cons	5.2374	0.11374
sigma	2.2635	

Task 2. Estimate the linear model, allowing for the essay random effect, use mass 20. Are the essay effects significant? What impact do they have on the model? Try using adaptive quadrature to see if fewer mass points are needed.

Result/Discussion

Log likelihood = -855.09330 on 393 residual degrees of freedom

Parameter	Estimate	Std. Err.
cons	5.2374	0.13958
sigma	1.5827	0.79535E-01
scale	1.6141	0.12628

The linear random effects model, only required 12 adaptive quadrature mass points. The `scale` parameter for this model suggests the presence of significant essay grade random effects.

Task 3. Re-estimate the linear model allowing for both the essay random effect and `dg4`, use adaptive quadrature with an increasing number of mass points until likelihood convergence occurs.

Result/Discussion

Log likelihood = -831.52131 on 392 residual degrees of freedom

Parameter	Estimate	Std. Err.
cons	5.7525	0.15643
dg4	-1.0303	0.14122
sigma	1.4051	0.70609E-01
scale	1.6943	0.11811

These results are for adaptive quadrature with 12 mass points.

Task 4. How do the results change as compared to a model with just a constant? Interpret your results.

Result/Discussion

The log likelihood of the homogeneous model of Task 1 is -884.88956 , and log likelihood of the random effects model of Task 2 is -855.09330 . The change in log likelihood over the homogeneous model is $-2(-884.88956+855.09330) = 59.593$. The sampling distribution of this test statistic is not chi-square with 1 df. Under the null hypothesis `scale` has the value 0, and it can only take values >0 under the alternative. The correct p value for this test statistics is obtained by dividing the naive p value of 59.593 for 1 degree of freedom by 1/2, and so its clearly significant, suggesting that the grades from the two graders are highly correlated. The log likelihood significantly reduces further when we add the grader indicator covariate `dg4`. This improvement in log likelihood has a chi-square of $-2(-855.09330+ 831.52131) = 47.144$, for 1 more degree of freedom. The value of `scale` (sigma for the random effects) increases from 1.6141 in the model without covariates to 1.6943 for the model with the `dg4` indicator. The coefficient on `dg4` is negative -1.0303 (S.E. 0.14122), which is very significant, suggesting that grader 4 is a much lower marker than grader 1. All the estimated models assume a common sigma.

1.2 Batch Script: C1.R

```
# save the log file
sink("C1.log")

# use the sabreR library
library(sabreR)

# read the data
grader2 <- read.table("grader2.tab")
attach(grader2)

# look at the 1st 10 lines and columns
grader2[1:10,1:6]

# estimate the 1st model
sabre.model.1 <- sabre(grade~1,case=essay,adaptive.quad=TRUE,
                      first.family="gaussian")
```

```
# show the results
sabre.model.1

# estimate the 2nd model
sabre.model.2 <- sabre(grade~dg4+1,case=essay,adaptive.quad=TRUE,
                      first.family="gaussian")

# show the results
sabre.model.2

# remove the created objects
detach(grader2)
rm(grader2,sabre.model.1,sabre.model.2)

# close the log file
sink()
```

2 Exercise C2. Linear Model of Educational Attainment

2.1 Relevant Results from C2.log and Discussion

Task 1. Estimate a linear model on attainment (`attain`) without covariates.

Result/Discussion

```
Log likelihood =      -3282.0735      on      2308 residual degrees of freedom

Parameter              Estimate              Std. Err.
-----
cons                   0.93396E-01              0.20850E-01
sigma                  1.0021
```

Task 2. Allow for the school random effect (`schid`), use adaptive quadrature with mass 4. Is this random effect significant?

Result/Discussion

```
Number of observations      =      2310
Number of cases            =       17

Log likelihood =      -3221.0818      on      2307 residual degrees of freedom

Parameter              Estimate              Std. Err.
-----
cons                   0.82269E-01              0.75715E-01
sigma                  0.96665                  0.14279E-01
scale                  0.29790                  0.58507E-01
```

The scale parameter estimate of 0.29790 (S.E. 0.58507E-01) has a z statistic of $0.29790/0.058507 = 5.0917$, which is quite large, similarly with the associated change in log likelihood which has a chi-square of $-2(-3282.0735+3221.0818) = 121.98$. The sampling distribution of this test statistic is not chi-square with 1 df. Under the null hypothesis `scale` has the value 0, and it can only take values >0 under the alternative. The correct p value for this test statistics is obtained by dividing the naive p value of 121.98 for 1 degree of freedom by 1/2, and so its clearly significant.

Task 3. Add the observed student specific effects, increase the number of mass points until the likelihood converges. How does the magnitude of the school random effect change?

Result/Discussion

Number of observations = 2310
 Number of cases = 17
 Log likelihood = -2403.9957 on 2300 residual degrees of freedom

Parameter	Estimate	Std. Err.
cons	0.80732E-01	0.26927E-01
p7vrq	0.28319E-01	0.22811E-02
p7read	0.27103E-01	0.17586E-02
dadocc	0.94839E-02	0.13558E-02
dadunemp	-0.14941	0.46945E-01
daded	0.15227	0.41103E-01
momed	0.65025E-01	0.37709E-01
male	-0.54138E-01	0.28642E-01
sigma	0.68347	0.10094E-01
scale	0.56053E-01	0.21390E-01

The scale parameter estimate shrinks from 0.29790 (S.E. 0.58507E-01) in the model without covariates to 0.56053E-01 (S.E. 0.21390E-01) for the model with the student specific effects.

Task 4. Add the neighbourhood effect (`deprive`). Check the number of mass points required. How does the magnitude of the school random effect change?

Result/Discussion

Log likelihood = -2384.8141 on 2299 residual degrees of freedom

Parameter	Estimate	Std. Err.
cons	0.85822E-01	0.27618E-01
p7vrq	0.27557E-01	0.22644E-02
p7read	0.26292E-01	0.17502E-02
dadocc	0.81675E-02	0.13600E-02
dadunemp	-0.12076	0.46813E-01
daded	0.14445	0.40787E-01
momed	0.59444E-01	0.37394E-01
male	-0.56061E-01	0.28403E-01
deprive	-0.15668	0.25269E-01
sigma	0.67754	0.10004E-01
scale	0.62311E-01	0.20628E-01

This model can be estimated with 12 adaptive quadrature mass points. The scale parameter estimate increases from 0.56053E-01 (S.E. 0.21390E-01) for the

model with just the student specific effects to 0.62311E-01 (S.E. 0.20628E-01) for the model with the student specific effects and the neighbourhood effect (`deprive`).

We now use a data set sorted by the neighbourhood identifier (`neighid`); called `neighbourhood2.dta`.

Task 5. Re-estimate the constant only model allowing for neighbourhood random effect (`neighid`), use adaptive quadrature with mass 12. Is there a significant `neighd` random effect?

Result/Discussion

The neighbourhood random effect (`neighid`) model with adaptive quadrature with mass 12 gives.

Log likelihood = -3207.9848 on 2307 residual degrees of freedom

Parameter	Estimate	Std. Err.
cons	0.82025E-01	0.28440E-01
sigma	0.89687	0.14815E-01
scale	0.44893	0.28651E-01

The associated change in log likelihood over the homogenous model of Task 1 has a chi-square of $-2(-3282.0735+3207.9848)=148.18$. The sampling distribution of this test statistic is not chi-square with 1 df. Under the null hypothesis `scale` has the value 0, and it can only take values >0 under the alternative. The correct p value for this test statistics is obtained by dividing the naive p value of 148.18 for 1 degree of freedom by 1/2, and so its clearly significant.

Task 6. Add the student specific effects, how does the magnitude of the `neighid` random effect change?

Result/Discussion

Log likelihood = -2403.9492 on 2300 residual degrees of freedom

Parameter	Estimate	Std. Err.
cons	0.77383E-01	0.23439E-01
p7vrq	0.28441E-01	0.22695E-02
p7read	0.26825E-01	0.17553E-02
dadocc	0.93107E-02	0.13681E-02

dadunemp	-0.14359	0.46900E-01
daded	0.14818	0.41109E-01
momed	0.67291E-01	0.37698E-01
male	-0.54457E-01	0.28608E-01
sigma	0.67583	0.11010E-01
scale	0.11593	0.31606E-01

The scale parameter estimate shrinks from 0.44893 (S.E. 0.28651E-01) in the model without covariates to 0.11593 (S.E. 0.31606E-01) for the model with the student specific effects.

Task 7. Add observed neighbourhood effect `deprive` to the model, how does the magnitude of the `neighid` random effect change?

Result/Discussion

Log likelihood = -2387.4993 on 2299 residual degrees of freedom

Parameter	Estimate	Std. Err.
-----	-----	-----
cons	0.80731E-01	0.22960E-01
p7vrq	0.27763E-01	0.22561E-02
p7read	0.26065E-01	0.17467E-02
dadocc	0.82389E-02	0.13668E-02
dadunemp	-0.11490	0.46832E-01
daded	0.14097	0.40829E-01
momed	0.62405E-01	0.37454E-01
male	-0.55381E-01	0.28434E-01
deprive	-0.14812	0.25331E-01
sigma	0.67574	0.11007E-01
scale	0.78917E-01	0.43246E-01

The scale parameter estimate increases from 0.11593 (S.E. 0.31606E-01) for the model with just the student specific effects to 0.78917E-01 (S.E. 0.43246E-01) for the model with the student specific effects and the neighbourhood effect (`deprive`). The scale parameter in the model with student specific effects and the neighbourhood effect is not significant, it has a z statistic $0.78917E-01/0.43246E-01 = -1.5232$.

Task 8. What do the results of using either the `schid` or the `neighid` random effects tell you about what effects are needed in the modelling of attainment with this data set?

Result/Discussion

Both the `schid` or the `neighid` random effects models are 2 level models, perhaps a 3 level model would be more appropriate on this data, i.e. pupils in schools, and schools in neighbourhoods.

Task 9. What do the two sets of results show/suggest?

Result/Discussion

That both student specific and neighbourhood effect (**deprive**) effects can be present in linear model of student attainment (**attain**). We can interpret the various covariate effects, e.g. the neighbourhood effect (**deprive**) a measure of social deprivation has a very significant negative effect on student attainment.

2.2 Batch Script: C2.R

```
# save the log file
sink("C2.log")

# use the sabreR library
library(sabreR)

# read the data
neighborhood <- read.table("neighborhood.tab")
attach(neighborhood)

# look at the 1st 10 lines and columns
neighborhood[1:10,1:10]

# estimate the 1st model
sabre.model.1 <- sabre(attain~1,case=schid,adaptive.quad=TRUE,
                      first.family="gaussian")

# show the results
sabre.model.1

# estimate the 2nd model
sabre.model.2 <- sabre(attain~p7vrq+p7read+dadocc+dadunemp+daded+
                      momed+male,case=schid,adaptive.quad=TRUE,
                      first.family="gaussian",con=5e-5)

# show the results
sabre.model.2

# estimate the 3rd model
sabre.model.3 <- sabre(attain~p7vrq+p7read+dadocc+dadunemp+daded+
                      momed+male+deprive,case=schid,
                      adaptive.quad=TRUE,first.family="gaussian")

# show the results
sabre.model.3

# read the data
neighborhood2 <- read.table("neighborhood2.tab")
attach(neighborhood2)

# look at the 1st 10 lines and columns
neighborhood2[1:10,1:10]
```

```

# estimate the 4th model
sabre.model.4 <- sabre(attain~1,case=neighid,adaptive.quad=TRUE,
                      first.family="gaussian")

# show the results
sabre.model.4

# estimate the 5th model
sabre.model.5 <- sabre(attain~p7vrq+p7read+dadocc+dadunemp+daded+
                      momed+male,case=neighid,adaptive.quad=TRUE,
                      first.family="gaussian")

# show the results
sabre.model.5

# estimate the 6th model
sabre.model.6 <- sabre(attain~p7vrq+p7read+dadocc+dadunemp+daded+
                      momed+male+deprive,case=neighid,
                      adaptive.quad=TRUE,first.family="gaussian")

# show the results
sabre.model.6

# remove the created objects
detach(neighborhood,neighborhood2)
rm(neighborhood,neighborhood2,sabre.model.1,sabre.model.2,
    sabre.model.3,sabre.model.4,sabre.model.5,sabre.model.6)

# close the log file
sink()

```

3 Exercise C3. Binary Response Model of Essay Grades

3.1 Relevant Results from C3.log and Discussion

Task 1. Fit a binary probit model to the binary response `pass`, but without any random effects.

Result/Discussion

```
Log likelihood =      -686.20763      on      989 residual degrees of freedom

Parameter              Estimate              Std. Err.
-----
cons                    0.50639E-02              0.39833E-01
```

Task 2. Fit a binary probit model to `pass` allowing for the `essay` random effect, is the `essay` effect significant? How many quadrature points should we use to estimate this model?

Result/Discussion

```
Log likelihood =      -613.87204      on      988 residual degrees of freedom

Parameter              Estimate              Std. Err.
-----
cons                    0.56694E-02              0.85207E-01
scale                   0.99151                  0.95013E-01
```

The result above is for an 12 mass adaptive quadrature model, the `essay` random effect is significant, the change in log likelihood over the homogeneous model is $-2(-686.20763+613.87204)= 144.67$. The sampling distribution of this test statistic is not chi-square with 1 df. Under the null hypothesis `scale` has the value 0, and it can only take values >0 under the alternative. The correct p value for this test statistics is obtained by dividing the naive p value of 144.67 for 1 degree of freedom by 1/2, and so its clearly significant.

Task 3. Add the 4 grader dummy variables to the model, what are the differences between the graders?

Result/Discussion

Log likelihood = -562.68165 on 984 residual degrees of freedom

Parameter	Estimate	Std. Err.
cons	0.86777	0.14749
grader2	-1.2153	0.16676
grader3	-0.72212	0.15941
grader4	-0.84969	0.16199
grader5	-1.5143	0.17153
scale	1.1795	0.11237

All the grader indicator effects are negative, relative to grader1 (the reference category) and they all have significant t statistics. The estimated scale parameter and its standard error have increased slightly. Relative to grader1, the lowest marker is **grader5**, then we have **grader2**, 4 and 3.

Task 4. Add the 6 essay characteristics (**wordlength-sentlength**) to the previous model. Which of them are significant? How has including the essay characteristics improved the model?

Result/Discussion

Log likelihood = -502.95053 on 978 residual degrees of freedom

Parameter	Estimate	Std. Err.
cons	-6.8057	1.1242
grader2	-1.2084	0.16632
grader3	-0.71298	0.15895
grader4	-0.83704	0.16079
grader5	-1.5031	0.17052
wordlength	1.0244	0.23545
sqrtwords	0.29128	0.32422E-01
commas	0.73205E-01	0.32721E-01
errors	-0.14654	0.39031E-01
prepos	0.58790E-01	0.23941E-01
sentlength	0.35979E-03	0.12914E-01
scale	0.71452	0.89305E-01

Only the **sentlength** essay characteristic is not significant in this extended model, **sqrtwords** is the most significant of the essay characteristics.

Task 5. Create interaction effects between the grader specific dummy variables and the `sqrtwords` explanatory variable and add these effects to the model. What do the results tell you?

Result/Discussion

Log likelihood = -496.55002 on 974 residual degrees of freedom

Parameter	Estimate	Std. Err.
cons	-6.8155	1.2189
grader2	-2.1526	0.70353
grader3	-1.9486	0.68342
grader4	-0.61700	0.63845
grader5	-0.73613	0.65089
wordlength	1.0592	0.24128
sqrtwords	0.27533	0.56617E-01
commas	0.73714E-01	0.33381E-01
errors	-0.14677	0.39805E-01
prepos	0.59744E-01	0.24425E-01
sentlength	0.95757E-04	0.13170E-01
grader2sqrt	0.98148E-01	0.73308E-01
grader3sqrt	0.13425	0.73450E-01
grader4sqrt	-0.23209E-01	0.68602E-01
grader5sqrt	-0.77556E-01	0.68640E-01
scale	0.73533	0.91437E-01

The model with interactions between the grader specific dummy variables and `sqrtwords` has a significant chi-square improvement of $-2(-502.95053+496.55002)=-12.801$ for 4 df. So there appears to be a different relationship between the length of the essay and essay grader for essay grade. However two of the grader indicators main effects i.e. `grader4`, `grader5`, have become non significant. The estimated scale parameter is still significant.

3.2 Batch Script: C3.R

```
# save the log file
sink("C3.log")

# use the sabreR library
library(sabreR)

# read the data
essays2 <- read.table("essays2.tab")
attach(essays2)

# look at the 1st 10 lines and columns
```



```

essays2[1:10,1:10]

# estimate the 1st model
sabre.model.1 <- sabre(pass~1,case=essay,adaptive.quad=TRUE,
                      first.link="probit")

# show the results
sabre.model.1

# estimate the 2nd model
sabre.model.2 <- sabre(pass~grader2+grader3+grader4+grader5,
                      case=essay,adaptive.quad=TRUE,
                      first.link="probit")

# show the results
sabre.model.2

# estimate the 3rd model
sabre.model.3 <- sabre(pass~grader2+grader3+grader4+grader5+
                      wordlength+sqrtwords+commas+errors+prepos+
                      sentlength,case=essay,adaptive.quad=TRUE,
                      first.link="probit")

# show the results
sabre.model.3

# estimate the 4th model
sabre.model.4 <- sabre(pass~wordlength+commas+errors+prepos+
                      sentlength+grader2*sqrtwords+
                      grader3*sqrtwords+grader4*sqrtwords+
                      grader5*sqrtwords,case=essay,
                      adaptive.quad=TRUE,first.link="probit")

# show the results
sabre.model.4

# remove the created objects
detach(essays2)
rm(essays2,sabre.model.1,sabre.model.2,sabre.model.3,sabre.model.4)

# close the log file
sink()

```

4 Exercise C4. Ordered Response Model of Essay Grades

4.1 Relevant Results from C4.log and Discussion

Task 1. Fit an ordered probit model to `ngrade` but without any random effects.

Result/Discussion

```
Log likelihood =      -1371.6074      on      987 residual degrees of freedom

Parameter              Estimate              Std. Err.
-----
cut1                   -0.66341                0.43188E-01
cut2                   -0.50639E-02            0.39833E-01
cut3                    0.62909                 0.42834E-01
```

Task 2. Fit an ordered probit model allowing for the `essay` random effect, is the `essay` effect significant? How many adaptive quadrature points should we use to estimate this model?

Result/Discussion

```
Log likelihood =      -1247.5966      on      986 residual degrees of freedom

Parameter              Estimate              Std. Err.
-----
cut1                   -0.93258                0.89587E-01
cut2                    0.24248E-02            0.85205E-01
cut3                    0.88906                 0.88940E-01
scale                   1.0044                  0.76825E-01
```

This model was estimated with 12 mass points. The change in log likelihood over the homogeneous model has a chi-square of $-2(-1371.6074+1247.5966)=248.02$. The sampling distribution of this test statistic is not chi-square with 1 df. Under the null hypothesis `scale` has the value 0, and it can only take values >0 under the alternative. The correct p value for this test statistics is obtained by dividing the naive p value of 248.02 for 1 degree of freedom by 1/2, and so its clearly significant.

Task 3. Add the dummy variables for `graders` (2,3,4,5) to the model, are there differences between the graders?

Result/Discussion

Log likelihood = -1181.4489 on 982 residual degrees of freedom

Parameter	Estimate	Std. Err.
grader2	-1.0885	0.12214
grader3	-0.63255	0.12004
grader4	-0.72804	0.11878
grader5	-1.2842	0.12316
cut1	-1.7957	0.13341
cut2	-0.74225	0.12268
cut3	0.25090	0.12080
scale	1.1464	0.85246E-01

Relative to **grader1**, **grader5**, is the lowest marker followed by 2, 4 and 3.

Task 4. Add the 6 essay characteristics (**wordlength-sentlength**) to the previous model. Which of them are significant? Has including the essay characteristics improved the model?

Result/Discussion

Log likelihood = -1116.1052 on 976 residual degrees of freedom

Parameter	Estimate	Std. Err.
grader2	-1.0895	0.12193
grader3	-0.62905	0.12001
grader4	-0.72839	0.11846
grader5	-1.2849	0.12285
wordlength	0.78477	0.20186
sqrtwords	0.28050	0.26610E-01
commas	0.64009E-01	0.28346E-01
errors	-0.16114	0.33795E-01
prepos	0.50995E-01	0.20497E-01
sentlength	-0.17035E-02	0.11399E-01
cut1	4.5615	0.93449
cut2	5.6071	0.93976
cut3	6.6058	0.94601
scale	0.71413	0.66264E-01

The covariate **sentlength** is not significant (z test). The change in log likelihood for adding the 6 essay characteristics is clearly significant, it has a chi-square of $-2(-1181.4489+1116.1052)= 130.69$.

Task 5. Create interaction effects between the **grader** specific dummy variables and the **sqrtwords** explanatory variable and add these effects to the model. What do the results tell you?

Result/Discussion

Log likelihood = -1094.4282 on 972 residual degrees of freedom

Parameter	Estimate	Std. Err.
grader2	-1.3937	0.48887
grader3	-2.3223	0.51754
grader4	0.20938	0.46529
grader5	-0.18398	0.47409
wordlength	0.81793	0.20952
sqrtwords	0.30176	0.43879E-01
commas	0.65559E-01	0.29393E-01
errors	-0.16543	0.35045E-01
prepos	0.52336E-01	0.21281E-01
sentlength	-0.13918E-02	0.11819E-01
grader2sqrt	0.28753E-01	0.51366E-01
grader3sqrt	0.18273	0.55407E-01
grader4sqrt	-0.10301	0.49563E-01
grader5sqrt	-0.11935	0.50102E-01
cut1	4.8642	1.0185
cut2	5.9357	1.0234
cut3	6.9724	1.0301
scale	0.75099	0.68526E-01

The change in log likelihood has a chi-square of $-2(-1116.1052+1094.4282)=43.354$ for 4 df, clearly significant overall. Various covariate effects are not significant in the model, these include **grader4**, **grader5**, **sentlength** and the interaction effect **grader2sqrt**.

Task 6. Repeat exercise components 2-6 treating **grade** as an ordered probit model with all the observed categories (1,2,...,8) of **grade**, grades (9,10) are not observed in this data set.

Result/Discussion

Log likelihood = -1707.3256 on 968 residual degrees of freedom

Parameter	Estimate	Std. Err.
grader2	-1.3262	0.44038
grader3	-2.1009	0.45656
grader4	0.60237	0.42374
grader5	0.55202E-02	0.42951
wordlength	0.90840	0.20927
sqrtwords	0.33947	0.41241E-01

commas	0.69427E-01	0.29487E-01
errors	-0.15169	0.34760E-01
prepos	0.54245E-01	0.20958E-01
sentlength	0.79695E-03	0.11814E-01
grader2sqrt	0.16434E-01	0.46235E-01
grader3sqrt	0.15843	0.48636E-01
grader4sqrt	-0.14085	0.44981E-01
grader5sqrt	-0.14256	0.45402E-01
cut1	4.7135	1.0044
cut2	5.6454	1.0062
cut3	6.2119	1.0079
cut4	6.7729	1.0104
cut5	7.3627	1.0139
cut6	7.8499	1.0170
cut7	8.4523	1.0209
scale	0.78548	0.62818E-01

We have only presented the result for full model with 7 cut points. Various covariate effects are not significant, these include `grader4`, `grader5`, `sentlength` and the interaction effect `grader2sqrt`.

Task 7. Are there any differences between the results obtained using the alternative ordered responses `ngrade` and `grade`? What does this tell you?

Result/Discussion

If the model is correct the covariate parameter estimates should be similar from the model based on the 4 aggregate `ngrade` categories to those of the model based on the original 8 `grade` categories, as aggregation used in `ngrade` is of adjacent categories from `grade`. The ordered model using the 8 `grade` categories is to be preferred, as it contains more information about the ordered `grade`. This is generally true, so long as the response data are not too sparse across the categories. The cut points from the `grade` categories model suggest that the distance between `cut1` and `cut2`, (about 0.9) is greater than that between any other cut points (about 0.5). The `ngrade` and `grade` models agree about the covariates effects that are significant and non significant. There are small differences in the magnitude of the significant covariates, but they do not appear to be too large to suggest that there is a problem with the model.

4.2 Batch Script: C4.R

```
# save the log file
sink("C4.log")

# use the sabreR library
library(sabreR)

# read the data
essays_ordered <- read.table("essays_ordered.tab")
attach(essays_ordered)
```

```

# look at the 1st 10 lines and columns
essays_ordered[1:10,1:10]

# estimate the 1st model
sabre.model.1 <- sabre(ngrade~1,case=essay,adaptive.quad=TRUE,
                      first.link="probit",ordered="TRUE")

# show the results
sabre.model.1

# estimate the 2nd model
sabre.model.2 <- sabre(ngrade~grader2+grader3+grader4+grader5-1,
                      case=essay,adaptive.quad=TRUE,
                      first.link="probit",ordered="TRUE")

# show the results
sabre.model.2

# estimate the 3rd model
sabre.model.3 <- sabre(ngrade~grader2+grader3+grader4+grader5+
                      wordlength+sqrtwords+commas+errors+prepos+
                      sentlength-1,case=essay,adaptive.quad=TRUE,
                      first.link="probit",ordered="TRUE")

# show the results
sabre.model.3

# estimate the 4th model
sabre.model.4 <- sabre(ngrade~wordlength+commas+errors+prepos+
                      sentlength+grader2*sqrtwords+
                      grader3*sqrtwords+grader4*sqrtwords+
                      grader5*sqrtwords-1,case=essay,
                      adaptive.quad=TRUE,first.link="probit",
                      ordered="TRUE")

# show the results
sabre.model.4

# estimate the 5th model
sabre.model.5 <- sabre(grade~1,case=essay,adaptive.quad=TRUE,
                      first.link="probit",ordered="TRUE")

# show the results
sabre.model.5

# estimate the 6th model
sabre.model.6 <- sabre(grade~grader2+grader3+grader4+grader5-1,
                      case=essay,adaptive.quad=TRUE,
                      first.link="probit",ordered="TRUE")

# show the results
sabre.model.6

# estimate the 7th model
sabre.model.7 <- sabre(grade~grader2+grader3+grader4+grader5+
                      wordlength+sqrtwords+commas+errors+prepos+
                      sentlength-1,case=essay,adaptive.quad=TRUE,
                      first.link="probit",ordered="TRUE")

# show the results
sabre.model.7

```

```
# estimate the 8th model
sabre.model.8 <- sabre(grade~wordlength+commas+errors+prepos+
  sentlength+grader2*sqrtwords+
  grader3*sqrtwords+grader4*sqrtwords+
  grader5*sqrtwords-1, case=essay,
  adaptive.quad=TRUE, first.link="probit",
  ordered="TRUE")

# show the results
sabre.model.8

# remove the created objects
detach(essays_ordered)
rm(essays_ordered, sabre.model.1, sabre.model.2, sabre.model.3,
  sabre.model.4, sabre.model.5, sabre.model.6, sabre.model.7,
  sabre.model.8)

# close the log file
sink()
```

5 Exercise C5. Poison Model of Headaches

5.1 Relevant Results from C5.log and Discussion

Task 1. Use the offset $\text{lt}=\log(\text{days})$ in the following Tasks.

Result/Discussion

```
trans lt log days
```

Task 2. Fit a Poisson model to y (number of headaches) with a log link without any `id` random effects.

Result/Discussion

Log likelihood = -234.50796 on 120 residual degrees of freedom

Parameter	Estimate	Std. Err.
-----	-----	-----
cons	-1.3972	0.69843E-01

Task 3. Fit a Poisson model to y allowing for the `id` random effect. Is the `id` random effect significant? How many adaptive quadrature points should we use to estimate this model?

Result/Discussion

Log likelihood = -205.61598 on 120 residual degrees of freedom

Parameter	Estimate	Std. Err.
-----	-----	-----
cons	-1.6035	0.15971
scale	0.68943	0.13888

We used 12 adaptive quadrature points. This gave a chi-square improvement of $-2(-234.50796+205.61598)= 57.784$ over the homogeneous model. The sampling distribution of this test statistic is not chi-square with 1 df. Under the null hypothesis `scale` has the value 0, and it can only take values >0 under the alternative. The correct p value for this test statistics is obtained by dividing the naive p value of 57.784 for 1 degree of freedom by 1/2, and so its clearly significant.

Task 4. Add the treatment indicator `aspartame` to the previous model, is there a significant treatment effect?

Result/Discussion

Log likelihood = -203.66800 on 119 residual degrees of freedom

Parameter	Estimate	Std. Err.
cons	-1.7154	0.17187
aspartame	0.28246	0.14216
scale	0.69543	0.14002

The treatment indicator `aspartame` has a significant z statistic, its $0.28246/0.14002=2.0173$.

5.2 Batch Script: C5.R

```
# save the log file
sink("C5.log")

# use the sabreR library
library(sabreR)

# read the data
headache <- read.table("headache.tab")
attach(headache)

# look at the 1st 10 lines and columns
headache[1:10,1:5]

# estimate the 1st model
sabre.model.1 <- sabre(y~1+offset(log(days)),case=id,
                      adaptive.quad=TRUE,first.family="poisson")

# show the results
sabre.model.1

# estimate the 2nd model
sabre.model.2 <- sabre(y~aspartame+offset(log(days)),case=id,
                      adaptive.quad=TRUE,first.family="poisson")

# show the results
sabre.model.2

# remove the created objects
detach(headache)
rm(headache,sabre.model.1,sabre.model.2)

# close the log file
sink()
```

6 Exercise L1. Linear Model of Psychological Distress

6.1 Relevant Results from L1.log and Discussion

Task 1. Estimate the linear model in sabre on `ghq`, with just a constant, and no random effects.

Result/Discussion

```
Log likelihood =      -76.935774      on      22 residual degrees of freedom

Parameter              Estimate              Std. Err.
-----
cons                   10.167                1.2448
sigma                  6.0982
```

Task 2. Estimate the linear model, allowing for the `student` random effect, use adaptive quadrature with mass 12. Are the `student` random effects significant? What does the significance mean? What impact do the `student` random effects have on the model?

Result/Discussion

```
Log likelihood =      -67.132857      on      21 residual degrees of freedom

Parameter              Estimate              Std. Err.
-----
cons                   10.167                1.6784
sigma                  1.9149                0.39087
scale                  5.6544                1.2222
```

The change in log likelihood over the homogeneous model has a chi-square of $-2(-76.935774+67.132857) = 19.606$. The sampling distribution of this test statistic is not chi-square with 1 df. Under the null hypothesis `scale` has the value 0, and it can only take values >0 under the alternative. The correct p value for this test statistics is obtained by dividing the naive p value of 19.606 for 1 degree of freedom by 1/2, and so its clearly significant.

Task 3. Re-estimate the linear model allowing for both `student` random effects and `dg2`. How do the results change (compared to Task 2)?

Result/Discussion

Log likelihood = -67.041252 on 20 residual degrees of freedom

Parameter	Estimate	Std. Err.
cons	10.333	1.7227
dg2	-0.33333	0.77579
sigma	1.9003	0.38789
scale	5.6568	1.2216

The change in log likelihood has a chi-square of $-2(-67.132857+67.041252)=0.18321$ for 1 df, which is not significant. The z statistic for the dg2 estimate is $-0.33333/0.77579=-0.42967$, which is also non significant. These results imply that there is no occasion effect on psychological distress in the data.

6.2 Batch Script: L1.R

```
# save the log file
sink("L1.log")

# use the sabreR library
library(sabreR)

# read the data
ghq2 <- read.table("ghq2.tab")
attach(ghq2)

# look at the 1st 10 lines and columns
ghq2[1:10,1:6]

# estimate the 1st model
sabre.model.1 <- sabre(ghq~1,case=student,adaptive.quad=TRUE,
  first.family="gaussian")

# show the results
sabre.model.1

# estimate the 2nd model
sabre.model.2 <- sabre(ghq~dg2,case=student,adaptive.quad=TRUE,
  first.family="gaussian")

# show the results
sabre.model.2

# remove the created objects
detach(ghq2)
rm(ghq2,sabre.model.1,sabre.model.2)

# close the log file
sink()
```

7 Exercise L2. Linear Model of log Wages

7.1 Relevant Results from L2.log and Discussion

Task 1. Estimate a linear model on `lwage` (log of hourly wage) without covariates.

Result/Discussion

Log likelihood = -3439.4161 on 4358 residual degrees of freedom

Parameter	Estimate	Std. Err.
-----	-----	-----
cons	1.6491	0.80661E-02
sigma	0.53261	

Task 2. Allow for the person identifier (`nr`) random effect, use adaptive quadrature with mass 12. Is this random effect significant?

Result/Discussion

Log likelihood = -2621.1724 on 4357 residual degrees of freedom

Parameter	Estimate	Std. Err.
-----	-----	-----
cons	1.6491	0.16722E-01
sigma	0.38723	0.44331E-02
scale	0.36559	0.12640E-01

This model has a chi-square improvement of $-2(-3439.4161+2621.1724)=1636.5$ over the homogeneous model. The sampling distribution of this test statistic is not chi-square with 1 df. Under the null hypothesis `scale` has the value 0, and it can only take values >0 under the alternative. The correct p value for this test statistics is obtained by dividing the naive p value of 1636.5 for 1 degree of freedom by 1/2, and so its clearly significant.

Task 3. Add the covariates (`educ`, `black`, `hisp`, `exper`, `expersq`, `married`, `union`, `factor(year)`). How does the magnitude of the `scale` parameter for person identifier random effects change?

Result/Discussion

Log likelihood = -2186.9588 on 4343 residual degrees of freedom

Parameter	Estimate	Std. Err.
-----	-----	-----

cons		0.23164E-01	0.15233
educ		0.91887E-01	0.10780E-01
black		-0.13938	0.48258E-01
hisp		0.21774E-01	0.43089E-01
exper		0.10598	0.15445E-01
expersq		-0.47369E-02	0.68805E-03
married		0.63565E-01	0.16779E-01
union		0.10548	0.17885E-01
fyear	(1)	0.0000	ALIASED [I]
fyear	(2)	0.40367E-01	0.24682E-01
fyear	(3)	0.30749E-01	0.32458E-01
fyear	(4)	0.20054E-01	0.41838E-01
fyear	(5)	0.42859E-01	0.51713E-01
fyear	(6)	0.57522E-01	0.61771E-01
fyear	(7)	0.91653E-01	0.71910E-01
fyear	(8)	0.13470	0.82135E-01
sigma		0.35066	0.40172E-02
scale		0.32987	0.11470E-01

This gave a chi-square improvement of $-2(-2621.1724+2186.9588)= 868.43$ for $4357-4343= 14$ df, which is very significant overall. But judged by the various covariate parameter estimates the following main effects are not significant: *hisp*, *fyear*(2-7). The *scale* parameter in the model with covariates is slightly smaller.

Task 4. Create interaction effects between the factor (*year*) indicators (*d81*, . . . , *d87*) and *educ*, add these effects to the previous model, do the returns to education vary with year? What do the results show?

Result/Discussion

Log likelihood = -2185.7569 on 4336 residual degrees of freedom

Parameter		Estimate	Std. Err.

cons		-0.30601E-01	0.18810
educ		0.94647E-01	0.13702E-01
black		-0.13961	0.48306E-01
hisp		0.22405E-01	0.43134E-01
exper		0.11554	0.17029E-01
expersq		-0.53658E-02	0.83374E-03
married		0.64033E-01	0.16782E-01
union		0.10448	0.17895E-01
fyear	(1)	0.0000	ALIASED [I]
fyear	(2)	-0.28781E-01	0.14519
fyear	(3)	-0.10056E-01	0.14673
fyear	(4)	0.17697E-01	0.14949

fyear	(5)	0.11328	0.15367
fyear	(6)	0.11713	0.15942
fyear	(7)	0.17924	0.16686
fyear	(8)	0.25606	0.17614
educ81		0.54357E-02	0.12197E-01
educ82		0.26951E-02	0.12298E-01
educ83		-0.79957E-03	0.12466E-01
educ84		-0.71021E-02	0.12700E-01
educ85		-0.61964E-02	0.12992E-01
educ86		-0.84785E-02	0.13339E-01
educ87		-0.11141E-01	0.13741E-01
sigma		0.35051	0.40155E-02
scale		0.33026	0.11483E-01

The addition of the interaction effects gave a chi-square improvement of $-2(-2186.9588+2185.7569)= 2.4038$ for $4343-4336= 7$ df, which is not significant. None of the individual interaction effects have significant z statistics, i.e. returns to education do not appear to change with year. Both the interaction effects and the main effects of `year` could be removed from this model. The `scale` parameter is still significant, suggesting a correlation between log wages for an individual over successive years.

7.2 Batch Script: L2.R

```
# save the log file
sink("L2.log")

# use the sabreR library
library(sabreR)

# read the data
wagepan <- read.table("wagepan.tab")
attach(wagepan)

# look at the 1st 10 lines and columns
wagepan[1:10,1:10]

# estimate the 1st model
sabre.model.1 <- sabre(lwage~1,case=nr,adaptive.quad=TRUE,
                      first.family="gaussian")

# show the results
sabre.model.1

# estimate the 2nd model
sabre.model.2 <- sabre(lwage~educ+black+hisp+exper+expersq+married+
                      union+factor(year),case=nr,adaptive.quad=TRUE,
                      first.family="gaussian")

# show the results
sabre.model.2

# estimate the 3rd model
sabre.model.3 <- sabre(lwage~black+hisp+exper+expersq+married+union+
                      factor(year)*educ,case=nr,adaptive.quad=TRUE,
```

```
                                first.family="gaussian")

# show the results
sabre.model.3

# remove the created objects
detach(wagepan)
rm(wagepan,sabre.model.1,sabre.model.2,sabre.model.3)

# close the log file
sink()
```

8 Exercise L3. Linear Growth Model of log of Unemployment Claims

8.1 Relevant Results from L3.log and Discussion

Task 1. Estimate a linear model on the log of number of unemployment claims (`luc1ms`) without covariates.

Result/Discussion

```
Log likelihood =      -213.81328      on      196 residual degrees of freedom

Parameter              Estimate              Std. Err.
-----
cons                   11.191                0.50759E-01
sigma                  0.71424
```

Task 2. Allow for the city identifier (`city`) random effect (use adaptive quadrature with mass 12). Is this random effect significant?

Result/Discussion

```
Log likelihood =      -166.35513      on      195 residual degrees of freedom

Parameter              Estimate              Std. Err.
-----
cons                   11.191                0.11550
sigma                  0.49075                0.26157E-01
scale                  0.51645                0.85713E-01
```

This model has a chi-square improvement of $-2(-213.81328+166.35513)= 94.916$ over the homogeneous model. The sampling distribution of this test statistic is not chi-square with 1 df. Under the null hypothesis `scale` has the value 0, and it can only take values >0 under the alternative. The correct p value for this test statistics is obtained by dividing the naive p value of 94.916 for 1 degree of freedom by 1/2, and so its clearly significant.

Task 3. Add the binary `ez` effect. How does the magnitude of the `scale` parameter estimate for the city random effect change? Is the enterprise zone effect significant in this model?

Result/Discussion

Log likelihood = -135.33303 on 194 residual degrees of freedom

Parameter	Estimate	Std. Err.
cons	11.363	0.12453
ez	-0.74164	0.85576E-01
sigma	0.40825	0.21770E-01
scale	0.56033	0.89814E-01

The **scale** parameter estimate is slightly larger in the model with the **ez** covariate. The **ez** parameter estimate has a z statistics of $-0.74164/0.085576 = -8.6664$ which is clearly significant. The negative coefficient on **ez** suggests that the log of the number of unemployment claims is smaller in cites which are in the enterprise zone.

Task 4. Add the linear time effect (**t**). How does the magnitude of the city specific random effect change?

Result/Discussion

Log likelihood = -59.438419 on 193 residual degrees of freedom

Parameter	Estimate	Std. Err.
cons	11.918	0.12196
ez	-0.13846	0.69012E-01
t	-0.13906	0.90240E-02
sigma	0.26722	0.14243E-01
scale	0.53601	0.83053E-01

Task 5. Interpret your preferred model, does **ez** have an effect on the response $\log(\text{uclms})$?

Result/Discussion

The Task 4 model has a chi-square improvement of $-2(-135.33303 + 59.438419) = 151.79$ over the Task 3 model. The **scale** parameter estimate is slightly smaller in the Task 4 model. Both the **ez** and **t** parameter estimates have significant z statistics. The magnitude of the negative **ez** parameter estimate in the Task 4 model is smaller than that of the Task 3 model. The coefficient on time **t** is negative, suggesting that both the enterprise and non enterprise zone unemployment claims are declining with year (1980-1988). The negative coefficient on **ez** suggests that the log of the number of unemployment claims is smaller in cites which are in the enterprise zone.

8.2 Batch Script: L3.R

```
# save the log file
sink("L3.log")

# use the sabreR library
library(sabreR)

# read the data
ezunem <- read.table("ezunem2.tab")
attach(ezunem)

# look at the 1st 10 lines and columns
ezunem[1:10,1:15]

# estimate the 1st model
sabre.model.1 <- sabre(luclms~1,case=city,adaptive.quad=TRUE,
                      first.family="gaussian")

# show the results
sabre.model.1

# estimate the 2nd model
sabre.model.2 <- sabre(luclms~ez,case=city,adaptive.quad=TRUE,
                      first.family="gaussian")

# show the results
sabre.model.2

# estimate the 3rd model
sabre.model.3 <- sabre(luclms~ez+t,case=city,adaptive.quad=TRUE,
                      first.family="gaussian")

# show the results
sabre.model.3

# remove the created objects
detach(ezunem)
rm(ezunem,sabre.model.1,sabre.model.2,sabre.model.3)

# close the log file
sink()
```

9 Exercise L4. Binary Model of Trade Union Membership

9.1 Relevant Results from L4.log and Discussion

Task 1. Estimate a logit model for trade union membership (`union`), without covariates.

Result/Discussion

```
Log likelihood =      -2422.8016      on      4359 residual degrees of freedom

Parameter              Estimate              Std. Err.
-----
cons                   -1.1307              0.35260E-01
```

Task 2. Allow for the respondent identifier (`nr`) random effect, use adaptive quadrature. Is this random effect significant? How many quadrature points should we use to estimate this model?

Result/Discussion

```
Log likelihood =      -1671.6755      on      4358 residual degrees of freedom

Parameter              Estimate              Std. Err.
-----
cons                   -2.4630              0.17429
scale                   3.0758              0.18129
```

This is the result with 72 adaptive quadrature mass points. This model has a chi-square improvement of $-2(-2422.8016+1671.6755)=1502.3$ over the homogeneous model. The sampling distribution of this test statistic is not chi-square with 1 df. Under the null hypothesis `scale` has the value 0, and it can only take values >0 under the alternative. The correct p value for this test statistics is obtained by dividing the naive p value of 1502.3 for 1 degree of freedom by 1/2, and so its clearly significant.

Task 3. Add the explanatory variables `black`, `hisp`, `exper`, `educ`, `poorhlth` and `married`. How does the magnitude of the `nr` random effect change? Are any of these individual characteristics significant in this model? Do the results make intuitive sense?

Result/Discussion

Log likelihood = -1659.5364 on 4352 residual degrees of freedom

Parameter	Estimate	Std. Err.
cons	-1.9169	1.1417
black	1.7662	0.46632
hisp	0.82086	0.42208
exper	-0.45506E-01	0.24070E-01
educ	-0.62424E-01	0.92438E-01
poorhlth	-0.75160	0.50254
married	0.34208	0.15907
scale	3.0203	0.17834

This gave a chi-square improvement of $-2(-1671.6755+1659.5364)= 24.278$ for $4358-4352= 6$ df, which is very significant overall. But judged by the various covariate parameter estimates, the following main effects are not significant: **educ**, **poorhlth**, while **exper** has borderline significance. The **scale** parameter in the model with covariates is still very significant and only slightly smaller. This model suggests that respondents who are **black** or **hisp** are more likely to be trade union members than whites. It also suggests that workers with longer labour market experience (**exper**) are less likely to be trade union members. While those who are **married** are more likely to be trade union members.

Task 4. Add the contextual explanatory variables **rur**, **nrthcen**, **nrtheast**, **south**. How does the magnitude of the individual specific random effects coefficient change? Are any of the contextual variables significant in this model? Do the new results make intuitive sense?

Result/Discussion

Log likelihood = -1654.9281 on 4348 residual degrees of freedom

Parameter	Estimate	Std. Err.
cons	-2.4347	1.2006
black	1.8870	0.47315
hisp	1.1052	0.44739
exper	-0.40595E-01	0.24199E-01
educ	-0.60500E-01	0.93061E-01
poorhlth	-0.75608	0.50335
married	0.34500	0.15984
rur	0.20794	0.24023
nrthcen	0.69825	0.38780
nrtheast	0.87514	0.42444
south	0.31154E-01	0.38514
scale	3.0130	0.17885

This gave a chi-square improvement over the model of Task 3 of $-2(-1659.5364+1654.9281)= 9.2166$ for $4352-4348= 4$ df, which is of marginal significance. But

judging by the various covariate parameter estimates, the following contextual effects are not significant: **rur**, **south**, while **nrthcen** is of marginal significance. The **scale** parameter in the model with covariates is slightly smaller.

Task 5. Add the indicator variables for year. Are any of the year indicator variables significant in this model? Do the new results make intuitive sense?

Result/Discussion

Log likelihood = -1648.5200 on 4341 residual degrees of freedom

Parameter	Estimate	Std. Err.
cons	-3.5267	1.5875
black	1.8547	0.47558
hisp	1.0994	0.44857
exper	0.78144E-01	0.11319
educ	0.29340E-02	0.11073
poorhlth	-0.75088	0.50414
married	0.35840	0.16124
rur	0.16395	0.24218
nrthcen	0.69374	0.38903
nrtheast	0.89547	0.42624
south	0.49953E-01	0.38611
d81	-0.13844	0.23405
d82	-0.14765	0.30445
d83	-0.37875	0.39646
d84	-0.40806	0.49582
d85	-0.81673	0.60154
d86	-1.0608	0.70928
d87	-0.55944	0.81502
scale	3.0219	0.17944

This gave a chi-square improvement of $-2(-1654.9281+1648.5200)= 12.816$ for $4348-4341= 7$ df, which is not significant at the 0.05 level. This is backed up by the year dummy variable parameter estimates, as none of them are significant.

Task 6. Include interaction effects between **rur** and **nrthcen**, **nrtheast**, **south** and add them to the model. Are any of these new effects significant?

Result/Discussion

Log likelihood = -1646.0610 on 4338 residual degrees of freedom

Parameter	Estimate	Std. Err.
cons	-3.5764	1.5937

black	1.8663	0.47779
hisp	1.1461	0.45152
exper	0.73943E-01	0.11369
educ	0.13740E-01	0.11129
poorhlth	-0.77703	0.50835
married	0.35646	0.16168
rur	-0.83058	0.73415
nrthcen	0.60996	0.40177
nrtheast	0.91324	0.43866
south	-0.18017	0.40372
d81	-0.13588	0.23467
d82	-0.14725	0.30549
d83	-0.36793	0.39818
d84	-0.39353	0.49811
d85	-0.79952	0.60429
d86	-1.0401	0.71255
d87	-0.53695	0.81878
rur_nrthcen	1.0602	0.85693
rur_nrtheast	0.32601	0.94706
rur_south	1.4901	0.82363
scale	3.0350	0.18135

This gave a chi-square improvement of $-2(-1648.5200+1646.0610)= 4.918$ for $4341-4338=3$ df, which is not significant at the 0.05 level.

Task 7. How can the final model be simplified?

Result/Discussion

We could drop some of the contextual covariates from the model, namely: the interaction effects between **rur** and **nrthcen**, **nrtheast**, **south** and the main effects of : **d81-d87**, **rur**, and **south**. We could also drop the individual specific covariates **exper**, **educ** and **poorhlth**.

Task 8. Interpret your preferred model.

Result/Discussion

The preferred model is that of Task 4. This model suggests that respondents who are **black** or **hisp** are more likely to be trade union members than whites. It also suggests that workers with longer labour market experience (**exper**) are less likely to be trade union members. While those who are **married** are more likely to be trade union members. Furthermore the respondents from **nrthcen** and the **nrtheast** US are more likely to be trade union members than the rest.

9.2 Batch Script: L4.R

```
# save the log file
sink("L4.log")
```

```

# use the sabreR library
library(sabreR)

# read the data
wagepan <- read.table("wagepan.tab")
attach(wagepan)

# look at the 1st 10 lines and columns
wagepan[1:10,1:10]

# estimate the 1st model
sabre.model.1 <- sabre(union~1,case=nr,adaptive.quad=TRUE,
                      first.mass=72)

# show the results
sabre.model.1

# estimate the 2nd model
sabre.model.2 <- sabre(union~black+hisp+exper+educ+poorhlth+
                      married,case=nr,adaptive.quad=TRUE,
                      first.mass=72)

# show the results
sabre.model.2

# estimate the 3rd model
sabre.model.3 <- sabre(union~black+hisp+exper+educ+poorhlth+
                      married+rur+nrthcen+nrtheast+south,case=nr,
                      adaptive.quad=TRUE,first.mass=72)

# show the results
sabre.model.3

# estimate the 4th model
sabre.model.4 <- sabre(union~black+hisp+exper+educ+poorhlth+
                      married+rur+nrthcen+nrtheast+south+
                      factor(year),case=nr,adaptive.quad=TRUE,
                      first.mass=72)

# show the results
sabre.model.4

# estimate the 5th model
sabre.model.5 <- sabre(union~black+hisp+exper+educ+poorhlth+
                      married+factor(year)+rur*nrthcen+rur*nrtheast+
                      rur*south,case=nr,adaptive.quad=TRUE,
                      first.mass=72)

# show the results
sabre.model.5

# remove the created objects
detach(wagepan)
rm(wagepan,sabre.model.1,sabre.model.2,sabre.model.3,sabre.model.4,
    sabre.model.5)

# close the log file
sink()

```

10 Exercise L5. Ordered Response Model of Attitudes to Abortion

10.1 Relevant Results from L5.log and Discussion

Task 1. Estimate an ordered logit model to `nscore`, without covariates.

Result/Discussion

Log likelihood = -1766.6663 on 1051 residual degrees of freedom

Parameter	Estimate	Std. Err.
cut1	-2.5150	0.11697
cut2	-0.80171	0.66557E-01
cut3	-0.28216	0.62159E-01
cut4	0.18996	0.61824E-01
cut5	0.75342	0.65965E-01

Task 2. Allow for the person identifier (`person`) random effect, is this random effect significant? How many adaptive quadrature points should we use to estimate this model?

Result/Discussion

Log likelihood = -1556.6472 on 1050 residual degrees of freedom

Parameter	Estimate	Std. Err.
cut1	-4.2791	0.24225
cut2	-1.4925	0.17958
cut3	-0.55745	0.17319
cut4	0.33330	0.17198
cut5	1.3759	0.17696
scale	2.4006	0.16334

This is the result with 24 adaptive quadrature mass points. This person level model has a chi-square improvement of $-2(-1766.6663+1556.6472)=420.04$ over the homogeneous model. The sampling distribution of this test statistic is not chi-square with 1 df. Under the null hypothesis `scale` has the value 0, and it can only take values >0 under the alternative. The correct p value for this test statistics is obtained by dividing the naive p value of 420.04 for 1 degree of freedom by 1/2, and so its clearly significant.

Task 3. Add the explanatory variables `male`, `age` and the three sets of dummy variables (`dr`, `dp`, `dc`). How does the magnitude of the person random effect change? Are any of these individual characteristics significant in this model? Do the results make intuitive sense?

Result/Discussion

Log likelihood = -1540.5327 on 1039 residual degrees of freedom

Parameter	Estimate	Std. Err.
male	0.16982	0.31372
age	0.95699E-03	0.10287E-01
dr2	1.8853	0.64382
dr3	0.55578	0.69683
dr4	2.6697	0.65074
dp2	0.12500	0.29870
dp3	0.64082E-01	0.30195
dp4	-0.10560E-01	0.51927
dp5	-0.20071E-01	0.56075
dc2	-0.27901	0.26781
dc3	-0.16280	0.27664
cut1	-2.4638	0.80401
cut2	0.33189	0.79843
cut3	1.2665	0.79976
cut4	2.1551	0.80193
cut5	3.1958	0.80568
scale	2.2332	0.15515

This gave a chi-square improvement of $-2(-1556.6472+1540.5327)= 32.229$ for $1050-1039= 11$ df, which is significant at the 0.05 level. But judged by the various covariate parameter estimates, the following main effects are not significant: `male`, `age`, `dr3` (other religion), the way the respondent votes (`dp2-5`), and the respondent's self asses social class (`dc2-3`). The `scale` parameter in the model with covariates is still very significant and only slightly smaller. This model, which is clustered by person over time, suggests that respondent's who are protestant (`dr2`) or agnostic (`dr4`) are more likely to support legalising abortion, and that other effects: e.g. gender, age, the way the respondent votes and their self assessed social class have no effect.

Task 4. Repeat parts (2), (3) using `district` as the level-2 random effect, to do this you will need to use a version of the data set sorted by `district`, this has been done for you in `abortion3.dta`.

Result/Discussion

For the model without covariates we have

Log likelihood = -1741.0190 on 1050 residual degrees of freedom

Parameter	Estimate	Std. Err.
cut1	-2.6736	0.15065

cut2	-0.89016	0.11418
cut3	-0.33529	0.11119
cut4	0.17788	0.11086
cut5	0.79479	0.11360
scale	0.64059	0.98315E-01

For the model with covariates we have

Log likelihood = -1685.2618 on 1039 residual degrees of freedom

Parameter	Estimate	Std. Err.
male	0.21814	0.12569
age	-0.20262E-02	0.42416E-02
dr2	0.83663	0.26861
dr3	-0.70121E-01	0.29630
dr4	1.6493	0.26835
dp2	0.38519E-01	0.15562
dp3	0.33915E-01	0.16789
dp4	-0.18177	0.34109
dp5	0.19365	0.41731
dc2	-0.28431	0.17290
dc3	-0.31155	0.16514
cut1	-2.1957	0.37683
cut2	-0.29027	0.36705
cut3	0.31419	0.36646
cut4	0.87675	0.36628
cut5	1.5488	0.36737
scale	0.81142	0.11553

The results for the respondents clustered by district and over time are with 12 adaptive quadrature mass points. This gave a chi-square improvement of $-2(-1741.0190+1685.2618)= 111.51$ for $1050-1039= 11$ df, which is significant at the 0.05 level. But judged by the various covariate parameter estimates, the following main effects are not significant: **male**, **age**, **dr3** (other religion), the way the respondent votes (**dp2-5**), and the respondent's self assess social class (**dc2-3**). The **scale** parameter in the district model with covariates is still very significant and larger than the value obtained from the district model without covariates. This model is clustered by district and thus includes persons over time suggests that respondent's who are protestant (**dr2**) or agnostic (**dr4**) are more likely to support legalising abortion, but that gender, age and the way the respondent votes and their self assess social class have no effect.

Task 5. Does the significance of the explanatory variables change? Do the results make intuitive sense?

Result/Discussion

The covariate inferences for the person and district level models are very similar. The main difference is in the magnitude of the significant covariate effects, this occurs because of differences in the magnitude of the scale parameter. The magnitude of the scale parameter has an effect on the magnitude of the covariate effects in this class of ordered response models. The person level model has a `scale` of 2.4006 (S.E. 0.16334), while that of the district level model has a `scale` of 0.81142 (S.E. 0.11553).

Task 6. Interpret your preferred model. Can your preferred model be simplified?

Result/Discussion

While the district level effect includes the highly correlated responses of an individual over time, it also includes the low correlated responses of different individuals in the same district. Perhaps a 3 level model of time, respondents and districts with just the respondents religion as a covariate would be more appropriate.

Task 7. Are there any interaction effects you would like to try to add to this model? Why?

Result/Discussion

It may be worth trying the 3 way interaction of religion with age and gender and including the associated two way interaction effects. It could be that respondent's become more conservative as they grow older, and the magnitude of this change could be different for men and women.

10.2 Batch Script: L5.do

```
# save the log file
sink("L5.log")

# use the sabreR library
library(sabreR)

# read the data
abortion2 <- read.table("abortion2.tab")
attach(abortion2)

# look at the 1st 10 lines and columns
abortion2[1:10,1:10]

# estimate the 1st model
sabre.model.1 <- sabre(nscore~1,case=person,adaptive.quad=TRUE,
                      first.mass=24,ordered="TRUE")

# show the results
sabre.model.1

# estimate the 2nd model
sabre.model.2 <- sabre(nscore~male+age+dr2+dr3+dr4+dp2+dp3+dp4+dp5+
                      dc2+dc3-1,case=person,adaptive.quad=TRUE,
```

```

                                first.mass=24,ordered="TRUE")

# show the results
sabre.model.2

# read the data
abortion3 <- read.table("abortion3.tab")
attach(abortion3)

# look at the 1st 10 lines and columns
abortion3[1:10,1:10]

# estimate the 3rd model
sabre.model.3 <- sabre(nscore~1,case=district,adaptive.quad=TRUE,
                      ordered="TRUE")

# show the results
sabre.model.3

# estimate the 4th model
sabre.model.4 <- sabre(nscore~male+age+dr2+dr3+dr4+dp2+dp3+dp4+dp5+
                      dc2+dc3-1,case=district,adaptive.quad=TRUE,
                      ordered="TRUE")

# show the results
sabre.model.4

# remove the created objects
detach(abortion2,abortion3)
rm(abortion2,abortion3,sabre.model.1,sabre.model.2,sabre.model.3,
   sabre.model.4)

# close the log file
sink()

```

11 Exercise L6. Ordered Response Model of Respiratory Status

11.1 Relevant Results from L6.log and Discussion

Task 1. Estimate an ordered logit model for status without any covariates.

Result/Discussion

Log likelihood = -829.79872 on 551 residual degrees of freedom

Parameter	Estimate	Std. Err.
cut1	-2.4771	0.15877
cut2	-1.4790	0.10918
cut3	-0.14802	0.85128E-01
cut4	0.81744	0.92086E-01

Task 2. Estimate the ordered logit model for status, allowing for the patient random effect. Are the random patient effects significant? How many adaptive quadrature points should we use to estimate this model?

Result/Discussion

Log likelihood = -714.06206 on 550 residual degrees of freedom

Parameter	Estimate	Std. Err.
cut1	-4.1063	0.32842
cut2	-2.5515	0.27634
cut3	-0.25255	0.24631
cut4	1.4646	0.25333
scale	2.2652	0.21966

This is the result with 20 adaptive quadrature mass points. This model has a chi-square improvement of $-2(-829.79872+714.06206)= 231.47$ over the homogeneous model. The sampling distribution of this test statistic is not chi-square with 1 df. Under the null hypothesis **scale** has the value 0, and it can only take values >0 under the alternative. The correct p value for this test statistics is obtained by dividing the naive p value of 231.47 for 1 degree of freedom by 1/2, and so its clearly significant.

Task 3. Re-estimate the model allowing for **drug**, **male**, **age** and **base**. How does the magnitude of the patient random effect change? Are any of these explanatory variables significant in this model? Do the results make intuitive sense?

Result/Discussion

Log likelihood = -703.29855 on 546 residual degrees of freedom

Parameter	Estimate	Std. Err.
drug	-1.4348	0.43353
male	-0.30416	0.55166
age	-0.16700E-01	0.16112E-01
base	0.27552	0.81994E-01
cut1	-6.5127	1.1787
cut2	-4.9909	1.1554
cut3	-2.7151	1.1349
cut4	-0.98493	1.1264
scale	1.9823	0.20691

This gave a chi-square improvement of $-2(-714.06206+703.29855)= 21.527$ for $550-546= 4$ df, which is significant at the 0.05 level. But judged by the various covariate parameter estimates, the following main effects are not significant: **male**, **age**. The **scale** parameter in the model with covariates is still very significant and a little smaller. This model for respiratory status, which is clustered by respondent over visit, suggests that respondent's who are in the treatment group (**drug**) have a poorer response than those who were given the placebo, while those who had a high baseline response (**base**) are more likely to have a high respiratory response.

Task 4. Add the linear trend variable to the model, then add an interaction between **trend** and **drug**. Does the impact of treatment vary with visit?

Result/Discussion

Log likelihood = -703.02730 on 545 residual degrees of freedom

Parameter	Estimate	Std. Err.
drug	-1.4317	0.42726
male	-0.30837	0.54353
age	-0.16850E-01	0.15877E-01
base	0.32628	0.10685
trend	-0.57596E-01	0.78104E-01
cut1	-6.5221	1.1631
cut2	-5.0032	1.1396
cut3	-2.7355	1.1190
cut4	-1.0132	1.1107
scale	1.9470	0.21005

This model suggests that respiratory response varies with **drug** and **base**. The negative parameter estimate for **trend** is not significant.

Log likelihood = -697.88118 on 544 residual degrees of freedom

Parameter	Estimate	Std. Err.
drug	-0.70110	0.48780
male	-0.28725	0.55095
age	-0.16673E-01	0.16114E-01
base	0.32507	0.10712
trend	0.53462	0.20229
trend_drug	-0.38516	0.12083
cut1	-5.4385	1.2199
cut2	-3.8906	1.2006
cut3	-1.5984	1.1850
cut4	0.14683	1.1805
scale	1.9802	0.21261

This model suggests that respiratory response varies with **base**, **trend** has a significant positive effect (for those on the placebo), while there is linear decline of respiratory status with visit (**trend**) for those on the treatment (**drug**). The main effect of **drug** which is negative, is not significant in this model.

We also need to remember that this is a highly selective sample, in that individuals who do not have respiratory illness are excluded. If the random effects for respiratory illness are independent of the covariates for epilepsy in the population, then this type of selectivity on outcome will have induced a correlation between the random effects and the included covariates, This correlation has not been allowed for in the analysis and our model is misspecified, e.g. by producing bias in the covariate parameters. Including **base** as a covariate complicates things further, this arises from the inclusion of **base** as an explanatory covariate as **base** can be treated as an endogenous initial condition for the response process. Further discussion of this issue is covered elsewhere.

11.2 Batch Script: L6.R

```
# save the log file
sink("L6.log")

# use the sabreR library
library(sabreR)

# read the data
respiratory2 <- read.table("respiratory2.tab")
attach(respiratory2)

# look at the 1st 10 lines and columns
respiratory2[1:10,1:10]

# estimate the 1st model
sabre.model.1 <- sabre(status~1,case=patient,adaptive.quad=TRUE,
                      first.mass=20,ordered="TRUE")

# show the results
```

```

sabre.model.1

# estimate the 2nd model
sabre.model.2 <- sabre(status~drug+male+age+base-1,case=patient,
                      adaptive.quad=TRUE,first.mass=20,
                      ordered="TRUE")

# show the results
sabre.model.2

# estimate the 3rd model
sabre.model.3 <- sabre(status~drug+male+age+base+trend-1,
                      case=patient,adaptive.quad=TRUE,first.mass=20,
                      ordered="TRUE")

# show the results
sabre.model.3

# estimate the 4th model
sabre.model.4 <- sabre(status~male+age+base+trend*drug-1,
                      case=patient,adaptive.quad=TRUE,first.mass=20,
                      ordered="TRUE")

# show the results
sabre.model.4

# remove the created objects
detach(respiratory2)
rm(respiratory2,sabre.model.1,sabre.model.2,sabre.model.3,
   sabre.model.4)

# close the log file
sink()

```


12 Exercise L8. Poisson Model of Epileptic Seizures

12.1 Relevant Results from L8.log and Discussion

Task 1. Estimate a Poisson model for the response number of epileptic seizures (y) with a constant but without any random effects.

Result/Discussion

Log likelihood = -1643.8739 on 235 residual degrees of freedom

Parameter	Estimate	Std. Err.
cons	2.1118	0.22646E-01

Task 2. Re-estimate model (1) allowing for the patient effect (`subj`) random effects. Are the patient random effects significant? Use adaptive quadrature with mass 12.

Result/Discussion

Log likelihood = -701.05330 on 234 residual degrees of freedom

Parameter	Estimate	Std. Err.
cons	1.6213	0.12807
scale	0.94582	0.96382E-01

This model has a chi-square improvement of $-2(-1643.8739+701.05330)=1885.6$ over the homogeneous model. The sampling distribution of this test statistic is not chi-square with 1 df. Under the null hypothesis `scale` has the value 0, and it can only take values >0 under the alternative. The correct p value for this test statistics is obtained by dividing the naive p value of 1885.6 for 1 degree of freedom by 1/2, and so its clearly significant.

Task 3. Re-estimate model (2) allowing for `lbas`, `treat`, `lbas.trt`, `lage`, `visit`. How does the magnitude of the patient random effect change? Are any of these explanatory variables significant in this model? Do the results make intuitive sense?

Result/Discussion

Log likelihood = -665.58007 on 229 residual degrees of freedom

Parameter	Estimate	Std. Err.
cons	2.1145	0.21972

lbas	0.88443	0.13123
treat	-0.93304	0.40083
lbas_trt	0.33826	0.20334
lage	0.48424	0.34728
visit	-0.29362	0.10142
scale	0.50282	0.58625E-01

This gave a chi-square improvement over the previous model of $-2(-701.05330 + 665.58007) = 70.946$ for $234-229 = 5$ df, which is significant at the 0.05 level. But judged by the various covariate parameter estimates and their standard errors, the following main effects are not significant: `lbas_trt` and `lage`. The `scale` parameter in the model with covariates is still very significant, its nearly 1/2 the previous value but with a much smaller standard error.

Task 4. Re-estimate model (3) adding `v4`, in place of `visit`, which model would you prefer?

Result/Discussion

Log likelihood =	-665.29074	on	229 residual degrees of freedom
Parameter	Estimate	Std. Err.	

cons	2.1143	0.21972	
lbas	0.88443	0.13123	
treat	-0.93304	0.40083	
lbas_trt	0.33826	0.20334	
lage	0.48424	0.34728	
v4	-0.16109	0.54576E-01	
scale	0.50282	0.58625E-01	

There is very little difference between the likelihood of this model, and that of Task 3. In terms of fit there is not much to choose between them. Both models use 1 parameter estimate for the variation over time. The real difference is in the way the models parameterise the variation over time; `visit` is a linear trend, while `v4` is just a binary indicator for the 4th visit. The similarity in fit suggests that most of the nonstationarity in the response sequence occurs at the last visit. Is this an end effect (bias report) that occurs at the finish of a trial that patients are sad to leave? A data set with a longer seizure sequence is needed to establish what is happening,

Task 5. Interpret your results. Can your preferred model be simplified?

Result/Discussion

This model, which is clustered by patient (`subj`) over time, suggests that patient's with a high baseline (`lbas`) or `age` have a higher seizure rate. The coefficient on `visit` or `v4` is negative, as is the main effect on `treat`, i.e. these

effects reduce the seizure rate. The interaction between treatment and baseline (`lbas_trt`) is not significant. The model could be simplified by removing `lbas_trt` and `lage`.

Task 6. Are there any other interaction effects you would like to try in this model? Why?

Result/Discussion

We could add the interaction effect of `treat` with `visit` or (`v4`), to examine whether the impact of treatment wears off. We could also try an interaction of the baseline `lbas` with `treat`, to test whether the effectiveness of the treatment differs with the severity of the condition.

There is an interesting modeling issue in this exercise, this arises from the inclusion of `lbas` as an explanatory covariate as `lbas` can be treated as an endogenous initial condition for the response process. Further discussion of this issue is covered elsewhere.

We also need to remember that this is a highly selective sample, in that individuals who do not have epileptic seizures are excluded. If the random effects for epilepsy are independent of the covariates for epilepsy in the population, then this type of selectivity on outcome will have induced a correlation between the random effects and the included covariates. This correlation has not been allowed for in the analysis and our model is misspecified, e.g. by producing bias in the covariate parameters. Including `lbas` as a covariate complicates things further.

12.2 Batch Script: L8.R

```
# save the log file
sink("L8.log")

# use the sabreR library
library(sabreR)

# read the data
epilep <- read.table("epilep.tab")
attach(epilep)

# look at the 1st 10 lines and columns
epilep[1:10,1:9]

# estimate the 1st model
sabre.model.1 <- sabre(y~1,case=subj,adaptive.quad=TRUE,
                      first.family="poisson")

# show the results
sabre.model.1

# estimate the 2nd model
sabre.model.2 <- sabre(y~lbas+treat+lbas.trt+lage+visit,case=subj,
                      adaptive.quad=TRUE,first.family="poisson")

# show the results
sabre.model.2
```

```
# estimate the 3rd model
sabre.model.3 <- sabre(y~lbas+treat+lbas.trt+lage+v4,case=subj,
                    adaptive.quad=TRUE,first.family="poisson")

# show the results
sabre.model.3

# remove the created objects
detach(epilep)
rm(epilep,sabre.model.1,sabre.model.2,sabre.model.3)

# close the log file
sink()
```

13 Exercise L9. Bivariate Linear Model of Expiratory Flow Rates

13.1 Relevant Results from L9.log and Discussion

13.1.1 Standard Wright Meter: data set pefr.tab

Task 1. Estimate a linear model for the response `wp` with occasion 2 (`occ2`) as a binary indicator with an `id` random effect. Is `occ2` significant? Are the random person effects (`id`) significant? Use adaptive quadrature with mass 12 and set the starting value for `scale` to 110.

Result/Discussion

```
Log likelihood =      -180.57200      on      30 residual degrees of freedom

Parameter              Estimate          Std. Err.
-----
cons                   450.35           27.759
occ2                   -4.9412           5.1115
sigma                  14.903            2.5558
scale                  113.48            19.630
```

The 95% or 99% normal confidence intervals on `scale` with a S.E. 19.630 do not include 0. Similarly the z statistic for the null hypothesis that `scale` is 0, takes the value $113.48/19.630 = 5.7809$, which greatly exceeds the critical value for a direction predicted z test at the 95% or 99% levels.

13.1.2 Mini Wright Meter: data set pefr.tab

Task 2. Estimate a linear model for the response `wm` with occasion 2 (`occ2`) as a binary indicator with an `id` random effect. Is `occ2` significant? Are the random person effects (`id`) significant? Use adaptive quadrature with mass 12 and set the starting value for `scale` to 100.

Result/Discussion

```
Log likelihood =      -184.48885      on      30 residual degrees of freedom

Parameter              Estimate          Std. Err.
-----
cons                   452.47           26.406
occ2                   2.8824           6.7935
sigma                  19.806            3.3967
scale                  107.06            18.677
```

The 95% or 99% normal confidence intervals on `scale` with a S.E. 18.677 do not include 0. Similarly the z statistic for the null hypothesis that `scale` is 0, takes the value $107.06/18.677 = 5.7322$, which greatly exceeds the critical value for a direction predicted z test at the 95% or 99% levels.

13.1.3 Joint Model: data set pefr.tab

Task 3. Estimate a joint model for `wp` and `wm` with `occ2` as a binary indicator in both linear predictors, use adaptive quadrature with 12 mass points for both dimensions. As this is a very small data set the likelihood is not well defined. Use the following starting values: 0.9 for `rho`, 20 for both values of `sigma`, 110 for the first `scale` and 110 for the second. What is the significance of the correlation between the random effects of each type of meter? How does the significance of the `occ2` effect change, relative to that obtained in Task 1 and 2?

Result/Discussion

Log likelihood = -343.56561 on 59 residual degrees of freedom

Parameter	Estimate	Std. Err.
r1	450.35	27.759
r1_occ2	-4.9412	5.1115
r2	452.47	26.406
r2_occ2	2.8824	6.7935
sigma1	14.903	2.5558
sigma2	19.806	3.3967
scale1	113.48	19.630
scale2	107.06	18.676
corr	0.97163	0.17255E-01

The 95% or 99% normal confidence intervals on `corr` with a S.E. 0.17255E-01 include 1 but do not include 0. The z statistic for the null hypothesis that `corr` is 0, takes the value $0.97163/0.017255 = 56.31$, which is clearly significant. The value of the estimates and standard errors for `r1_occ2` and `r2_occ2` from the joint analysis are the same as those obtained in Tasks 1 and 2

Task 4. On the basis of these results, would you be prepared to replace the Standard Wright flow meter with the new Mini Wright Meter?

Result/Discussion

The very high correlation suggests that the two flow meters are equally good at measuring peak expiratory flow rate. Some other criterion, such as relative cost of flow meters would have to be used to make a decision between them. However, this is a very small sample, and the analysis should really be repeated in different contexts with larger samples before a decision made.

13.2 Batch Script: L9.R

```
# save the log file
sink("L9.log")
```

```

library(sabreR)

pefr <- read.table("pefr.tab")
attach(pefr)

pefr[1:10,1:5]

sabre.model.1 <- sabre(wp~occ2,case=id,first.family="gaussian",
                    adaptive.quad=TRUE,first.scale=110)

sabre.model.1

sabre.model.2 <- sabre(wm~occ2,case=id,first.family="gaussian",
                    adaptive.quad=TRUE,first.scale=100)

sabre.model.2

sabre.model.3 <- sabre(wp~occ2,wm~occ2,case=id,
                    first.family="gaussian",
                    second.family="gaussian",adaptive.quad=TRUE,
                    first.sigma=20,second.sigma=20,
                    first.scale=110,second.scale=100,
                    first.rho=0.9,convergence=5e-5)

sabre.model.3

detach(pefr)
rm(pefr,sabre.model.1,sabre.model.2,sabre.model.3)

sink()

```

14 Exercise L10. Bivariate Model, Linear (Wages) and Binary (Trade Union Membership)

14.1 Relevant Results from L10.log and Discussion

14.1.1 Univariate models

14.1.2 Wage equation: data wagepan.tab

Task 1. Estimate a linear model for `lwage` (log of hourly wage) with the covariates (`educ`, `black`, `hisp`, `exper`, `expersq`, `married`, `union`), with the data clustered over time for `nr` (respondent identifier). Is this random effect significant? Use adaptive quadrature, mass 12.

Result/Discussion

Log likelihood = -2193.2846 on 4350 residual degrees of freedom

Parameter	Estimate	Std. Err.
cons	-0.10783	0.11195
educ	0.10124	0.90191E-02
black	-0.14414	0.48198E-01
hisp	0.20187E-01	0.43128E-01
exper	0.11225	0.82472E-02
expersq	-0.40754E-02	0.59074E-03
married	0.62362E-01	0.16792E-01
union	0.10674	0.17872E-01
sigma	0.35120	0.40230E-02
scale	0.33018	0.11478E-01

The 95% or 99% normal confidence intervals on `scale` with a S.E. 0.11478E-01 do not include 0. Similarly the z statistic for the null hypothesis that `scale` is 0, takes the value 0.33018/0.011478= 28.766 which greatly exceeds the critical value for a direction predicted z test at the 95% or 99% levels.

14.1.3 Trade union membership: data wagepan.tab

Task 2. Estimate a logit model for trade union membership (`union`), with the covariates (`black`, `hisp`, `exper`, `educ`, `poorhlth`, `married`, `rur`, `nrthcen`, `nrtheast`, `south`). Use adaptive quadrature, mass 64. Use `case nr`, (respondent identifier). Is this random effect significant?

Result/Discussion

Log likelihood = -1654.9281 on 4348 residual degrees of freedom

Parameter	Estimate	Std. Err.

cons	-2.4347	1.2006
black	1.8871	0.47315
hisp	1.1052	0.44739
exper	-0.40595E-01	0.24199E-01
educ	-0.60500E-01	0.93060E-01
poorhlth	-0.75608	0.50335
married	0.34500	0.15984
rur	0.20794	0.24023
nrthcen	0.69825	0.38780
nrtheast	0.87514	0.42444
south	0.31154E-01	0.38514
scale	3.0130	0.17885

The 95% or 99% normal confidence intervals on `scale` with a S.E. 0.17885 do not include 0. Similarly the z statistic for the null hypothesis that `scale` is 0, takes the value $3.0130/0.17885 = 16.847$ which greatly exceeds the critical value for a direction predicted z test at the 95% or 99% levels.

14.1.4 Joint model: data wagepan.tab

Task 3. Using the model specifications for $\log(\text{wages})$ and trade union membership you have just used, estimate a joint model of the determinants of $\log(\text{wages})$ and trade union membership. Use adaptive quadrature, mass 12 for the linear model and mass 64 for the binary response model.

Result/Discussion

Log likelihood = -3844.4397 on 8697 residual degrees of freedom

Parameter	Estimate	Std. Err.
r1	-0.10219	0.11223
r1_educ	0.10126	0.90413E-02
r1_black	-0.14102	0.48334E-01
r1_hisp	0.21318E-01	0.43241E-01
r1_exper	0.11179	0.82461E-02
r1_expersq	-0.40491E-02	0.59057E-03
r1_married	0.62457E-01	0.16778E-01
r1_union	0.86886E-01	0.19234E-01
r2	-2.5927	1.1917
r2_black	1.8804	0.47009
r2_hisp	1.1430	0.44495
r2_exper	-0.38736E-01	0.24185E-01
r2_educ	-0.50835E-01	0.92232E-01
r2_poorhlth	-0.74877	0.50277
r2_married	0.32735	0.15948
r2_rur	0.27268	0.24120
r2_nrthcen	0.75647	0.38587
r2_nrtheast	0.83701	0.42036

r2_south	0.11396	0.38250
sigma1	0.35112	0.40208E-02
scale1	0.33116	0.11517E-01
scale2	2.9962	0.17732
corr	0.16309	0.58340E-01

Task 4. What is the magnitude and significance of the correlation between the random effects for log(wages) and union membership? How does the magnitude and significance of the direct effect of union in the wage equation change? What are the reasons for this? Have any other features of the models changed? What does this imply?

Result/Discussion

The 95% or 99% normal confidence intervals on `corr` with a S.E. 0.58340E-01 do not include 0. The z statistic for the null hypothesis that `corr` is 0, takes the value $0.16309/0.058340 = 2.795$, which is significant at the 95% level. The estimated value of `corr` is 0.16309, implying a positive correlation between the random effects for log wages and trade union membership.

The parameter estimate on `union` in the log wage equation of Task 1 was 0.10674 (S.E. 0.17872E-01). In the joint model of Task 3 this becomes 0.86886E-01 (S.E. 0.19234E-01), i.e. smaller. Some of the magnitude of the estimated `union` parameter in the independent model of Task 1 has been taken up by the positive correlation of the random effects of the two response sequences in the joint model of Task 3. A larger `corr` would have had more impact. Had `corr` been negative, the estimate of the `union` effect in the wage equation of the joint model would have been bigger. There have been other minor changes, but nothing that is worthy of note.

14.2 Batch Script: L10.R

```
# save the log file
sink("L10.log")

library(sabreR)

wagepan <- read.table("wagepan.tab")
attr(wagepan,"names")[35] <- "tunion"
attach(wagepan)

wagepan[1:10,1:10]

sabre.model.1 <- sabre(lwage~educ+black+hispanic+exper+expersq+married+
  tunion,case=nr,first.family="gaussian",
  adaptive.quad=TRUE)

sabre.model.1

sabre.model.2 <- sabre(tunion~black+hispanic+educ+poorhlth+married+
  rur+nrthcen+nrtheast+south,case=nr,
  adaptive.quad=TRUE,first.mass=64)

sabre.model.2
```

```
sabre.model.3 <- sabre(lwage~educ+black+his+exper+expersq+married+
  tunion,tunion~black+his+exper+educ+poorhlth+
  married+rur+nrthcen+nrtheast+south,case=nr,
  first.family="gaussian",adaptive.quad=TRUE,
  second.mass=64)
```

```
sabre.model.3
```

```
detach(wagepan)
```

```
rm(wagepan,sabre.model.1,sabre.model.2,sabre.model.3)
```

```
sink()
```

15 Exercise L11. Renewal Model of Angina Pectoris (Chest Pain)

15.1 Relevant Results from L11.log and Discussion

Task 1. We are going to estimate various Weibull survival models on the renewal data by using (`logt`) as a covariate with the `cloglog` link. The 1st model is the homogeneous common baseline hazard model, i.e. with the same constant for each exercise time, the same parameter for `logt`, but with different coefficients on `dose` for the two treatment times, use interactions with the `t2` and `t3` dummy variables to set this model up. There is no point putting `dose` in the linear predictor for the model of pre-treatment data.

Result/Discussion

```
Log likelihood =      -347.61120      on  20981 residual degrees of freedom

Parameter           Estimate           Std. Err.
-----
cons                -10.365             1.1652
logt                 0.94104            0.21372
t2_dose             -3.1632            0.98709
t3_dose             -1.9604            0.88064
```

Task 2. The 2nd model allows for a different baseline hazard for each exercise session. Interact the `t2` and `t3` dummy variables with `logt`, add both the interaction effects and the `t2` and `t3` dummies to the model. Can the model be simplified? What does this result tell you?

Result/Discussion

```
Log likelihood =      -345.08870      on  20977 residual degrees of freedom

Parameter           Estimate           Std. Err.
-----
cons                -12.770            2.1821
t1_logt             1.4132            0.39951
t2                  3.1187            3.1588
t2_logt             0.61208           0.36732
t2_dose            -0.11826           2.2308
t3                  1.9366            3.1959
t3_logt             0.97444           0.39177
t3_dose            -1.2289           2.0951
```

This gave a chi-square improvement over the previous model of $-2(-347.61120 + 345.08870) = 5.045$ for 4 df, which is not significant at the 0.05 level. But

judged by the various covariate parameter estimates and their standard errors, the following effects are not significant: `t2`, `t2_logt`, `t2_dose` `t3`, `t3_dose`. The only effects that are significant are `t1_logt`, `t3_logt`.

Task 3. Add a subject specific random effect (`id`) to the renewal model. Use adaptive quadrature with mass 24. How do the effects of `logt` and `dose` change, relative to the models estimated in questions 1 and 2?

Result/Discussion

Log likelihood =	-319.69936	on	20976 residual degrees of freedom
Parameter	Estimate	Std. Err.	

<code>cons</code>	-37.671	6.3256	
<code>t1_logt</code>	6.1198	1.1582	
<code>t2</code>	16.820	5.6102	
<code>t2_logt</code>	3.0605	0.71798	
<code>t2_dose</code>	-6.7730	4.3705	
<code>t3</code>	10.646	4.9201	
<code>t3_logt</code>	4.3845	0.89413	
<code>t3_dose</code>	-7.5816	3.8103	
<code>scale</code>	2.8539	0.63481	

Task 4. What is your preferred model and why?

Result/Discussion

The model of Task 3 is to be preferred over that of Task 2. The Task 3 model has a chi-square improvement of $-2(-347.61120+319.69936)= 55.824$ over the homogeneous model. The sampling distribution of this test statistic is not chi-square with 1 df. Under the null hypothesis `scale` has the value 0, and it can only take values >0 under the alternative. The correct p value for this test statistics is obtained by dividing the naive p value of 55.824 for 1 degree of freedom by 1/2, and so its clearly significant.

Relative to the model of Task 2, the pattern of significance in the covariate effects has changed, now the only effect that is not significant at the 95% level is `t2_dose`. The model of Task 3 also suggests that the higher the `dose`, the lower the probability of angina pectoris in an interval, even though its not significant at time 2. Perhaps `dose` takes more than 1 hour to be fully effective. The parameter estimates on `logt` suggest an increasing failure rate, i.e. the more intervals that have passed without angina pectoris, the more likely it is to happen.

A complication in interpreting all the results is the slight negative correlation between the initial response and `dose`, i.e. those subjects with shorter initial times to angina pectoris have been given larger doses.

15.2 Batch Script: L11.R

```
# save the log file
sink("L11.log")

# use the sabreR library
library(sabreR)

# read the data
angina <- read.table("angina.tab")
attach(angina)

# look at the 1st 10 lines and columns
angina[1:10,1:10]

# estimate the 1st model
sabre.model.1 <- sabre(y~log(t)+(t2+t3):dose,case=id,
                      first.link="cloglog",adaptive.quad=TRUE,
                      first.mass=24)

# show the results
sabre.model.1

# estimate the 2nd model
sabre.model.2 <- sabre(y~(t1+t2+t3):log(t)+t2+(t2+t3):dose+t3,
                      case=id,first.link="cloglog",
                      adaptive.quad=TRUE,first.mass=24)

# show the results
sabre.model.2

# remove the created objects
detach(angina)
rm(angina,sabre.model.1,sabre.model.2)

# close the log file
sink()
```

16 Exercise L12. Bivariate Competing Risk Model of German Unemployment Data

16.1 Relevant Results from L12.log and Discussion

Task 1. Estimate a Weibull (`logt`), non random effects model, for the `r1=1` (full time job) and `r2=1` (part time job) exits from unemployment, use the covariates: `nationality`, `gender`, `age`, `age2`, `age3`, `training`, `university`.

Result/Discussion

Log likelihood = -863.34908 on 6054 residual degrees of freedom

Parameter	Estimate	Std. Err.
r1	-0.65484	0.45936
r1_logt	-0.40989	0.83365E-01
r1_nation	0.10020	0.18813
r1_gender	-0.95154	0.17211
r1_age2	0.29558	0.18359
r1_age3	-1.1159	0.28392
r1_training	-0.57196	0.17156
r1_uni	0.39942	0.25236
r2	-4.6425	0.87518
r2_logt	0.71448E-01	0.16142
r2_nation	-1.3664	0.53701
r2_gender	0.27443	0.29517
r2_age2	-0.41115	0.43252
r2_age3	-2.8920	1.0148
r2_training	-0.90111E-01	0.33052
r2_uni	1.7091	0.37030

There are quite a few significant effects in this model, for full time job there is: `r1_logt`, `r1_gender`, `r1_age3`, `r1_training`, and for part time job there is: `r2_nation`, `r2_age3`, `r2_uni`.

Task 2. Re-estimate the model from question 1 but allow each exit type to have an independent random effect for each failure type, use 32 point adaptive quadrature. Hint, use a bivariate model, but set `rho=0`. What do the results tell you?

Result/Discussion

Log likelihood = -858.28512 on 6052 residual degrees of freedom

Parameter	Estimate	Std. Err.
r1	-0.77929	0.54531

r1_logt	-0.25932	0.13074
r1_nation	0.16157E-01	0.23254
r1_gender	-1.0365	0.20469
r1_age2	0.35790	0.21942
r1_age3	-1.2412	0.32407
r1_training	-0.63586	0.20499
r1_uni	0.54050	0.30442
r2	-6.4812	1.7150
r2_logt	0.47311	0.30686
r2_nation	-2.0969	0.85421
r2_gender	0.42721	0.42568
r2_age2	-0.49077	0.56016
r2_age3	-3.7307	1.3156
r2_training	0.16193	0.45701
r2_uni	2.2742	0.67070
scale1	0.68982	0.26742
scale2	1.6341	0.57926

The model of Task 2 is to be preferred over that of Task 1. The Task 2 model has a chi-square improvement of $-2(-863.34908+858.28512)= 10.128$ over the homogeneous model. The sampling distribution of this test statistic is not chi-square with 2 df. Under the null hypothesis the two **scales** have the value 0, and they can only take values >0 under the alternative. The correct p value for this test statistics is obtained by dividing the naive p value of 10.128 for 2 degrees of freedom by $1/2$, and so the **scale** effects are clearly significant.

Relative to the model of Task 1, the pattern of significance for the duration effects (**logt**) effects has changed. For transitions to full time job, **r1_logt** now has border line significance, **r2_logt** remains non significant. The covariates that were significant for Task 1 are still significant, i.e.: **r1_gender**, **r1_age3**, **r1_training**, and **r2_nation**, **r2_age3**, **r2_uni**.

Task 3. Re-estimate the model from question 2 but allow for the correlation between the random effects of each failure type. How do the results change?

Result/Discussion

Log likelihood = -854.82180 on 6051 residual degrees of freedom

Parameter	Estimate	Std. Err.
r1	-0.85561	0.55468
r1_logt	-0.26861	0.12096
r1_nation	0.53793E-01	0.23762
r1_gender	-1.0380	0.20881
r1_age2	0.37800	0.22498
r1_age3	-1.2128	0.32617
r1_training	-0.65213	0.21040
r1_uni	0.54125	0.30705
r2	-6.9983	1.8612

r2_logt	0.34010	0.28645
r2_nation	-2.2709	0.92092
r2_gender	0.58557	0.45707
r2_age2	-0.48868	0.57597
r2_age3	-3.6769	1.3490
r2_training	0.30118	0.48255
r2_uni	2.3040	0.71016
scale1	0.78025	0.24496
scale2	1.8157	0.59038
corr	-1.0000	0.0000

Task 4. What is your preferred model and why?

Result/Discussion

We cant put 95% or 99% normal confidences intervals on `corr` as its S.E. is too small to be printed. However, the Task 3 model has a chi-square improvement of $-2(-858.28512+854.82180)= 6.9266$ for 1 df over the independent model of Task 2, which is significant.

In the correlated model the pattern of significance has changed slightly. For transitions to full time job, `r1_logt` has become significant, `r2_logt` remains non significant. The covariates that were significant for Task 2 are still significant, i.e.: `r1_gender`, `r1_age3`, `r1_training`, and `r2_nation`, `r2_age3`, `r2_uni`. In both transitions age3 has a large negative values, suggesting that the older unemployed are less likely to find employment of any kind. The large negative correlation in the random effects is a manifestation of single spell competing risk data, i.e. if a transition from unemployment to full time job occurs, then the transition to part time job cannot occur.

This analysis also ignores a selection problem that occurs with an analysis that is restricted to specific flows, i.e. does not simultaneously consider all the transitions, e.g. from the origin, part time work. If the random effects and observed covariates for labour behaviour are independent in the population, then the random effects and observed covariates for any specific flow or subset of flows will be correlated, see Chesher A. & Lancaster T., (1981), Stock and Flow Sampling, Economics Letters, Vol. 8, 63-65, for further details. As this correlation is not taken into account by the model, the parameter estimates will be biased. A complement of this problem occurs if the random effects and observed covariates are correlated in the population, then they could be either less or even more correlated in specific flows. Consequently, its probably best to compare inferences from both the joint and separate analysis of all the flows with the proposed state space.

16.2 Batch Script: L12.R

```
# save the log file
sink("L12.log")

library(sabreR)

unemployed <- read.table("unemployed.tab")
```

```
attach(unemployed)

unemployed[1:10,1:10]

sabre.model.1 <- sabre(full_time~log(t)+nationality+gender+age2+age3+
  training+university,part_time~log(t)+
  nationality+gender+age2+age3+training+
  university,case=id,first.link="cloglog",
  second.link="cloglog",adaptive.quad=TRUE,
  first.mass=32,second.mass=32,correlated="no")

sabre.model.1

sabre.model.2 <- sabre(full_time~log(t)+nationality+gender+age2+age3+
  training+university,part_time~log(t)+
  nationality+gender+age2+age3+training+
  university,case=id,first.link="cloglog",
  second.link="cloglog",adaptive.quad=TRUE,
  first.mass=32,second.mass=32)

sabre.model.2

detach(unemployed)
rm(unemployed,sabre.model.1,sabre.model.2)

sink()
```

17 Exercise 3LC1. Linear Model: Pupil Rating of School Managers (856 Pupils in 94 Schools)

17.1 Relevant Results from 3LC1.log and Discussion

Task 1. Estimate a linear model (without random effects) for the scores with the pupil- and school- level covariates `dirsex`, `sctype` and `pupsex`.

Result/Discussion

```

Log likelihood =      -7758.0889      on      4975 residual degrees of freedom

Parameter              Estimate              Std. Err.
-----
cons                    2.1708                0.70508E-01
dirsex                  0.91255E-01           0.32600E-01
fsctype ( 1)           0.0000                ALIASED [I]
fsctype ( 2)           0.37444               0.38193E-01
fsctype ( 3)           0.15259               0.43772E-01
pupsex                  -0.21601E-01          0.33829E-01
sigma                   1.1492

```

The covariate `fsctype` is the factor variable for `sctype`, `fsctype(1)` is ALIASED because the model contains a constant.

Task 2. Allow for the pupil identifier random effect (`id`), use adaptive quadrature with `mass=12`, in a 2-level model. Is this random effect significant?

Result/Discussion

```

Log likelihood =      -7272.8266      on      4974 residual degrees of freedom

Parameter              Estimate              Std. Err.
-----
cons                    2.1638                0.11778
dirsex                  0.10048               0.54458E-01
fsctype ( 1)           0.0000                ALIASED [I]
fsctype ( 2)           0.39401               0.63790E-01
fsctype ( 3)           0.19282               0.72611E-01
pupsex                  -0.21618E-01          0.56559E-01
sigma                   0.91863               0.10132E-01
scale                   0.69752               0.22281E-01

```

The log likelihood of the homogeneous model of Task 1 is -7758.0889, and log likelihood of the random effects model of Task 2 is -7272.8266. The change in log likelihood over the homogeneous model is $-2(-7758.0889+7272.8266)= 970$.

52. The sampling distribution of this test statistic is not chi-square with 1 df. Under the null hypothesis `scale` has the value 0, and it can only take values >0 under the alternative. The correct p value for this test statistics is obtained by dividing the naive p value of 970.52 for 1 degree of freedom by 1/2, and so its clearly significant, suggesting that the `scores` from pupils to 6 different questions are highly correlated.

Task 3. Allow for both the pupil identifier random effect (`id`) and for the school random effect (`school`) in a 3-level model, use adaptive quadrature with mass 24 for both levels. Are both these random effects significant? Is this model a significant improvement over the model estimated in part 2 of this exercise?

Result/Discussion

Log likelihood = -7223.1596 on 4973 residual degrees of freedom

Parameter	Estimate	Std. Err.
cons	2.2429	0.16818
dirsex	0.10251	0.92085E-01
fschtype (1)	0.0000	ALIASED [I]
fschtype (2)	0.39067	0.10834
fschtype (3)	0.19933	0.12026
pupsex	-0.77852E-01	0.53255E-01
sigma	0.91881	0.10137E-01
scale2	0.58396	0.21798E-01
scale3	0.38029	0.38309E-01

The log likelihood of the homogeneous model of Task 1 is -7758.0889, and the log likelihood of the 3-level random effects model of Task 3 is -7223.1596. The change in log likelihood over the homogeneous model is $-2(-7758.0889 + 7223.1596) = 1069.9$. The sampling distribution of this test statistic is not chi-square with 2 df. The null hypothesis is that `scale2` and `scale3` have the value 0, they can only take values >0 under the alternative. The correct p value for this test statistics is obtained by dividing the naive p value of 1069.9 for 2 degrees of freedom by 1/2, and so its clearly significant, suggesting that the `scores` from pupils to 6 different questions with the same school are highly correlated. The highest correlation occurs between `scores` of the same pupil than between `scores` of different pupils in the same school, as `scale2` is greater than `scale3`.

The log likelihood of the 2-level model of Task 2 is -7272.8266, and log likelihood of the 3-level model of Task 3 is -7223.1596. The change in log likelihood over the Task 2 model is $-2(-7272.8266+7223.1596) = 99.334$. The sampling distribution of this test statistic is not chi-square with 1 df. Under the null hypothesis that `scale3` have the value 0, and it can only take values >0 under the alternative. The correct p value for this test statistics is obtained by dividing the naive p value of 99.334 for 1 degrees of freedom by 1/2, and so its clearly significant.

Task 4. Which covariates have a significant effect on the scores? How did your results change when you allowed for pupil-level (level 2) and then school-level (level 3) effects

Result/Discussion?

The significant covariates in the Task 1 and 2 models are: `fschtype(2)`, `fschtype(3)`, but only `fschtype(2)` remains significant in the Task 3 model. The main change as we move from the Task 1 to the Task 2 model, is that the standard errors of the covariates become noticeably larger. The standard errors tended to become larger again as we moved from the Task2 to the Task 3 results.

17.2 Batch Script: 3LC1.R

```
# save the log file
sink("3LC1.log")

# load the sabreR library
library(sabreR)

# read the data
manager_id <- read.table("manager_id.tab")
attach(manager_id)

# look at the 1st 10 lines and columns of the data
manager_id[1:10,1:10]

# create the 1st model
sabre.model.1 <- sabre(scores~dirsex+factor(schtype)+pupsex,case=id,
                      first.family="gaussian",adaptive.quad=TRUE)

# show the results
sabre.model.1

# read the data
manager <- read.table("manager.tab")
attach(manager)

# look at the 1st 10 lines and columns of the data
manager[1:10,1:10]

# create the 2nd model
sabre.model.2 <- sabre(scores~dirsex+factor(schtype)+pupsex,
                      case=list(id,school),first.family="gaussian",
                      adaptive.quad=TRUE,first.mass=24,
                      second.mass=24)

# show the results
sabre.model.2

# remove the objects
detach(manager_id,manager)
rm(manager_id,manager,sabre.model.1,sabre.model.2)

# close the log file
sink()
```

18 Exercise 3LC2. Binary Response Model for the Tower of London tests (226 Individuals in 118 Families)

18.1 Relevant Results from 31C2.log and Discussion

Task 1. Estimate a logit model (without random effects) for the binary response `dt1m` with the covariate `level`, and dummy variables for `group=2` and `group=3`.

Result/Discussion

```
Log likelihood =      -313.89079      on      673 residual degrees of freedom

Parameter              Estimate          Std. Err.
-----
cons                   -1.1605          0.18245
level                  -1.3134          0.14095
fgroup      ( 1)       0.0000          ALIASED [I]
fgroup      ( 2)      -0.13966          0.22825
fgroup      ( 3)      -0.83133          0.27423
```

The covariate `fgroup` is the factor variable for `group`, `fgroup(1)` is ALIASED because the model contains a constant.

Task 2. Allow for the level-2 subject random effect (`id`), use adaptive quadrature with `mass 12`. Is this random effect significant?

Result/Discussion

```
Log likelihood =     -305.95929      on      672 residual degrees of freedom

Parameter              Estimate          Std. Err.
-----
cons                   -1.4827          0.28356
level                  -1.6488          0.19335
fgroup      ( 1)       0.0000          ALIASED [I]
fgroup      ( 2)      -0.16907          0.33425
fgroup      ( 3)      -1.0227          0.39385
scale                   1.2943          0.25571
```

The log likelihood of the homogeneous model of Task 1 is -313.89079, and log likelihood of the random effects model of Task 2 is -305.95929. The change in log likelihood over the homogeneous model is $-2(-313.89079 + 305.95929) = 15.863$. The sampling distribution of this test statistic is not chi-square with 1 df. Under the null hypothesis `scale` has the value 0, it can only take values >0 under the alternative. The correct p value for this test statistics is obtained by dividing the naive p value of 15.863 for 1 degree of freedom by 1/2, and so its

clearly significant, suggesting that the `dt1m` values from subjects at 3 different occasions are highly correlated.

Task 3. Allow for both the level-2 subject random effect (`id`), and for the level-3 family random effects (`famnum`), use adaptive quadrature with `mass 12`. Are both these random effects significant? Is this model a significant improvement over the model estimated in part 2 of this exercise?

Result/Discussion

```

Log likelihood =      -305.12036      on      671 residual degrees of freedom

Parameter              Estimate      Std. Err.
-----
cons                   -1.4859      0.28486
level                  -1.6485      0.19322
fgroup      ( 1)       0.0000      ALIASED [I]
fgroup      ( 2)      -0.24867      0.35440
fgroup      ( 3)      -1.0523      0.39999
scale2                  1.0668      0.32154
scale3                  0.75445      0.34591

```

The log likelihood of the homogeneous model of Task 1 is -313.89079, and the log likelihood of the 3-level random effects model of Task 3 is -305.12036. The change in log likelihood over the homogeneous model is $-2(-313.89079 + 305.12036) = 17.541$. The sampling distribution of this test statistic is not chi-square with 2 df. The null hypothesis is that `scale2` and `scale3` have the value 0, they can only take values >0 under the alternative. The correct p value for this test statistics is obtained by dividing the naive p value of 17.541 for 2 degrees of freedom by 1/2, and so its clearly significant, suggesting that the `dt1m` values from subjects at 3 different occasions with the same family are correlated.

The log likelihood of the 2-level model of Task 2 is -305.95929, and log likelihood of the 3-level model of Task 3 is -305.12036. The change in log likelihood over the Task 2 model is $-2(-305.95929 + 305.12036) = 1.6779$. The sampling distribution of this test statistic is not chi-square with 1 df. Under the null hypothesis that `scale3` has the value 0, it can only take values >0 under the alternative. The correct p value for this test statistics is obtained by dividing the naive p value of 1.6779 for 1 degrees of freedom by 1/2, and so its not a significant improvement over the model of Task 2

Task 4. How did your results on `group=2` and `group=3` change when you allowed for `subject` (level 2) and then `family` (level 3) effects?

Result/Discussion

The significant covariates in the Task 1, 2 and 3 models are: `level1`, and `fgroup(3)`. The main change as we move from the Task 1 to the Task 2 model, is that the estimates and standard errors become larger, this is one of the features

of a binary response model with significant random effects. Even though a 95% confidence interval on scale3 does not include the value 0, we would take the likelihood ratio test for the model of Task2 against the model of Task 3 as a more reliable indicator of significance.

18.2 Batch Script: 3LC2.R

```
# save the log file
sink("3LC2.log")

# load the sabreR library
library(sabreR)

# read the data
towerl_id <- read.table("towerl_id.tab")
attach(towerl_id)

# look at the 1st 10 lines and colums of the data
towerl_id[1:10,1:10]

# create the 1st model
sabre.model.1 <- sabre(dt1m~level+factor(group),case=id,
                      adaptive.quad=TRUE)

# show the results
sabre.model.1

# read the data
towerl <- read.table("towerl.tab")
attach(towerl)

# look at the 1st 10 lines and colums of the data
towerl[1:10,1:10]

# create the 2nd model
sabre.model.2 <- sabre(dt1m~level+factor(group),case=list(id,famnum),
                      adaptive.quad=TRUE)

# show the results
sabre.model.2

# remove the objects
detach(towerl_id,towerl)
rm(towerl_id,towerl,sabre.model.1,sabre.model.2)

# close the log file
sink()
```


19 Exercise 3LC3. Binary Response Model of the Guatemalan Immunisation of Children (1595 Mothers in 161 Communities)

19.1 Relevant Results from 3LC3.log and Discussion

Task 1. Estimate a logit model (without random effects) with a constant for the binary response `immun` with the covariates `kid2p`, `mom25p`, `order23`, `order46`, `order7p`, `indnospa`, `indspa`, `momedpri`, `momedsec`, `husedpri`, `husedsec`, `huseddk`, `momwork`, `rural` and `pcind81`.

Result/Discussion

Log likelihood = -1399.5897 on 2143 residual degrees of freedom

Parameter	Estimate	Std. Err.
-----	-----	-----
cons	-0.72573	0.21946
kid2p	0.95096	0.11437
mom25p	-0.78252E-01	0.12141
order23	-0.83857E-01	0.13429
order46	0.92846E-01	0.15967
order7p	0.15486	0.19721
indnospa	0.27805	0.19899
indspa	0.21984	0.16372
momedpri	0.24986	0.10575
momedsec	0.29884	0.23791
husedpri	0.28872	0.10994
husedsec	0.21011	0.19872
huseddk	0.32750E-01	0.17710
momwork	0.24757	0.95179E-01
rural	-0.49695	0.11418
pcind81	-0.77611	0.20570

Task 2. Allow for the family random effect (`mom`), use adaptive quadrature with `mass 24`. Is this random effect significant?

Result/Discussion

Log likelihood = -1339.3508 on 2142 residual degrees of freedom

Parameter	Estimate	Std. Err.
-----	-----	-----
cons	-1.2768	0.43706
kid2p	1.7261	0.21823
mom25p	-0.21704	0.23276
order23	-0.26755	0.23411

order46	0.10310	0.29648
order7p	0.35413	0.37359
indnospa	0.48022	0.40812
indspa	0.31757	0.33314
momedpri	0.53171	0.22215
momedsec	0.57291	0.48630
husedpri	0.52739	0.22910
husedsec	0.40611	0.41083
huseddk	-0.68018E-02	0.36130
momwork	0.47754	0.19918
rural	-0.91104	0.24219
pcind81	-1.3932	0.42842
scale	2.5036	0.27063

The log likelihood of the homogeneous model of Task 1 is -1399.5897, and log likelihood of the random effects model of Task 2 is -1339.3508. The change in log likelihood over the homogeneous model is $-2(-1399.5897 + 1339.3508) = 120.48$. The sampling distribution of this test statistic is not chi-square with 1 df. Under the null hypothesis `scale` has the value 0, it can only take values >0 under the alternative. The correct p value for this test statistics is obtained by dividing the naive p value of 120.48 for 1 degree of freedom by 1/2, and so its clearly significant, suggesting that the `immun` values from kids from the same family (`mom`) are highly correlated.

Task 3. Allow for both the level 2 family random effect (`mom`) and for the level 3 community random effects (`cluster`), use adaptive quadrature with `mass 32` for both levels. Are both these random effects significant? Is this model a significant improvement over the model estimated in part 2 of this exercise?

Result/Discussion

Log likelihood = -1323.9524 on 2141 residual degrees of freedom

Parameter	Estimate	Std. Err.
cons	-1.2362	0.48246
kid2p	1.7174	0.21750
mom25p	-0.21457	0.23155
order23	-0.26133	0.23197
order46	0.17784	0.29446
order7p	0.43080	0.37227
indnospa	-0.17518	0.48971
indspa	-0.83921E-01	0.36352
momedpri	0.43242	0.22239
momedsec	0.41924	0.48397
husedpri	0.54095	0.23248
husedsec	0.50729	0.41425
huseddk	-0.60728E-02	0.35689
momwork	0.39027	0.20279

rural	-0.88619	0.30507
pcind81	-1.1512	0.50069
scale2	2.3172	0.26215
scale3	1.0249	0.15995

The log likelihood of the homogeneous model of Task 1 is -1399.5897, and the log likelihood of the 3-level random effects model of Task 3 is -1323.9524. The change in log likelihood over the homogeneous model is $-2(-1399.5897 + 1323.9524) = 151.27$. The sampling distribution of this test statistic is not chi-square with 2 df. The null hypothesis is that `scale2` and `scale3` have the value 0, they can only take values >0 under the alternative. The correct p value for this test statistics is obtained by dividing the naive p value of 151.27 for 2 degrees of freedom by 1/2, and so its clearly significant, suggesting that the `immun` values from kids in the same family and from different families in the same community are correlated.

The log likelihood of the 2-level model of Task 2 is -305.95929, and log likelihood of the 3-level model of Task 3 is -305.12036. The change in log likelihood over the Task 2 model is $-2(-1339.3508 + 1323.9524) = 30.797$. The sampling distribution of this test statistic is not chi-square with 1 df. Under the null hypothesis that `scale3` has the value 0, it can only take values >0 under the alternative. The correct p value for this test statistics is obtained by dividing the naive p value of 30.797 for 1 degrees of freedom by 1/2, and so its a significant improvement over the model of Task 2

Task 4. How did your covariate inference change when you allowed for mom-level (level 2) and then community-level (`cluster`, level 3) effects?

Result/Discussion

The same covariates: `kid2p`, `momedpri`, `husedpri`, `momwork`, `rural`, and `pcind81` are more or less significant in all 3 models, the main difference is that in the Task 3 model, `momedpri` and `momwork` are marginal. The main change as we move on from the Task 1, Task 2 and Task 3 models, is that there is a tendency for estimates and standard errors become larger, this is one of the features of a binary response model with significant random effects. Though this effect is not allways that clear between Task 2 and 3, for instance the parameter estimate on `kid2p` from the model of Task 1 is 0.95096 (S.E.0.11437), Task 2 is 1.7261 (S.E. 0.21823), while that from the model of Task 3 is 1.7174 (S.E. 0.21750)

19.2 Batch Script: 3LC3.R

```
# save the log file
sink("3LC3.log")

# load the sabreR library
library(sabreR)

# read the data
guatemala_immun <- read.table("guatemala_immun.tab")
```

```

attach(guatemala_immun)

# look at the 1st 10 lines and columns of the data
guatemala_immun[1:10,1:10]

# create the 1st model
sabre.model.1 <- sabre(immun~kid2p+mom25p+order23+order46+order7p+
  indnospa+indspa+momedpri+momedsec+husedpri+
  husedsec+huseddk+momwork+rural+pcind81,
  case=mom,adaptive.quad=TRUE,first.mass=24)

# show the results
sabre.model.1

# create the 2nd model
sabre.model.2 <- sabre(immun~kid2p+mom25p+order23+order46+order7p+
  indnospa+indspa+momedpri+momedsec+husedpri+
  husedsec+huseddk+momwork+rural+pcind81,
  case=list(mom,cluster),adaptive.quad=TRUE,
  first.mass=32,second.mass=32)

# show the results
sabre.model.2

# remove the objects
detach(guatemala_immun)
rm(guatemala_immun,sabre.model.1,sabre.model.2)

# close the log file
sink()

```

20 Exercise 3LC4. Poisson Model of Skin Cancer Deaths (78 Regions in 9 Nations)

20.1 Relevant Results from 3LC4.log and Discussion

Task 1. Estimate a Poisson model (without random effects) for the number of deaths (`deaths`) with the covariate `uvb`. Use `log expected` deaths as an offset.

Result/Discussion

```
Log likelihood =      -1723.7727      on      351 residual degrees of freedom

Parameter              Estimate              Std. Err.
-----
cons                   -0.70104E-01          0.11047E-01
uvb                    -0.57191E-01          0.26770E-02
```

Task 2. Allow for the level-2 region random effect (`region`), use adaptive quadrature with `mass 12`. Is this random effect significant?

Result/Discussion

```
Log likelihood =      -1125.1505      on      351 residual degrees of freedom

Parameter              Estimate              Std. Err.
-----
cons                   -0.13860              0.49393E-01
uvb                    -0.34415E-01          0.10038E-01
scale                  0.41217              0.37598E-01
```

The log likelihood of the homogeneous model of Task 1 is -1723.7727 , and log likelihood of the random effects model of Task 2 is -1339.3508 . The change in log likelihood over the homogeneous model is $-2(-1723.7727 + 1125.1505) = 1197.2$. The sampling distribution of this test statistic is not chi-square with 1 df. Under the null hypothesis `scale` has the value 0, it can only take values >0 under the alternative. The correct p value for this test statistics is obtained by dividing the naive p value of 1197.2 for 1 degree of freedom by 1/2, and so its clearly significant, suggesting that the `death` values from different `counties` from the same family (`region`) are highly correlated.

Task 3. Re-estimate the model with the level-2 random effect (`region`) and with `nation` as a level-3 random effect (`nation`). Use adaptive quadrature with `mass 96` for both levels. Are both these random effects significant?

Result/Discussion

Log likelihood = -1095.3100 on 350 residual degrees of freedom

Parameter	Estimate	Std. Err.
cons	-0.63968E-01	0.13358
uvb	-0.28204E-01	0.11400E-01
scale2	0.21988	0.24804E-01
scale3	0.37037	0.97658E-01

The log likelihood of the homogeneous model of Task 1 is -1723.7727, and the log likelihood of the 3-level random effects model of Task 3 is -1095.3100. The change in log likelihood over the homogeneous model is $-2(-1723.7727 + 1095.3100) = 1256.9$. The sampling distribution of this test statistic is not chi-square with 2 df. The null hypothesis is that `scale2` and `scale3` have the value 0, they can only take values >0 under the alternative. The correct p value for this test statistics is obtained by dividing the naive p value of 1256.9 for 2 degrees of freedom by 1/2, and so its clearly significant, suggesting that the `death` values from different `counties` from the same family (`region`), and from different `regions` in the same `nation` are highly correlated.

The log likelihood of the 2-level model of Task 2 is -1125.1505, and log likelihood of the 3-level model of Task 3 is -1095.3100. The change in log likelihood over the Task 2 model is $-2(-1125.1505+1095.3100) = 59.681$. The sampling distribution of this test statistic is not chi-square with 1 df. Under the null hypothesis that `scale3` has the value 0, it can only take values >0 under the alternative. The correct p value for this test statistics is obtained by dividing the naive p value of 59.681 for 1 degrees of freedom by 1/2, and so its a significant improvement over the model of Task 2

Task 4. How did your inference for the estimate of `uvb` change when you allowed for region-level (level 2) and then nation-level (level 3) effects?

Result/Discussion

The z statistics for `uvb` from the model of Task 1 is $-0.057191/0.0026770 = -21.364$, Task 2 is $-0.034415/0.010038 = -3.4285$, while that from the model of Task 3 is $-0.028204/0.011400 = -2.474$, i.e. the estimates decline and become a lot less less significant (S.E.s increase) as higher level random effects are added.

20.2 Batch Script: 3LC4.R

```
# save the log file
sink("3LC4.log")

# load the sabreR library
library(sabreR)

# read the data
death <- read.table("deaths.tab")
attach(death)

# look at the 1st 10 lines and columns of the data
```

```
death[1:10,1:7]

# create the 1st model
sabre.model.1 <- sabre(deaths~uvb+offset(log(expected)),case=region,
                      first.family="poisson",adaptive.quad=TRUE)

# show the results
sabre.model.1

# create the 2nd model
sabre.model.2 <- sabre(deaths~uvb+offset(log(expected)),
                      case=list(region,nation),
                      first.family="poisson",adaptive.quad=TRUE,
                      first.mass=96,second.mass=96)

# show the results
sabre.model.2

# remove the objects
detach(death)
rm(death,sabre.model.1,sabre.model.2)

# close the log file
sink()
```

21 Exercise 3LC5. Event History Cloglog Link Model of Time to Fill Vacancies (1736 Vacancies in 515 Firms)

21.1 Relevant Results from 3LC5.log and Discussion

Task 1. Estimate a cloglog link model (without random effects) for the binary response `match`, treat `t` as a factor variable and include the covariates (`loguu`, `logvv`, `nonman`, `written`, `size`, `wage`, `grade`, `dayrel`).

Result/Discussion

Log likelihood = -2340.6156 on 28773 residual degrees of freedom

Parameter		Estimate	Std. Err.
ft	(1)	-7.3253	0.76287
ft	(2)	-7.6077	0.76647
ft	(3)	-8.1945	0.76760
ft	(4)	-8.4380	0.77476
ft	(5)	-9.1986	0.80081
ft	(6)	-9.4309	0.78929
ft	(7)	-9.0874	0.77870
ft	(8)	-9.3464	0.79907
ft	(9)	-9.7955	0.83441
ft	(10)	-10.490	0.89070
loguu		0.74703	0.83416E-01
logvv		-0.15591	0.76683E-01
nonman		-0.19363	0.10924
written		-0.67264	0.11567
size		0.27550E-01	0.36976E-01
wage		-0.24750E-01	0.51028E-01
grade		0.86721E-01	0.54348E-01
dayrel		-0.39327	0.12075

The covariate `ft(.)` is the factor variable for `t`, there is no constant in the model.

Task 2. Allow for a level-2 vacancy random effect (`vacref`), use adaptive quadrature with `mass 48`. Is this random effect significant?

Result/Discussion

Log likelihood = -2268.2074 on 28772 residual degrees of freedom

Parameter	Estimate	Std. Err.
-----------	----------	-----------

ft	(1)	-10.660	1.3780
ft	(2)	-10.458	1.3499
ft	(3)	-10.728	1.3365
ft	(4)	-10.715	1.3324
ft	(5)	-11.294	1.3435
ft	(6)	-11.318	1.3329
ft	(7)	-10.756	1.3412
ft	(8)	-10.643	1.3635
ft	(9)	-10.883	1.3841
ft	(10)	-11.280	1.4424
loguu		1.0886	0.15437
logvv		-0.26518	0.13096
nonman		-0.44384	0.19154
written		-0.94262	0.21713
size		0.87120E-01	0.63396E-01
wage		0.60059E-01	0.91802E-01
grade		0.56564E-01	0.10113
dayrel		-0.66028	0.22303
scale		1.9924	0.20134

The log likelihood of the homogeneous model of Task 1 is -2340.6156, and log likelihood of the random effects model of Task 2 is -2268.2074. The change in log likelihood over the homogeneous model is $-2(-2340.6156 + 2268.2074) = 144.82$. The sampling distribution of this test statistic is not chi-square with 1 df. Under the null hypothesis `scale` has the value 0, it can only take values >0 under the alternative. The correct p value for this test statistics is obtained by dividing the naive p value of $= 144.82$ for 1 degree of freedom by 1/2, and so its clearly significant, suggesting that the binary response values (`match`) from different `weeks` from the same `vacancy` are highly correlated.

Task 3. Re-estimate the model with the level-2 random effect (`vacref`) and firm (`empref`) as the level 3 random effect. Use adaptive quadrature with `mass 64` for both levels. Are both these random effects significant?

Result/Discussion

Log likelihood =	-2247.6656	on	28771 residual degrees of freedom
Parameter	Estimate	Std. Err.	

ft	(1)	-9.7980	1.4117
ft	(2)	-9.6039	1.3854
ft	(3)	-9.8799	1.3725
ft	(4)	-9.8826	1.3689
ft	(5)	-10.452	1.3803

ft	(6)	-10.451	1.3703
ft	(7)	-9.8342	1.3806
ft	(8)	-9.6961	1.4088
ft	(9)	-9.8826	1.4293
ft	(10)	-10.246	1.4852
loguu		1.1429	0.16637
logvv		-0.48556	0.14794
nonman		-0.44829	0.20378
written		-0.79079	0.22718
size		0.72855E-01	0.78514E-01
wage		0.11520E-01	0.95085E-01
grade		0.15733E-01	0.10515
dayrel		-0.66339	0.23044
scale2		1.5626	0.19974
scale3		1.2265	0.15780

The log likelihood of the homogeneous model of Task 1 is -2340.6156, and the log likelihood of the 3-level random effects model of Task 3 is -2247.6656. The change in log likelihood over the homogeneous model is $-2(-2340.6156 + 2247.6656) = 185.9$. The sampling distribution of this test statistic is not chi-square with 2 df. The null hypothesis is that `scale2` and `scale3` have the value 0, they can only take values >0 under the alternative. The correct p value for this test statistics is obtained by dividing the naive p value of 185.9 for 2 degrees of freedom by 1/2, and so its clearly significant, suggesting that the the binary response values (`match`) from different `weeks` from the same `vacancy` are highly correlated and similarly from different `vacancies` of the same employer (`empref`) are highly correlated.

The log likelihood of the 2-level model of Task 2 is -2268.2074, and log likelihood of the 3-level model of Task 3 is -2247.6656. The change in log likelihood over the Task 2 model is $-2(-2268.2074+2247.6656) = 41.084$. The sampling distribution of this test statistic is not chi-square with 1 df. Under the null hypothesis that `scale3` has the value 0, it can only take values >0 under the alternative. The correct p value for this test statistics is obtained by dividing the naive p value of 41.084 for 1 degrees of freedom by 1/2, and so its a significant improvement over the model of Task 2.

Task 4. How did your results on some important variables e.g. `t` change, when you allowed for both vacancy-level (level 2) and then firm-level (level 3) random effects?

Result/Discussion

The same external covariates are significant in all Tasks, namely: `loguu`, `logvv`, `nonman`, `written`, `dayrel`. The main change as we move from the Task 1 to the Task 2 model, is that both the magnitude of the estimate and the standard errors of the covariates become noticeably larger. The same happens again as we move from the Task 2 to the Task 3 results.

The dummy variables for vacancy duration `ft()` are also significant in all Tasks. The estimates on the various levels of vacancy duration also tend to increase in magnitude and their standard errors increase as we add more levels.

21.2 Batch Script: 3LC5.R

```
# save the log file
sink("3LC5.log")

# load the sabreR library
library(sabreR)

# read the data
vwks4vac <- read.table("vwks4vac_30k.tab")
attach(vwks4vac)

# look at the 1st 10 lines and columns of the data
vwks4vac[1:10,1:10]

# create the 1st model
sabre.model.1 <- sabre(match~factor(t)+loguu+logvv+nonman+written+
                      size+wage+grade+dayrel,case=vacref,
                      first.link="cloglog",adaptive.quad=TRUE,
                      first.mass=48)

# show the results
sabre.model.1

# read the data
vwks4emp <- read.table("vwks4emp_30k.tab")
attach(vwks4emp)

# look at the 1st 10 lines and columns of the data
vwks4emp[1:10,1:10]

# create the 2nd model
sabre.model.2 <- sabre(match~factor(t)+loguu+logvv+nonman+written+
                      size+wage+grade+dayrel,
                      case=list(vacref,empref),first.link="cloglog",
                      adaptive.quad=TRUE,first.mass=64,
                      second.mass=64)

# show the results
sabre.model.2

# remove the objects
detach(vwks4vac,vwks4emp)
rm(vwks4vac,vwks4emp,sabre.model.1,sabre.model.2)

# close the log file
sink()
```

22 Exercise EP1. Trade Union Membership with Endpoints

22.1 Relevant Results from EP1.log and Discussion

Task 1. Estimate a binary response model for the response variable `union`, with the covariates: `age`, `age2`, `black`, `msp`, `grade`, `not_smsa`, `south`, `cons`. Use a probit link with adaptive quadrature and mass 36.

Result/Discussion

Log likelihood = -7641.6559 on 18986 residual degrees of freedom

Parameter	Estimate	Std. Err.
cons	-2.6788	0.39094
age	0.22961E-01	0.23695E-01
age2	-0.22716E-03	0.37805E-03
black	0.84389	0.72350E-01
msp	-0.65237E-01	0.41003E-01
grade	0.70700E-01	0.12640E-01
not_smsa	-0.11693	0.59975E-01
south	-0.74693	0.58813E-01
scale	1.5077	0.40779E-01

Task 2. Re-estimate the same model but allow for both lower and upper endpoints. How much of an improvement in log likelihood do you get with the endpoints model? Can the model be simplified? How do you interpret the results of your preferred model?

Result/Discussion

Log likelihood = -7632.6474 on 18985 residual degrees of freedom

Parameter	Estimate	Std. Err.
cons	-2.7029	0.38943
age	0.22211E-01	0.23671E-01
age2	-0.21579E-03	0.37757E-03
black	0.85198	0.69163E-01
msp	-0.61507E-01	0.40672E-01
grade	0.71592E-01	0.12613E-01
not_smsa	-0.12214	0.59017E-01
south	-0.72293	0.58290E-01
scale	1.3478	0.49969E-01

PROBABILITY

endpoint 0	0.00000	FIXED	0.00000
endpoint 1	0.21517E-01	0.54267E-02	0.21064E-01

The log likelihood of the homogeneous model of Task 1 is -7641.6559, and log likelihood of the random effects model of Task 2 is -7632.6474. The change in log likelihood over the Task 1 model is $-2(-7641.6559+7632.6474)= 18.017$. The sampling distribution of this test statistic is not chi-square with 2 df. Under the null hypothesis **endpoint 0 and 1** have the value 0, and they can only take values >0 under the alternative. The correct p value for this test statistics is obtained by dividing the naive p value of 18.017 for 2 degrees of freedom by 1/2, and so its clearly significant, suggesting that one or both are significant.

The estimate of **endpoint 0** is 0, suggesting that there is not a subgroup that will never be a union member. The estimate of the parameter for **endpoint 1** is small at 0.21517E-01 (S.E. 0.54267E-02), so that the probability of the upper endpoint is also small at 0.21064E-01 but it is significant and it does suggest that there is a subgroup of the population that will always be union members at this time.

The covariate parameter estimates of the model with endpoints are only slightly different to those of the model without, this is down to the fact that the magnitude of **endpoint 1** is small and that of **endpoint 0** is 0. The **scale** parameter of the model without endpoints is slightly larger because it is trying to include the stayers (extreme end of the distribution) as part of the Gaussian random effect distribution. It might be worth trying a nonparametric random effects distribution as an alternative to a continuous distribution with discrete endpoints.

22.2 Batch Script: EP1.R

```
# save the log file
sink("EP1.log")

# use the sabreR library
library(sabreR)

# read the data
nls <- read.table("nls.tab")
attach(nls)

# look at the 1st 10 lines and columns
nls[1:10,1:10]

# estimate the 1st model
sabre.model.1 <- sabre(union~age+age2+black+msp+grade+not.smsa+south,
                      case=idcode,first.link="probit",
                      adaptive.quad=TRUE,first.mass=36)

# show the results
sabre.model.1

# estimate the 2nd model
sabre.model.2 <- sabre(union~age+age2+black+msp+grade+not.smsa+south,
                      case=idcode,first.link="probit",
                      adaptive.quad=TRUE,first.mass=36,
                      left.end.point=0,right.end.point=0)
```

```
# show the results
sabre.model.2

# remove the created objects
detach(nls)
rm(nls,sabre.model.1,sabre.model.2)

# close the log file
sink()
```

23 Exercise EP2. Poisson Model of the Number of Fish Caught by Visitors to a US National Park.

23.1 Relevant Results from EP2.log and Discussion

Task 1. Estimate a Poisson model for the response variable `count`, with the covariates: `persons`, `livebait`, `cons`. Use adaptive quadrature and `mass 36`.

Result/Discussion

```

Log likelihood =      -447.47621      on      246 residual degrees of freedom

Parameter              Estimate              Std. Err.
-----
cons                   -3.5349              0.64611
persons                0.59934              0.14043
livebait               1.4084              0.51517
scale                  1.9260              0.16693

```

Task 2. Re-estimate the same model but allow for lower endpoints. How much of an improvement in log likelihood do you get with the endpoints model? What happens to your inference on the covariates? How do you interpret the results of your preferred model?

Result/Discussion

```

Log likelihood =      -438.30927      on      245 residual degrees of freedom

Parameter              Estimate              Std. Err.
-----
cons                   -2.6703              0.56426
persons                0.73530              0.11845
livebait               1.5762              0.44179
scale                  1.1659              0.13378

                                PROBABILITY
                                -----
endpoint 0              0.67121              0.14608              0.40163

```

The log likelihood of the homogeneous model of Task 1 is -447.47621, and log likelihood of the random effects model of Task 2 is -438.30927. The change in log likelihood over the Task 1 model is $-2(-447.47621+438.30927)= 18.334$. The sampling distribution of this test statistic is not chi-square with 2 df. Under the null hypothesis `endpoint 0` has the value 0, it can only take the value >0 under the alternative. The correct p value for this test statistics is obtained

by dividing the naive p value of 18.334 for 1 degree of freedom by 1/2, and so its clearly significant, suggesting that there is a large subgroup who will never catch any fish, perhaps its because they do not fish.

The estimate of the parameter for the **endpoint** 0 is large at 0.67121 (S.E. 0.14608), so that the probability of an endpoint is also large at 0.40163, it is very significant and it does suggest that there is a subgroup of the population that will never catch any fish.

The covariate parameter estimates are significant in both the Task 1 and Task 2 models. In the Task 2 model, the estimate of the **persons** effect has increased and its S.E has become smaller. The estimate of the **livebait** effect has also increased slightly and its S.E has also become smaller. Both models suggests that the use of **livebait** increases the rate at which fish are caught, and the larger the number of **persons** in the party the larger the rate at which fish are caught. The **scale** estimate is much larger in the model of Task 1 as it is trying to include the group that will never catch any fish (extreme left hand end of the latent distribution) as part of the Gaussian random effect distribution. It might be worth trying a nonparametric random effects distribution as an alternative to a continuous distribution with discrete endpoints.

23.2 Batch Script: EP2.R

```
# save the log file
sink("EP2.log")

library(sabreR)

# read the data
fish <- read.table("fish.tab")
attach(fish)

# look at the data
fish[1:10,1:9]

# create the model
sabre.model.1 <- sabre(count~persons+livebait,case=id,
                      first.family="poisson",adaptive.quad=TRUE,
                      first.mass=36)

# show the results
sabre.model.1

# create the model
sabre.model.2 <- sabre(count~persons+livebait,case=id,
                      first.family="poisson",adaptive.quad=TRUE,
                      first.mass=36,left.end.point=0)

# show the results
sabre.model.2

detach(fish)
rm(fish,sabre.model.1,sabre.model.2)

sink()
```


24 Exercise EP3. Binary Response Model of Female Employment Participation.

24.1 Relevant Results from EP3.log and Discussion

Task 1. Estimate a heterogenous logit model for the response variable y , allow for nonstationarity by treating t as a factor variable. Use adaptive quadrature with `mass 64`.

Result/Discussion

```

Log likelihood =      -3698.2985      on      7909 residual degrees of freedom

Parameter              Estimate          Std. Err.
-----
cons                   -0.82912          0.13772
ft          ( 1)         0.0000          ALIASED [I]
ft          ( 2)         0.37129          0.11761
ft          ( 3)         0.69983          0.11836
ft          ( 4)         0.46031          0.11775
ft          ( 5)         0.34388          0.11758
scale                  3.9658          0.15594

```

The covariate `ft(.)` is the factor for t , `ft(1)` is ALIASED as the model contains a constant.

Task 2. Re-estimate the same model but allow for lower and upper endpoints. How much of an improvement in log likelihood do you get with the endpoints model? How do you interpret the results?

Result/Discussion

```

Log likelihood =      -3693.6887      on      7907 residual degrees of freedom

Parameter              Estimate          Std. Err.
-----
cons                   -0.23907          0.18669
ft          ( 1)         0.0000          ALIASED [I]
ft          ( 2)         0.36716          0.11698
ft          ( 3)         0.69568          0.11808
ft          ( 4)         0.45568          0.11719
ft          ( 5)         0.33996          0.11693
scale                  1.9485          0.39295

                                PROBABILITY
                                -----
endpoint 0                    0.41203          0.10310          0.24915
endpoint 1                    0.24172          0.93774E-01      0.14616

```

The log likelihood of the homogeneous model of Task 1 is -3698.2985, and log likelihood of the random effects model of Task 2 is -3693.6887. The change in log likelihood over the Task 1 model is $-2(-3698.2985+3693.6887)= 9.2196$. The sampling distribution of this test statistic is not chi-square with 2 df. Under the null hypothesis **endpoint 0 and 1** have the value 0, and they can only take values >0 under the alternative. The correct p value for this test statistics is obtained by dividing the naive p value of 9.2196 for 2 degrees of freedom by 1/2, and so its clearly significant, suggesting that one or both are significant.

The estimate of the parameter for **endpoint 0** is 0.41203 (S.E 0.10310) suggesting that the probability that a randomly sampled woman from this population will never work over this time period is 0.24915. The estimate of the parameter for the **endpoint 1** is smaller at 0.24172 (S.E. 0.93774E-01), so that the probability of a randomly sampled female form this population will always work over this time period is 0.14616.

The parameter estimates of `ft(.)` are all significant, suggesting that the series is non stationary. The `scale` parameter of the model without endpoints is much larger because it is trying to include the both groups of stayers (both extreme ends of the latent distribution) as part of the Gaussian random effect distribution. It might be worth trying a nonparametric random effects distribution as an alternative to a continuous distribution with discrete endpoints.

24.2 Batch Script: EP3.R

```
# save the log file
sink("EP3.log")

# use the sabreR library
library(sabreR)

# read the data
labour <- read.table("labour.tab")
attach(labour)

# look at the 1st 10 lines and columns
labour[1:10,1:3]

# estimate the 1st model
sabre.model.1 <- sabre(y~factor(t),case=case,adaptive.quad=TRUE,
                      first.mass=64)

# show the results
sabre.model.1

# estimate the 2nd model
sabre.model.2 <- sabre(y~factor(t),case=case,adaptive.quad=TRUE,
                      first.mass=64,left.end.point=0,
                      right.end.point=0)

# show the results
sabre.model.2

# remove the created objects
detach(labour)
rm(labour,sabre.model.1,sabre.model.2)

# close the log file
```

`sink()`

25 Exercise FOL1. Binary Response Model for Trade Union Membership 1980-1987 of Young Males (Wooldridge, 2005)

25.1 Conditional analysis: Relevant Results from FOL1.log and Discussion

Task 1. Estimate a random effect probit model (adaptive quadrature, mass 24) of trade union membership (`union`), with a constant, the lagged union membership variable (`union_1`), `educ`, `black` and the marital status dummy variable (`married`), the `marr81-marr87` and the `d82-d87` sets of dummy variables.

Result/Discussion

Log likelihood = -1338.8321 on 3796 residual degrees of freedom

Parameter	Estimate	Std. Err.
-----	-----	-----
<code>cons</code>	-1.3240	0.43605
<code>union_1</code>	1.1275	0.10259
<code>educ</code>	-0.19585E-01	0.35869E-01
<code>black</code>	0.66836	0.18558
<code>married</code>	0.17530	0.10904
<code>marr81</code>	0.54328E-01	0.21341
<code>marr82</code>	0.12027	0.25065
<code>marr83</code>	-0.10103	0.25427
<code>marr84</code>	-0.38317E-02	0.27284
<code>marr85</code>	0.20568	0.25782
<code>marr86</code>	0.13950	0.25941
<code>marr87</code>	-0.30950	0.20259
<code>d82</code>	0.51020E-02	0.11071
<code>d83</code>	-0.11691	0.11477
<code>d84</code>	-0.73547E-01	0.11643
<code>d85</code>	-0.28268	0.11992
<code>d86</code>	-0.31868	0.12205
<code>d87</code>	0.67375E-01	0.11633
<code>scale</code>	1.0919	0.10699

The parameter estimate for the lagged endogenous covariate `union_1` is the most significant effect in this conditional model. The estimates of the parameters for the time constant covariates `married` and `educ` are not significant, but `black` is. There is a lot of non stationarity effects in this model, but only the year dummy variables `d85` and `d86` are significant.

Task 2. Add the initial condition of trade union membership in 1980 (`union80`) to the previous model. How does the inference on the lagged responses (`union_1`) and the scale parameters differ between the two models?

Result/Discussion

Log likelihood = -1283.7471 on 3795 residual degrees of freedom

Parameter	Estimate	Std. Err.
cons	-1.6817	0.44298
union_1	0.89739	0.92660E-01
union80	1.4448	0.16437
educ	-0.18453E-01	0.36230E-01
black	0.52993	0.18371
married	0.16892	0.11077
marr81	0.42777E-01	0.21512
marr82	-0.81286E-01	0.25313
marr83	-0.88790E-01	0.25567
marr84	0.26043E-01	0.27628
marr85	0.39631	0.26087
marr86	0.12489	0.26099
marr87	-0.38636	0.20445
d82	0.27602E-01	0.11368
d83	-0.89635E-01	0.11753
d84	-0.50365E-01	0.11913
d85	-0.26696	0.12253
d86	-0.31599	0.12449
d87	0.73028E-01	0.11898
scale	1.0765	0.90234E-01

The parameter estimate for `union_1` in Task 1 is 1.1275 (S.E. 0.10259). In task 2 this estimate is a lot smaller i.e. 0.89739 (S.E. 0.92660E-01). The estimate of the `scale` parameter hardly changes from Task1 to Task2. In Task 1 it is 1.0919 (S.E. 0.10699) and in Task 2 it is 1.0765 (S.E. 0.90234E-01). The estimates of the parameters for the time constant covariates have changed, `married` and `educ` are still not significant and the positive estimate on `black` is smaller. As in the Task 1 only the year dummy variables `d85` and `d86` are significant.

25.2 Joint analysis of the initial condition and subsequent responses: Relevant Results from FOL1.log and Discussion

Task 3. Estimate a common random effect common scale parameter joint probit model (adaptive quadrature, mass 24) of trade union membership (`union_1`). Use the `d1` and `d2` dummy variables to set up the linear predictors. Use constants in both linear predictors. For the initial response, use the `married`, `educ` and `black` regressors. For the subsequent response, use the regressors: lagged union membership variable (`union_1`), `educ`, `black` and the marital status dummy variable (`married`), the `marr81`-`marr87` and the `year` dummy variables. What does this model suggest about state dependence and unobserved heterogeneity?

Result/Discussion

Log likelihood = -1590.1430 on 4337 residual degrees of freedom

Parameter	Estimate	Std. Err.
d1	-0.58996	0.62227
d1_married	0.25759	0.20583
d1_educ	-0.48046E-01	0.52393E-01
d1_black	0.59148	0.26113
d2	-1.2521	0.45364
d2_union_1	0.96357	0.87825E-01
d2_married	0.16569	0.10906
d2_educ	-0.27017E-01	0.37433E-01
d2_black	0.69899	0.19187
d2_marr81	0.97707E-01	0.19300
d2_marr82	-0.93949E-01	0.22448
d2_marr83	-0.89210E-01	0.22766
d2_marr84	0.36295E-01	0.24895
d2_marr85	0.38505	0.23111
d2_marr86	0.98316E-01	0.22917
d2_marr87	-0.35818	0.17973
d2_d82	0.33469E-01	0.11200
d2_d83	-0.80935E-01	0.11563
d2_d84	-0.42037E-01	0.11717
d2_d85	-0.25302	0.12040
d2_d86	-0.29618	0.12218
d2_d87	0.80604E-01	0.11719
scale	1.1716	0.89832E-01

The parameter estimate for the lagged endogenous covariate `union_1` is 0.96357 (S.E. 0.87825E-01), it is the most significant covariate effect in this joint model. This estimate lies between those of the Task 1 and Task 2 conditional models. There is a very significant parameter estimate for the residual heterogeneity `scale`, which takes the value 1.1716 (S.E. 0.89832E-01) in this joint model. The only covariate effect that is significant in the model for the initial condition is `black`. The estimates of the parameters for the time constant covariates in the subsequent response model i.e. `married` and `educ` are still not significant and the positive estimate on `black` is larger than previously. As in the Task 1 and Task 2 conditional models, non of the `marr81-marr86` effects are significant, but `marr87` now is now marginally significant. As before, the year dummy variables `d85` and `d86` are significant.

Task 4. Re-estimate the model allowing the scale parameters for the initial and subsequent responses to be different. Is this a significant improvement over the common scale parameter model?

Result/Discussion

Log likelihood = -1587.3937 on 4336 residual degrees of freedom

Parameter	Estimate	Std. Err.
d1	-0.55996	0.55785
d1_married	0.23441	0.18924
d1_educ	-0.40286E-01	0.46985E-01
d1_black	0.52854	0.23547
d2	-1.2616	0.49391
d2_union_1	0.89734	0.92530E-01
d2_married	0.16901	0.11093
d2_educ	-0.30145E-01	0.40841E-01
d2_black	0.74873	0.21034
d2_marr81	0.10080	0.21806
d2_marr82	-0.79352E-01	0.25414
d2_marr83	-0.91932E-01	0.25750
d2_marr84	0.31681E-01	0.28034
d2_marr85	0.39320	0.26147
d2_marr86	0.11828	0.26002
d2_marr87	-0.38018	0.20383
d2_d82	0.29233E-01	0.11386
d2_d83	-0.87934E-01	0.11768
d2_d84	-0.48132E-01	0.11928
d2_d85	-0.26486	0.12262
d2_d86	-0.31378	0.12458
d2_d87	0.75523E-01	0.11921
scale1	0.93682	0.11943
scale2	1.2928	0.10895

The log likelihood of the common random effect model of Task 3 is -1590.1430 and log likelihood of the random effects model of Task 4 is -1587.3937. The change in log likelihood over the Task 3 model is $-2(-1590.1430+1587.3937)=5.4986$. The sampling distribution of this test statistic is chi-square with 1 df. Under the null hypothesis `scale1` and `scale2` are equal, The test statistic is clearly significant, suggesting that `scale1` and `scale2` are significantly different from each other.

Task 5. To the different scale parameter model, add the baseline response (`union80`). Does this make a significant improvement to the model?

Result/Discussion

Log likelihood = -1587.3902 on 4335 residual degrees of freedom

Parameter	Estimate	Std. Err.
d1	-0.55091	0.54565

d1_married	0.22934	0.19315
d1_educ	-0.37589E-01	0.54714E-01
d1_black	0.50766	0.32984
d2	-1.2900	0.59611
d2_union_1	0.89724	0.92550E-01
d2_union80	0.99365E-01	1.2048
d2_married	0.16896	0.11090
d2_educ	-0.29059E-01	0.42171E-01
d2_black	0.73161	0.29121
d2_marr81	0.96561E-01	0.22362
d2_marr82	-0.80274E-01	0.25416
d2_marr83	-0.90811E-01	0.25754
d2_marr84	0.30503E-01	0.27999
d2_marr85	0.39368	0.26141
d2_marr86	0.11981	0.26070
d2_marr87	-0.38154	0.20444
d2_d82	0.29096E-01	0.11385
d2_d83	-0.88060E-01	0.11766
d2_d84	-0.48324E-01	0.11928
d2_d85	-0.26502	0.12262
d2_d86	-0.31395	0.12458
d2_d87	0.75265E-01	0.11921
scale1	0.85413	0.98069
scale2	1.2631	0.36167

The log likelihood of the common random effect but different scales model of Task 4 is -1587.3937 and log likelihood of the model of Task 5 is -1587.3902. The change in log likelihood over the Task 4 model is $-2(-1587.3937+1587.3902)=0.007$. The sampling distribution of this test statistic is chi-square with 1 df. Under the null hypothesis $d2_union80=0$. The test statistic is clearly not significant. The same result is given by the z statistic for the parameter estimate of $d2_union80$ which is $0.099365/1.2048=8.2474 \times 10^{-2}$.

25.3 Batch Script: FOL1.R

```
# save the log file
sink("FOL1.log")

# load sabreR
library(sabreR)

# read the data
unionjmw1 <- read.table("unionjmw1.tab")

# union is a reserved name in R, it is used by sabreR
# not changing it will cause the reserved name to be overwritten
# when the data is attached
names(unionjmw1)
# change the name
attr(unionjmw1,"names")[6] <- "tunion"
# check it
names(unionjmw1)
```



```

attach(unionjmw1)

# look at the data
unionjmw1[1:10,1:10]

# 1st common RE model
sabre.model.1 <- sabre(tunion~union_1+educ+black+married+marr81+
  marr82+marr83+marr84+marr85+marr86+marr87+
  factor(year),case=nr,first.link="probit",
  adaptive.quad=TRUE,first.mass=24)

# show the results
sabre.model.1

# 2nd common RE model
sabre.model.2 <- sabre(tunion~union_1+union80+educ+black+married+
  marr81+marr82+marr83+marr84+marr85+marr86+
  marr87+factor(year),case=nr,
  first.link="probit",adaptive.quad=TRUE,
  first.mass=24)

# show the results
sabre.model.2

# read the data
unionjmw2 <- read.table("unionjmw2.tab")

# union is a reserved name in R, it is used by sabreR
# not changing it will cause the reserved name to be overwritten
# when the data is attached
names(unionjmw2)
# change the name
attr(unionjmw2,"names")[6] <- "tunion"
# check it
names(unionjmw2)
attach(unionjmw2)

# look at the data
unionjmw2[1:10,1:27]

# common RE model
sabre.model.3 <- sabre(tunion~d1+d1:(married+educ+black)+d2+
  d2:(union_1+married+educ+black+marr81+marr82+
  marr83+marr84+marr85+marr86+marr87+d82+d83+
  d84+d85+d86+d87)-1,case=nr,
  first.link="probit",adaptive.quad=TRUE,
  first.mass=24)

# show the results
sabre.model.3

# 1st different scale common RE model
sabre.model.4 <- sabre(tunion[d==1]~married[d==1]+educ[d==1]+
  black[d==1],tunion[d==2]~union_1[d==2]+
  married[d==2]+educ[d==2]+black[d==2]+
  marr81[d==2]+marr82[d==2]+marr83[d==2]+
  marr84[d==2]+marr85[d==2]+marr86[d==2]+
  marr87[d==2]+d82[d==2]+d83[d==2]+d84[d==2]+
  d85[d==2]+d86[d==2]+d87[d==2],
  case=list(nr[d==1],nr[d==2]),
  first.link="probit",adaptive.quad=TRUE,
  first.mass=24,depend=TRUE)

```

```

# show the results
sabre.model.4

# 2nd different scale common RE model
sabre.model.5 <- sabre(tunion[d==1]~married[d==1]+educ[d==1]+
  black[d==1],tunion[d==2]~union_1[d==2]+
  union80[d==2]+married[d==2]+educ[d==2]+
  black[d==2]+marr81[d==2]+marr82[d==2]+
  marr83[d==2]+marr84[d==2]+marr85[d==2]+
  marr86[d==2]+marr87[d==2]+d82[d==2]+d83[d==2]+
  d84[d==2]+d85[d==2]+d86[d==2]+d87[d==2],
  case=list(nr[d==1],nr[d==2]),
  first.link="probit",adaptive.quad=TRUE,
  first.mass=24,depend=TRUE)

# show the results
sabre.model.5

detach(unionjmw1,unionjmw2)
rm(unionjmw1,unionjmw2,sabre.model.1,sabre.model.2,sabre.model.3,
  sabre.model.4,sabre.model.5)

sink()

```

26 Exercise FOL2. Probit Model for Trade Union Membership of Females

26.1 Conditional analysis: Relevant Results from FOL2.log and Discussion

Task 1. Estimate a heterogenous probit (level-2 with idcode, adaptive quadrature, mass 16) model of trade union membership (`union`), with a constant and the lagged union membership variable (`lagunion`), `age`, `grade`, and `southxt` regressors.

Result/Discussion

```

Log likelihood =      -1561.1661      on      3989 residual degrees of freedom

Parameter              Estimate          Std. Err.
-----
cons                   -0.12753          0.39251
lagunion                1.1723           0.14108
age                    -0.15189E-01     0.84733E-02
grade                  -0.38049E-01     0.20260E-01
southxt                -0.27348E-01     0.67395E-02
scale                  1.0210           0.15065

```

The parameter estimate for the lagged endogenous covariate (`lagunion`) is the most significant effect in this conditional random effects model, its z statistic is $1.1723/0.14108 = 8.3095$. The estimates of the parameters for `grade` and `age` are marginally significant, but the estimates of `southxt` is very significant.

Task 2. Add the initial condition of trade union membership in 1978 (`baseunion`) to the previous model. How do the inference on the lagged responses (`lagunion`) and the scale effects differ between the two models.

Result/Discussion

```

Log likelihood =      -1440.9676      on      3988 residual degrees of freedom

Parameter              Estimate          Std. Err.
-----
cons                   -0.55370E-01     0.41636
lagunion                0.61315          0.97749E-01
baseunion               2.0856           0.18478
age                    -0.23876E-01     0.91305E-02
grade                  -0.58040E-01     0.22610E-01
southxt                -0.15529E-01     0.71251E-02
scale                  1.1519           0.94868E-01

```

The parameter estimate for `lagunion` in Task 1 is 1.1723 (S.E. 0.14108). In task 2 this estimate is a lot smaller i.e. 0.61315 (S.E. 0.97749E-01). The estimate of the `scale` parameter hardly changes from Task 1 to Task 2. In Task 1 it is 1.0210 (S.E. 0.15065) and in Task 2 it is 1.1519 (S.E. 0.94868E-01). The estimates for the other covariate parameters have changed. The estimates of the parameters for `grade` and `age` are now significant, but the estimates of `southxt` is now of marginal significance, suggesting that the very significant endogenous covariate `baseunion` is correlated with these explanatory covariates.

26.2 Joint analysis of the initial condition and subsequent responses: Relevant Results from FOL2.log and Discussion

Task 3. Estimate a common random effect common scale joint probit model (adaptive quadrature, `mass 24`) of trade union membership (`union`). Use constants in both linear predictors. Use the `d1` and `d2` dummy variables to set up the linear predictors. For the initial response use the regressors: `age`, `grade`, `southxt` and `not_smsa`. For the subsequent response use the regressors: lagged union membership variable (`lagunion`), `age`, `grade`, `southxt`. What does this model suggest about state dependence and unobserved heterogeneity?

Result/Discussion

Log likelihood = -1859.3298 on 4783 residual degrees of freedom

Parameter	Estimate	Std. Err.
d1	-1.2135	0.87794
d1_age	0.15555E-01	0.24851E-01
d1_grade	-0.63505E-02	0.35847E-01
d1_southxt	-0.96174E-01	0.20873E-01
d1_not_smsa	-0.44161	0.16998
d2	0.69683E-01	0.44656
d2_lagunion	0.68544	0.90929E-01
d2_age	-0.15415E-01	0.92712E-02
d2_grade	-0.49664E-01	0.25326E-01
d2_southxt	-0.33817E-01	0.76453E-02
scale	1.4361	0.10073

The parameter estimate for the lagged endogenous covariate (`d2_lagunion`) is 0.68544 (S.E. 0.90929E-01), it is the most significant covariate effect in this joint model. This estimate lies between those of the Task 1 and Task 2 conditional models. There is a very significant parameter estimate for the residual heterogeneity `scale`, which takes the value 1.4361 (S.E. 0.10073). This estimate of the `scale` effect is larger than the estimates of Task 1 and Task 2. The only covariate effects that are significant in the model for the initial condition are: `d1_southxt` and `d1_not_smsa`. The estimates of the parameters for the time constant covariates in the subsequent response model, i.e. `d2_grade`, `d2_southxt` are significant. The estimate `d2_age` is not significant.

Task 4. Re-estimate the model allowing the scale parameters for the initial and subsequent responses to be different (use adaptive quadrature with `mass 32`). Is this a significant improvement over the common scale parameter model?

Result/Discussion

Log likelihood = -1858.7970 on 4782 residual degrees of freedom

Parameter	Estimate	Std. Err.
d1	-1.2135	0.83951
d1_age	0.16495E-01	0.23826E-01
d1_grade	-0.51061E-02	0.34065E-01
d1_southxt	-0.91276E-01	0.20370E-01
d1_not_smsa	-0.41669	0.16479
d2	0.11430	0.46088
d2_lagunion	0.64705	0.98257E-01
d2_age	-0.16227E-01	0.94731E-02
d2_grade	-0.52032E-01	0.26467E-01
d2_southxt	-0.34468E-01	0.79324E-02
scale1	1.3189	0.14238
scale2	1.5062	0.12400

The log likelihood of the common random effect model of Task 3 is -1859.3298 and log likelihood of the random effects model of Task 4 is -1858.7970. The change in log likelihood over the Task 3 model is $-2(-1859.3298+1858.7970)=1.0656$. The sampling distribution of this test statistic is chi-square with 1 df. Under the null hypothesis `scale1` and `scale2` are equal, The test statistic is clearly not significant, suggesting that `scale1` and `scale2` are not significantly different from each other.

Task 5. Re-estimate the model using a bivariate model for the random effects (common scale). Are these results different to those of Task 4?

Result/Discussion

Log likelihood = -1858.7970 on 4782 residual degrees of freedom

Parameter	Estimate	Std. Err.
d1	-1.3255	0.92173
d1_age	0.18018E-01	0.25485E-01
d1_grade	-0.55778E-02	0.37603E-01
d1_southxt	-0.99705E-01	0.23454E-01
d1_not_smsa	-0.45517	0.19332

d2	0.11430	0.45735
d2_lagunion	0.64705	0.99895E-01
d2_age	-0.16227E-01	0.96947E-02
d2_grade	-0.52032E-01	0.25438E-01
d2_southxt	-0.34468E-01	0.82239E-02
scale	1.5062	0.12352
corr	0.95647	0.40383E-01

There is not much difference between the log likelihood and results and those of Task 3 (log likelihood -1859.3298) or Task 4 (log likelihood -1858.7970). This is reinforced by the fact that the 95% confidence interval on **corr** includes 1, a value which gives the common random effect model of Task 3 and the estimated different scales model of Task 4.

Task 6. To the bivariate model of Task 5 add the initial or baseline response (**baseunion**). Are these results different to those of Task 5?

Result/Discussion

Log likelihood = -1849.0718 on 4781 residual degrees of freedom

Parameter	Estimate	Std. Err.
d1	-2.6975	0.94777
d1_age	0.68087E-01	0.26635E-01
d1_grade	0.32122E-02	0.34305E-01
d1_southxt	-0.10413	0.22391E-01
d1_not_smsa	-0.43624	0.17741
d2	-0.81790E-01	0.44251
d2_lagunion	0.61259	0.10019
d2_baseunion	2.5607	0.79879
d2_age	-0.26334E-01	0.98441E-02
d2_grade	-0.59834E-01	0.22166E-01
d2_southxt	-0.11618E-01	0.94130E-02
scale	1.1707	0.10772
corr	-0.31741	0.51614

The log likelihood of the common scale different random effect model of Task 5 is -1858.7970 and log likelihood of the model of Task 6 is -1849.0718. The change in log likelihood over the Task 5 model is $-2(-1858.7970+1849.0718)=19.45$. The sampling distribution of this test statistic is chi-square with 1 df. Under the null hypothesis **d2_baseunion**=0. The test statistic for **d2_baseunion** not equal to 0 is clearly significant. The same result is given by the z statistic for the parameter estimate of **d2_baseunion** which is $2.5607/0.79879=3.2057$.

In this bivariate model **corr** is estimated to be negative but non significant, implying independence between the initial condition and the subsequent responses, perhaps the Task 2 model is a reasonable representation of the data.

26.3 Batch Script: FOL2.R

```
# save the log file
sink("FOL2.log")

# load sabreR
library(sabreR)

# read the data
unionred1 <- read.table("unionred1.tab")

# union is a reserved name in R, it is used by sabreR
# not changing it will cause the reserved name to be overwritten
# when the data is attached
names(unionred1)
# change the name
attr(unionred1,"names")[7] <- "tunion"
# check it
names(unionred1)
attach(unionred1)

# look at the data
unionred1[1:10,1:10]

# 1st common RE model
sabre.model.1 <- sabre(tunion~lagunion+age+grade+southXt,case=idcode,
                      first.link="probit",adaptive.quad=TRUE,
                      first.mass=16)

# show the results
sabre.model.1

# 2nd common RE model
sabre.model.2 <- sabre(tunion~lagunion+baseunion+age+grade+southXt,
                      case=idcode,first.link="probit",
                      adaptive.quad=TRUE,first.mass=16)

# show the results
sabre.model.2

# read the data
unionred2 <- read.table("unionred2.tab")

# union is a reserved name in R, it is used by sabreR
# not changing it will cause the reserved name to be overwritten
# when the data is attached
names(unionred2)
# change the name
attr(unionred2,"names")[7] <- "tunion"
# check it
names(unionred2)
attach(unionred2)

# look at the data
unionred2[1:10,1:10]

# 1st RE model
sabre.model.3 <- sabre(tunion~d1+d1:(age+grade+southXt+not_smsa)+d2+
                      d2:(lagunion+age+grade+southXt),case=idcode,
                      first.link="probit",adaptive.quad=TRUE,
                      first.mass=24)
```

```

# show the results
sabre.model.3

# 2nd RE model
sabre.model.4 <- sabre(tunion[d==1]~age[d==1]+grade[d==1]+
  southXt[d==1]+not_smsa[d==1],tunion[d==2]~
  lagunion[d==2]+age[d==2]+grade[d==2]+
  southXt[d==2],
  case=list(idcode[d==1],idcode[d==2]),
  first.link="probit",adaptive.quad=TRUE,
  first.mass=24,depend=TRUE)

# show the results
sabre.model.4

# 3rd RE model
sabre.model.5 <- sabre(tunion[d==1]~age[d==1]+grade[d==1]+
  southXt[d==1]+not_smsa[d==1],tunion[d==2]~
  lagunion[d==2]+age[d==2]+grade[d==2]+
  southXt[d==2],
  case=list(idcode[d==1],idcode[d==2]),
  first.link="probit",second.link="probit",
  adaptive.quad=TRUE,first.mass=24,
  second.mass=24,equal.scale=TRUE,
  only.first.derivatives=TRUE)

# show the results
sabre.model.5

# 4th RE model
sabre.model.6 <- sabre(tunion[d==1]~age[d==1]+grade[d==1]+
  southXt[d==1]+not_smsa[d==1],tunion[d==2]~
  lagunion[d==2]+baseunion[d==2]+age[d==2]+
  grade[d==2]+southXt[d==2],
  case=list(idcode[d==1],idcode[d==2]),
  first.link="probit",second.link="probit",
  adaptive.quad=TRUE,first.mass=24,
  second.mass=24,equal.scale=TRUE,
  only.first.derivatives=TRUE)

# show the results
sabre.model.6

detach(unionred1,unionred2)
rm(unionred1,unionred2,sabre.model.1,sabre.model.2,sabre.model.3,
  sabre.model.4,sabre.model.5,sabre.model.6)

sink()

```


27 Exercise FOL3. Binary Response Model for Female Labour Force Participation in the UK

27.1 Conditional analysis: Relevant Results from FOL3.log and Discussion

Task 1. Estimate a heterogenous logit (level-2 with `case`, use adaptive quadrature, `mass 12`) model of female employment participation (`femp`), with a constant and the lagged female employment participation variable (`ylag`), `mune`, `und5`, and `age` regressors..

Result/Discussion

```

Log likelihood =      -384.71153      on      1268 residual degrees of freedom

Parameter              Estimate              Std. Err.
-----
cons                   -0.84840              0.25399
ylag                    3.7180               0.25145
mune                   -1.6654              0.44273
und5                   -1.0786              0.28686
age                     0.79040E-03          0.16505E-01
scale                   0.87551              0.25075

```

The parameter estimate for the lagged endogenous covariate (`ylag`) is the most significant effect in this conditional random effects model, its z statistic is $3.7180/0.25145 = 14.786$. The estimates of the parameters for `mune` and `und5` are very significant, but the estimate of `age` is not significant.

Task 2. Add the initial condition of employed in the 1st year (`ybase`) to the previous model. How do the inference on the lagged responses (`ylag`) and the scale effects differ between the two models?

Result/Discussion

```

Log likelihood =      -380.63889      on      1267 residual degrees of freedom

Parameter              Estimate              Std. Err.
-----
cons                   -1.1012              0.26233
ylag                    3.3566               0.26986
ybase                   0.91324              0.35759
mune                   -1.7769              0.46858
und5                   -1.1307              0.29507
age                     0.34266E-03          0.17862E-01
scale                   1.0665               0.24790

```

The parameter estimate for `ylag` in Task 1 is 3.7180 (S.E. 0.25145). In task 2 this estimate is smaller i.e. 3.3566 (S.E. 0.26986). The estimate of the `scale` parameter is larger in the Task 2 model than it is in the Task 2 model. In Task 1 it is 0.87551 (S.E. 0.25075) and in Task 2 it is 1.0665 (S.E. 0.24790). The estimates for the other covariate parameters have changed slightly, but the pattern of significance is the same, suggesting that the significant endogenous covariate `ybase` is only lightly correlated with these explanatory covariates.

27.2 Joint analysis of the initial condition and subsequent responses: Relevant Results from FOL3.log and Discussion

Task 3. Estimate a common random effect common scale joint logit model (adaptive quadrature, `mass 12`) of female employment participation (`femp`). Use constants in both linear predictors. Use the `r1` and `r2` dummy variables to set up the linear predictors. For the initial response use the regressors: `mune`, `und5`, and `age` regressors. For the subsequent responses use the regressors: the lagged female employment participation variable (`ylag`), `mune`, `und5`, and `age`. What does this model suggest about state dependence and unobserved heterogeneity?

Result/Discussion

Log likelihood =	-463.56628	on	1415 residual degrees of freedom
Parameter	Estimate	Std. Err.	

<code>r1</code>	1.5314	0.32754	
<code>r1_mune</code>	-1.5048	0.96871	
<code>r1_und5</code>	-2.4403	0.49140	
<code>r1_age</code>	0.39628E-02	0.29897E-01	
<code>r2</code>	-0.57860	0.26726	
<code>r2_y_{lag}</code>	3.3681	0.26379	
<code>r2_mune</code>	-1.9178	0.47149	
<code>r2_und5</code>	-1.1457	0.29263	
<code>r2_age</code>	0.52903E-02	0.18133E-01	
<code>scale</code>	1.1572	0.23703	

The parameter estimate for the lagged endogenous covariate (`r2_ylag`) is 3.3681 (S.E. 0.26379), it is the most significant covariate effect in this joint model. This estimate lies between those of the Task 1 and Task 2 conditional models. There is a very significant parameter estimate for the residual heterogeneity `scale`, which takes the value 1.1572 (S.E. 0.23703). This estimate of the `scale` effect is larger than the estimates of Task 1 and Task 2. The only covariate effect that is significant in the model for the initial condition is `r1_und5`. The estimates of the parameters for the time constant covariates in the subsequent response model, i.e. `r2_mune`, `r2_und5` are significant. The estimate `r2_age` is not significant.

Task 4. Re-estimate the model allowing the scale parameters for the initial and subsequent responses to be different.

Result/Discussion

Log likelihood = -463.55824 on 1414 residual degrees of freedom

Parameter	Estimate	Std. Err.
r1	1.5554	0.38557
r1_mune	-1.5126	0.98150
r1_und5	-2.4821	0.60308
r1_age	0.40872E-02	0.30345E-01
r2	-0.58392	0.26949
r2_ylag	3.3699	0.26373
r2_mune	-1.9135	0.47098
r2_und5	-1.1415	0.29341
r2_age	0.51288E-02	0.18080E-01
scale1	1.2085	0.47715
scale2	1.1424	0.26382

The estimates of **scale1** and **scale2** look very similar. The log likelihood of the common random effect model of Task 3 is -463.56628 and log likelihood of the random effects model of Task 4 is -463.55824. The change in log likelihood over the Task 3 model is $-2(-463.56628+463.55824)= 0.01608$. The sampling distribution of this test statistic is chi-square with 1 df. Under the null hypothesis **scale1** and **scale2** are equal. The test statistic is clearly not significant, suggesting that **scale1** and **scale2** are not significantly different from each other.

Task 5. In this model, replace the lagged female employment participation variable (**ylag**) with the initial or baseline response (**ybase**). Are these results different to those of Task 4?

Result/Discussion

Log likelihood = -547.21951 on 1414 residual degrees of freedom

Parameter	Estimate	Std. Err.
r1	1.3616	0.32490
r1_mune	-1.3711	0.90300
r1_und5	-2.1719	0.50052
r1_age	0.38719E-02	0.26628E-01
r2	0.77068	0.70389

r2_ybase	2.1017	1.0935
r2_mune	-2.5860	0.54281
r2_und5	-2.0783	0.30095
r2_age	0.21867E-01	0.24741E-01
scale1	0.70483	0.55268
scale2	2.7334	0.34122

The estimates of `scale1` and `scale2` now seem to be very different, in fact `scale1` looks to be non significant, perhaps the inclusion of `r2_ybase` in the model for the subsequent responses has captured the dependence between the two sub models. The log likelihood of the Task 5 model is -547.21951 which is much poorer than the model of Task 4 is -463.55824. The Task 4 and 5 models are not nested, so we can not formally compare the two models using a likelihood ratio test.

Task 6. In this model, include both the lagged response (`y1ag`) and the baseline response (`ybase`). Are these results different to those of Task 5?

Result/Discussion

Log likelihood = -463.52580 on 1413 residual degrees of freedom

Parameter	Estimate	Std. Err.
r1	1.4748	0.45687
r1_mune	-1.4938	0.94264
r1_und5	-2.3532	0.72203
r1_age	0.30407E-02	0.28941E-01
r2	-0.66531	0.41447
r2_y1ag	3.3563	0.26850
r2_ybase	0.15846	0.62399
r2_mune	-1.8982	0.47553
r2_und5	-1.1411	0.29391
r2_age	0.43770E-02	0.18278E-01
scale1	1.0035	0.87665
scale2	1.1246	0.26678

The log likelihood of the common scale different random effect model of Task 5 is -547.21951 and log likelihood of the model of Task 6 is -463.52580. The change in log likelihood over the Task 5 model is $-2(-547.21951+463.52580)=167.39$ The sampling distribution of this test statistic is chi-square with 1 df. Under the null hypothesis `r2_y1ag=0`. The test statistic for `r2_y1ag` not equal to 0 is clearly significant. The same result is given by the z statistic for the parameter estimate of `r2_y1ag` which is $3.3563/0.26850=12.5$. The z statistic for the parameter estimate of `r2_ybase` is $0.15846/0.62399=0.25395$ which is not significant. The estimates of `scale1` and `scale2` look very similar, as in the Task 4 model.

Task 7. Re-estimate the model with the baseline response (`ybase`) and the lagged response (`ylag`) using a bivariate model for the random effects (common scale).

Result/Discussion

Log likelihood = -463.53052 on 1413 residual degrees of freedom

Parameter	Estimate	Std. Err.
r1	1.5262	0.35220
r1_mune	-1.5241	0.86212
r1_und5	-2.4372	0.49228
r1_age	0.33644E-02	0.33696E-01
r2	-0.65442	0.40181
r2_ylag	3.3582	0.27252
r2_ybase	0.13621	0.64180
r2_mune	-1.8994	0.40353
r2_und5	-1.1409	0.26281
r2_age	0.44463E-02	0.17992E-01
scale	1.1244	0.24811
corr	0.94690	0.60503

There is not much difference between the log likelihood and results of the Task 4 model (log likelihood -463.55824), the Task 6 model (log likelihood -463.52580) and those of the Task 7 model (log likelihood -463.53052). This is reinforced by the fact that the estimate of `r2_ybase` is not significant in the Task 7 model and the 95% confidence interval on `corr` includes 1, a value which gives the common random effect model of Task 4 and the estimated different scales model of Task 6.

Task 8. Compare the results obtained for the various models on the covariates and role of employment status in the previous year. Are both state dependence and unobserved heterogeneity present in this data?

Result/Discussion

The results obtained for the various models (Task 4, 5, 6, 7) on the covariates and role of employment status in the previous year are very similar. In the joint models of Tasks 6 and 7 which contain both `r2_ylag` and `r2_ybase`, `r2_ybase` is not significant. The estimate of the state dependence effect (`r2_ylag`) in the Task 7 model is 3.3582 (S.E. 0.27252), it has a z statistic of $3.3582/0.27252=12.323$, which is very significant. Similar inference occurs in the Task 4, and 6 models. The 95% confidence interval on the `scale` parameter estimate does not include 0, suggesting the presence of residual heterogeneity. Both state dependence and unobserved heterogeneity present in this data.

27.3 Batch Script: FOL3.R

```
# save the log file
sink("FOL3.log")

# load sabreR
library(sabreR)

# read the data
wemp_base1 <- read.table("wemp_base1.tab")

attach(wemp_base1)

# look at the data
wemp_base1[1:10,1:15]

# 1st common RE model
sabre.model.1 <- sabre(femp~ylag+mune+und5+age,case=case,
                      adaptive.quad=TRUE)

# show the results
sabre.model.1

# 2nd common RE model
sabre.model.2 <- sabre(femp~ylag+ybase+mune+und5+age,case=case,
                      adaptive.quad=TRUE)

# show the results
sabre.model.2

# read the data
wemp_base2 <- read.table("wemp_base2.tab")

attach(wemp_base2)

# look at the data
wemp_base2[1:10,1:15]

# 1st RE model
sabre.model.3 <- sabre(femp~r1+(r1+r2):(mune+und5+age)+r2+r2:ylag,
                      case=case,adaptive.quad=TRUE)

# show the results
sabre.model.3

# 2nd RE model
sabre.model.4 <- sabre(femp[r==1]~mune[r==1]+und5[r==1]+age[r==1],
                      femp[r==2]~ylag[r==2]+mune[r==2]+und5[r==2]+
                      age[r==2],case=list(case[r==1],case[r==2]),
                      adaptive.quad=TRUE,depend=TRUE)

# show the results
sabre.model.4

# 3rd RE model
sabre.model.5 <- sabre(femp[r==1]~mune[r==1]+und5[r==1]+age[r==1],
                      femp[r==2]~ybase[r==2]+mune[r==2]+und5[r==2]+
                      age[r==2],case=list(case[r==1],case[r==2]),
                      adaptive.quad=TRUE,depend=TRUE)

# show the results
sabre.model.5
```

```

# 4th RE model
sabre.model.6 <- sabre(femp[r==1]~mune[r==1]+und5[r==1]+age[r==1],
                      femp[r==2]~ylag[r==2]+ybase[r==2]+mune[r==2]+
                      und5[r==2]+age[r==2],
                      case=list(case[r==1],case[r==2]),
                      adaptive.quad=TRUE,depend=TRUE)

# show the results
sabre.model.6

# 5th RE model
sabre.model.7 <- sabre(femp[r==1]~mune[r==1]+und5[r==1]+age[r==1],
                      femp[r==2]~ylag[r==2]+ybase[r==2]+mune[r==2]+
                      und5[r==2]+age[r==2],
                      case=list(case[r==1],case[r==2]),
                      adaptive.quad=TRUE,first.mass=24,
                      second.mass=24,equal.scale=TRUE,
                      only.first.derivatives=TRUE)

# show the results
sabre.model.7

detach(wemp_base1,wemp_base2)
rm(wemp_base1,wemp_base2,sabre.model.1,sabre.model.2,sabre.model.3,
   sabre.model.4,sabre.model.5,sabre.model.6,sabre.model.7)

sink()

```

28 Exercise FOC4. Poisson Model of Patents and R&D Expenditure

28.1 Relevant Results from FOC4.log and Discussion

Task 1. We are going to estimate several versions of the joint model of the initial and subsequent responses, to do this we will want the covariates to have different parameter estimates in the model for the initial conditions to those we want to obtain for the subsequent responses.

Result/Discussion

This implies that we will need either to create explicit interaction effects with the r1 and r2 indicators or do it implicitly with the model formula e.g.

```
pat~r1+(r1+r2):(logr+logk+scisect)+r2+r2:(year3+year4+year5
```

Task 2. The 1st model to be estimated has a common random effect for the baseline and subsequent responses but excludes the lagged response. Use the covariates: r1, r1_logr, r1_logk, r1_scisect for the baseline, and the covariates r2, r2_logr, r2_logk, r2_scisect, r2_year3, r2_year4, r2_year5 for the subsequent responses. Use adaptive quadrature with mass 36. Add the previous outcome, r2_pat1 to establish if we have a 1st order model. If this is significant we can add r2_base to establish whether the Wooldridge (2005) control adds anything to the model. Interpret your results?

Result/Discussion

(a) Common random effect model to baseline and subsequent responses without endogenous covariates.

Log likelihood =	-5109.3189	on	1668 residual degrees of freedom
Parameter	Estimate	Std. Err.	
-----	-----	-----	
r1	-0.31596	0.17375	
r1_logr	0.52562	0.37290E-01	
r1_logk	0.33700	0.41101E-01	
r1_scisect	0.50912	0.12782	
r2	-0.43888	0.16764	
r2_logr	0.48243	0.34783E-01	
r2_logk	0.37341	0.39376E-01	
r2_scisect	0.53284	0.12622	
r2_year3	-0.76923E-02	0.12885E-01	
r2_year4	-0.13744	0.13595E-01	
r2_year5	-0.18812	0.14428E-01	
scale	1.0262	0.49693E-01	

(b) Common random effect model to baseline and subsequent responses with `pat1`.

```

Log likelihood =      -5103.4358      on      1667 residual degrees of freedom

Parameter              Estimate              Std. Err.
-----
r1                      -0.31642              0.17251
r1_logr                 0.54497              0.37556E-01
r1_logk                 0.33078              0.40870E-01
r1_scisect              0.49212              0.12686
r2                      -0.39311              0.16681
r2_pat1                 0.30541E-03          0.89147E-04
r2_logr                 0.48773              0.34637E-01
r2_logk                 0.35968              0.39291E-01
r2_scisect              0.51490              0.12524
r2_year3                -0.62285E-02         0.12892E-01
r2_year4                -0.13618              0.13596E-01
r2_year5                -0.18114              0.14561E-01
scale                   1.0166                0.49293E-01

```

(c) Common random effect model to baseline and subsequent responses with `pat1` and `base`.

```

Log likelihood =      -5010.8108      on      1666 residual degrees of freedom

Parameter              Estimate              Std. Err.
-----
r1                      -0.32317              0.17456
r1_logr                 0.49949              0.37931E-01
r1_logk                 0.34851              0.41333E-01
r1_scisect              0.52671              0.12868
r2                      -0.48806              0.16923
r2_pat1                 0.20237E-02          0.15990E-03
r2_base                 -0.22065E-02         0.16540E-03
r2_logr                 0.48395              0.34898E-01
r2_logk                 0.38086              0.39783E-01
r2_scisect              0.54412              0.12710
r2_year3                0.37597E-02          0.12923E-01
r2_year4                -0.12636              0.13631E-01
r2_year5                -0.14101              0.14850E-01
scale                   1.0331                0.50124E-01

```

The log likelihood improves at each step, (a) -5109.3189, (b) -5103.4358, (c) -5010.8108. Each improvement has a significant chi square statistic (not shown), suggesting that both the endogenous covariates `pat1` and `base` are significant. The biggest improvement is between models b and c.

Task 3. Repeat Task 2 with a 1 factor model for the baseline and subsequent responses with adaptive quadrature, `mass 24` and accurate arithmetic.

Result/Discussion

(a) 1 factor random effect model to baseline and subsequent responses without endogenous covariates.

Log likelihood = -5108.0097 on 1667 residual degrees of freedom

Parameter	Estimate	Std. Err.
r1	-0.26999	0.17237
r1_logr	0.52802	0.36580E-01
r1_logk	0.33165	0.40372E-01
r1_scisect	0.49814	0.12521
r2	-0.43901	0.16837
r2_logr	0.48698	0.35072E-01
r2_logk	0.37082	0.39589E-01
r2_scisect	0.52956	0.12679
r2_year3	-0.78688E-02	0.12886E-01
r2_year4	-0.13788	0.13602E-01
r2_year5	-0.18886	0.14447E-01
scale1	1.0032	0.50564E-01
scale2	1.0306	0.49942E-01

(b) 1 factor random effect model to baseline and subsequent responses with pat1.

Log likelihood = -5103.4351 on 1666 residual degrees of freedom

Parameter	Estimate	Std. Err.
r1	-0.31766	0.17572
r1_logr	0.54503	0.37613E-01
r1_logk	0.33088	0.40981E-01
r1_scisect	0.49230	0.12702
r2	-0.39283	0.16695
r2_pat1	0.30716E-03	0.10051E-03
r2_logr	0.48764	0.34711E-01
r2_logk	0.35967	0.39286E-01
r2_scisect	0.51488	0.12522
r2_year3	-0.62152E-02	0.12896E-01
r2_year4	-0.13616	0.13605E-01
r2_year5	-0.18108	0.14645E-01
scale1	1.0172	0.51527E-01
scale2	1.0164	0.49497E-01

(c) 1 factor random effect model to baseline and subsequent responses with pat1 and base.

Log likelihood = -5004.1494 on 1665 residual degrees of freedom

Parameter	Estimate	Std. Err.
r1	-0.19313	0.16899
r1_logr	0.48936	0.36085E-01
r1_logk	0.33873	0.39252E-01
r1_scisect	0.51002	0.12193
r2	-0.53394	0.17326
r2_pat1	0.19393E-02	0.16226E-03
r2_base	-0.24280E-02	0.18114E-03
r2_logr	0.49286	0.35658E-01
r2_logk	0.38638	0.40635E-01
r2_scisect	0.55199	0.12987
r2_year3	0.27664E-02	0.12928E-01
r2_year4	-0.12795	0.13653E-01
r2_year5	-0.14462	0.14929E-01
scale1	0.97767	0.49653E-01
scale2	1.0560	0.51557E-01

The log likelihood improves at each step, (a) -5108.0097, (b) -5103.4351, (c) -5004.1494. Each improvement has a significant chi square statistic (not shown), suggesting that both the endogenous covariates `pat1` and `base` are significant. The biggest improvement is between models b and c.

Task 4. Repeat Task 3 using a bivariate model for the baseline and subsequent responses with adaptive quadrature, `mass 36` in both dimensions and with accurate arithmetic.

Result/Discussion

(a) Bivariate random effect model to baseline and subsequent responses without endogenous covariates.

Log likelihood = -4994.0714 on 1666 residual degrees of freedom

Parameter	Estimate	Std. Err.
r1	-0.17586	0.17752
r1_logr	0.56408	0.42068E-01
r1_logk	0.30412	0.43150E-01
r1_scisect	0.45684	0.12411
r2	-0.34140	0.17148
r2_logr	0.53246	0.37611E-01
r2_logk	0.33564	0.40939E-01

r2_scisect	0.47559	0.12796
r2_year3	-0.94811E-02	0.12894E-01
r2_year4	-0.14219	0.13657E-01
r2_year5	-0.19627	0.14609E-01
scale1	0.95748	0.50841E-01
scale2	1.0307	0.49924E-01
corr	0.97055	0.65365E-02

(b) Bivariate random effect model to baseline and subsequent responses with pat1.

Log likelihood = -4964.8702 on 1665 residual degrees of freedom

Parameter	Estimate	Std. Err.
r1	-0.21356	0.18249
r1_logr	0.59108	0.43822E-01
r1_logk	0.29866	0.44499E-01
r1_scisect	0.44247	0.12650
r2	-0.24339	0.16758
r2_pat1	0.11669E-02	0.15559E-03
r2_logr	0.52925	0.37078E-01
r2_logk	0.30651	0.40216E-01
r2_scisect	0.43689	0.12443
r2_year3	-0.34130E-02	0.12921E-01
r2_year4	-0.13639	0.13671E-01
r2_year5	-0.16896	0.15006E-01
scale1	0.96908	0.52022E-01
scale2	0.99743	0.48700E-01
corr	0.96375	0.76988E-02

(c) Bivariate random effect model to baseline and subsequent responses with pat1 and base.

Log likelihood = -4954.9182 on 1664 residual degrees of freedom

Parameter	Estimate	Std. Err.
r1	-0.17134	0.17566
r1_logr	0.55253	0.41689E-01
r1_logk	0.30843	0.42315E-01
r1_scisect	0.46404	0.12315
r2	-0.37801	0.17492
r2_pat1	0.14635E-02	0.16918E-03
r2_base	-0.16876E-02	0.34728E-03
r2_logr	0.53407	0.37547E-01
r2_logk	0.34224	0.41798E-01

r2_scisect	0.48522	0.12904
r2_year3	-0.19797E-02	0.12931E-01
r2_year4	-0.13535	0.13689E-01
r2_year5	-0.16317	0.15090E-01
scale1	0.95599	0.50521E-01
scale2	1.0372	0.51278E-01
corr	0.97859	0.55435E-02

The log likelihood improves at each step, (a) -4994.0714, (b) -4964.8702, (c) -4954.9182. Each improvement has a significant chi square statistic (not shown), suggesting that both the endogenous covariates `pat1` and `base` are significant. The biggest improvement is between models a and b.

Task 5. Compare the results, which is your preferred model and why?

Result/Discussion

In all 3 Tasks the preferred model is model c. All 3 Tasks suggest the presence of a positive effect for the lagged response for the number of patents applied for during the previous year. We are unaware of anyone else who has found this effect in this data. The three models of Task 2 and 3 are very similar. The Task 4 model is the most general of the 3 forms of random effect model that we have fitted. Task 4 model c is the best fitting model and a 95% confidence interval on `corr` does not include 1. The `scale1` and `scale2` parameters of Task 4 model c, are very similar. The significance of `base` in Task 4 model c, is lower than it is in Task 2 and 3.

The fact that `base` is significant in Task 4 model c, suggests that we have not been able to fully account for the initial conditions in this data. Perhaps higher order effects are present. We also suspect that there may be selection effects on the number of patents applied for, as there are very few firms with zero patents at all years in the data, if so its likely that there will be a correlation between the included and random effects.

28.2 Batch Script: F0C4.do

```
# save the log file
sink("F0C4.log")

library(sabreR)

# read the data
patents <- read.table("patents.tab")
attach(patents)

# look at the data
patents[1:10,1:10]

sabre.model.1 <- sabre(pat~r1+(r1+r2):(logr+logk+scisect)+r2+
                      r2:(year3+year4+year5)-1,case=cusip,
```

```

        first.family="poisson",adaptive.quad="TRUE",
        first.mass=36)

sabre.model.1

sabre.model.2 <- sabre(pat~r1+(r1+r2):(logr+logk+scisect)+r2+
        r2:(pat1+year3+year4+year5)-1,case=cusip,
        first.family="poisson",adaptive.quad="TRUE",
        first.mass=36)

sabre.model.2

sabre.model.3 <- sabre(pat~r1+(r1+r2):(logr+logk+scisect)+r2+
        r2:(pat1+base+year3+year4+year5)-1,case=cusip,
        first.family="poisson",adaptive.quad="TRUE",
        first.mass=36,
        convergence=5e-5)

sabre.model.3

sabre.model.4 <- sabre(pat[r==1]^logr[r==1]+logk[r==1]+scisect[r==1],
        pat[r==2]^logr[r==2]+logk[r==2]+scisect[r==2]+
        year3[r==2]+year4[r==2]+year5[r==2],
        case=list(cusip[r==1],cusip[r==2]),
        first.family="poisson",adaptive.quad="TRUE",
        first.mass=24,depend=TRUE)

sabre.model.4

sabre.model.5 <- sabre(pat[r==1]^logr[r==1]+logk[r==1]+scisect[r==1],
        pat[r==2]^pat1[r==2]+logr[r==2]+logk[r==2]+
        scisect[r==2]+year3[r==2]+year4[r==2]+
        year5[r==2],
        case=list(cusip[r==1],cusip[r==2]),
        first.family="poisson",adaptive.quad="TRUE",
        first.mass=24,depend=TRUE,
        arithmetic.type="accurate")

sabre.model.5

sabre.model.6 <- sabre(pat[r==1]^logr[r==1]+logk[r==1]+scisect[r==1],
        pat[r==2]^pat1[r==2]+base[r==2]+logr[r==2]+
        logk[r==2]+scisect[r==2]+year3[r==2]+
        year4[r==2]+year5[r==2],
        case=list(cusip[r==1],cusip[r==2]),
        first.family="poisson",adaptive.quad="TRUE",
        first.mass=24,depend=TRUE,
        arithmetic.type="accurate")

sabre.model.6

#sabre.model.7 <- sabre(pat[r==1]^logr[r==1]+logk[r==1]+scisect[r==1],
#
#        pat[r==2]^logr[r==2]+logk[r==2]+scisect[r==2]+
#        year3[r==2]+year4[r==2]+year5[r==2],
#        case=list(cusip[r==1],cusip[r==2]),
#        first.family="poisson",
#        second.family="poisson",adaptive.quad="TRUE",
#        first.mass=36,second.mass=36,
#        arithmetic.type="accurate")

#sabre.model.7

```

```

#sabre.model.8 <- sabre(pat[r==1]~logr[r==1]+logk[r==1]+scisect[r==1],
#
#       pat[r==2]~pat1[r==2]+logr[r==2]+logk[r==2]+
#       scisect[r==2]+year3[r==2]+year4[r==2]+
#       year5[r==2],
#       case=list(cusip[r==1],cusip[r==2]),
#       first.family="poisson",
#       second.family="poisson",adaptive.quad="TRUE",
#       first.mass=36,second.mass=36,
#       arithmetic.type="accurate")

#sabre.model.8

#sabre.model.9 <- sabre(pat[r==1]~logr[r==1]+logk[r==1]+scisect[r==1],
#
#       pat[r==2]~pat1[r==2]+base[r==2]+logr[r==2]+
#       logk[r==2]+scisect[r==2]+year3[r==2]+
#       year4[r==2]+year5[r==2],
#       case=list(cusip[r==1],cusip[r==2]),
#       first.family="poisson",
#       second.family="poisson",adaptive.quad="TRUE",
#       first.mass=36,second.mass=36,
#       arithmetic.type="accurate")

#sabre.model.9

detach(patents)
rm(patents,sabre.model.1,sabre.model.2,sabre.model.3,sabre.model.4,
  sabre.model.5,sabre.model.6)
#rm(patents,sabre.model.1,sabre.model.2,sabre.model.3,sabre.model.4,
#   sabre.model.5,sabre.model.6,sabre.model.7,sabre.model.8,
#   sabre.model.9)

sink()

```

29 Exercise FE1. Linear Model for the Effect of Job Training on Firm Scrap Rates

29.1 Relevant Results from FE1.log and Discussion

Task 1. Estimate a homogeneous linear model for the response `lscrap`, with covariates `grant`, `d89`, `d88` and `grant_1`. Estimate the same model using the fixed firm effects (`fcode`). What is the main difference between the results from the alternative estimators?

Result/Discussion

Homogeneous linear model

Log likelihood = -292.16964 on 156 residual degrees of freedom

Parameter	Estimate	Std. Err.
cons	0.59743	0.20306
d88	-0.23937	0.31086
d89	-0.49652	0.33793
grant	0.20002	0.33828
grant_1	0.48936E-01	0.43607
sigma	1.4922	

Fixed effects model

Parameter	Estimate	Std. Err.
d88	-0.80216E-01	0.11001
d89	-0.24720	0.13386
grant	-0.25231	0.15136
grant_1	-0.42159	0.21122
sigma	0.50015	

None of the estimated covariate parameters are significant in the homogenous linear model. In the fixed effects model, both the estimated parameters for `grant` and `grant_1` are negative, and that for `grant_1` is significant, with z statistic $-0.42159/0.21122 = -1.996$. The fixed effects model suggests that firms receiving a training grant have lower scrap rates the following year than those that do not, perhaps this is indicating improved productivity. The problem with this interpretation is that `grant` and `grant_1` are not randomly allocated as firms have chosen whether or not to apply for grants and not all firms applied.

The coefficient on `d89` is of marginal significance. The value of `sigma` is much smaller in the fixed effects model. The fact that the estimates from the homogenous and fixed effects models are different, suggests that incidental parameters are present.

Task 2. Re-estimate the models of Task 1 without the lagged grant indicator (`grant_1`). Is the model a poorer fit to the data?

Result/Discussion

Homogeneous linear model

Log likelihood = -292.17613 on 157 residual degrees of freedom

Parameter	Estimate	Std. Err.
cons	0.59743	0.20243
d88	-0.23641	0.30877
d89	-0.47775	0.29268
grant	0.19161	0.32884
sigma	1.4875	

Fixed effects model

Parameter	Estimate	Std. Err.
d88	-0.14007	0.10735
d89	-0.42704	0.10041
grant	-0.82214E-01	0.12687
sigma	0.50728	

None of the estimated covariate parameters are significant in the homogenous linear model. In the fixed effects model the estimated parameter for `d89` is very significant. The fixed effects model is suggesting that firms reduced their scrap rates in 1989, but that `grant` had no effect. The value of `sigma` is much smaller in the fixed effects model.

The log likelihood of the homogeneous model of Task 1 is -292.16964 and log likelihood of the homogeneous model of Task 2 is -292.17613. The change in log likelihood is $-2(-292.17613+292.16964) = 0.01298$. The sampling distribution of this test statistic is chi-square with 1 df. Under the null hypothesis `grant_1=0`. The test statistic is clearly not significant, suggesting that `grant_1=0`. The same inference is made by the z statistic for `grant_1`. The fact that the estimates from the homogeneous and fixed effects models are different, suggests that incidental parameters are present. There is no log likelihood that we can use to compare models for the fixed effects estimator.

Task 3. What does the coefficient for `d89` suggest in your preferred model?

Result/Discussion

My preferred model is the fixed effects model of Task 1. The negative estimated parameter on `d89`, suggests that 1989 had lower scrap rates than either 1987 or 1988.

Task 4. Re-estimate the fixed effects models of Tasks 1 and 2 using adaptive quadrature and mass 12. Compare the fixed and random effect model inferences. What do you find?

Result/Discussion

Random effects model with `grant_1`.

Log likelihood =	-201.25249	on	155 residual degrees of freedom
Parameter	Estimate	Std. Err.	

cons	0.59743	0.20118	
d88	-0.93319E-01	0.10701	
d89	-0.27095	0.12916	
grant	-0.21507	0.14515	
grant_1	-0.37369	0.20165	
sigma	0.48861	0.33268E-01	
scale	1.3953	0.14000	

Random effects model without `grant_1`.

Log likelihood =	-202.93415	on	156 residual degrees of freedom
Parameter	Estimate	Std. Err.	

cons	0.59743	0.20031	
d88	-0.14510	0.10525	
d89	-0.42969	0.98513E-01	
grant	-0.67913E-01	0.12384	
sigma	0.49783	0.33877E-01	
scale	1.3852	0.13912	

The log likelihood of the random effects model with `grant_1` is -201.25249 and log likelihood of the model without is -202.93415. The change in log likelihood is $-2(-202.93415+201.25249)= 3.3633$. The sampling distribution of this test statistic is chi-square with 1 df, and suggests that `grant_1` is not significant, the z statistic for `grant_1` gives a similar result. It may be worth estimating a model without `grant` but with `grant_1`.

Both the models of Task 4 are significant improvements over their respective homogenous versions (Task 1 and 2), suggesting that random effects are present. The differences between the parameter estimates of the fixed effect and random effect version of the same model suggests that the assumption of independence between the random effects and the included covariates may not hold.

29.2 Batch Script: FE1.do

```
# save the log file
sink("FE1.log")

# use the sabreR library
library(sabreR)

# read the data
jtrain <- read.table("jtrain.tab")
attach(jtrain)

# look at the 1st 10 lines and columns
jtrain[1:10,1:10]

# estimate the 1st FE model
sabre.model.1 <- sabre(lscrap~d88+d89+grant+grant_1-1,case=fcode,
                      first.family="gaussian",fixed.effects=TRUE)

# show the results
sabre.model.1

# estimate the 2nd FE model
sabre.model.2 <- sabre(lscrap~d88+d89+grant-1,case=fcode,
                      first.family="gaussian",fixed.effects=TRUE)

# show the results
sabre.model.2

# estimate the 1st RE model
sabre.model.3 <- sabre(lscrap~d88+d89+grant+grant_1,case=fcode,
                      first.family="gaussian",adaptive.quad=TRUE)

# show the results
sabre.model.3

# estimate the 2nd RE model
sabre.model.4 <- sabre(lscrap~d88+d89+grant,case=fcode,
                      first.family="gaussian",adaptive.quad=TRUE)

# show the results
sabre.model.4

# remove the created objects
detach(jtrain)
rm(jtrain,sabre.model.1,sabre.model.2,sabre.model.3,sabre.model.4)

# close the log file
sink()
```

30 Exercise FE2. Linear Model to Establish if the Returns to Education Changed over Time

30.1 Relevant Results from FE2.log and Discussion

Task 1. To establish if the returns to education have changed over time we need to start by creating interaction effects for `educ` with the year dummy variables (`d81, d82, ..., d87`), call these effects `edd81-edd97` respectively.

Result/Discussion

This can be done explicitly or implicitly in the model formula, e.g.

```
lwage~expersq+union+married+d81+d82+d83+d84+
      d85+d86+d87+educ:(d81+d82+d83+d84+d85+d86+
      d87
```

Task 2. Estimate a homogeneous linear model for the response `lwage` with the covariates `expersq`, `union`, `married`, `d81-d87`, `edd81-edd97`. Re-estimate the model using the respondent fixed effects (`nr`). What is the main difference between the results from the alternative estimators?

Result/Discussion

Homogeneous linear model

Log likelihood = -3023.3871 on 4341 residual degrees of freedom

Parameter	Estimate	Std. Err.
cons	1.3126	0.21684E-01
expersq	0.10610E-02	0.33426E-03
union	0.17733	0.17140E-01
married	0.12840	0.15590E-01
d81	-0.81625	0.14562
d82	-0.82033	0.14716
d83	-0.83814	0.14920
d84	-0.80049	0.15190
d85	-0.84403	0.15531
d86	-0.85702	0.15944
d87	-0.88431	0.16439
edd81	0.77787E-01	0.12085E-01
edd82	0.81445E-01	0.12158E-01
edd83	0.85194E-01	0.12239E-01
edd84	0.86192E-01	0.12334E-01
edd85	0.92685E-01	0.12443E-01

edd86	0.97193E-01	0.12553E-01
edd87	0.10227	0.12675E-01
sigma	0.48508	

Fixed effects model

Parameter	Estimate	Std. Err.
expersq	-0.60437E-02	0.86338E-03
union	0.78976E-01	0.19335E-01
married	0.47434E-01	0.18330E-01
d81	0.98420E-01	0.14602
d82	0.24720	0.14940
d83	0.40881	0.15574
d84	0.63992	0.16526
d85	0.77294	0.17801
d86	0.96993	0.19420
d87	1.1888	0.21361
edd81	0.49906E-02	0.12224E-01
edd82	0.16510E-02	0.12332E-01
edd83	-0.26621E-02	0.12511E-01
edd84	-0.98257E-02	0.12761E-01
edd85	-0.92145E-02	0.13074E-01
edd86	-0.12138E-01	0.13444E-01
edd87	-0.15789E-01	0.13870E-01
sigma	0.35119	

Most of the estimated covariate parameters are significant in the homogenous linear model. The fixed effects covariate parameter model estimates are very different to those of the homogeneous linear model, also non of the interaction effects of `educ` with year are significant in the fixed effects model.

The value of `sigma` is smaller in the fixed effects model. The fact that the estimates from the homogenous and fixed effects models are different, suggests that incidental parameters are present.

Task 3. Re-estimate the models of Task 2 without the time varying effects of education (`edd81-edd97`). Is the model a poorer fit to the data?

Result/Discussion

Homogeneous linear model

Log likelihood =	-3149.2321	on	4348 residual degrees of freedom
Parameter	Estimate	Std. Err.	
cons	1.3454	0.22199E-01	

expersq	-0.20775E-02	0.27670E-03
union	0.17680	0.17624E-01
married	0.15213	0.15943E-01
d81	0.11869	0.30320E-01
d82	0.18434	0.30638E-01
d83	0.24312	0.31337E-01
d84	0.33215	0.32448E-01
d85	0.41121	0.34132E-01
d86	0.50387	0.36497E-01
d87	0.59522	0.39612E-01
sigma	0.49889	

Fixed effects model

Parameter	Estimate	Std. Err.
expersq	-0.51855E-02	0.70453E-03
union	0.80002E-01	0.19313E-01
married	0.46680E-01	0.18313E-01
d81	0.15119	0.21952E-01
d82	0.25297	0.24422E-01
d83	0.35444	0.29246E-01
d84	0.49011	0.36231E-01
d85	0.61748	0.45249E-01
d86	0.76550	0.56135E-01
d87	0.92502	0.68782E-01
sigma	0.35104	

The log likelihood of the homogeneous model of Task 1 is -3023.3871 and log likelihood of the homogeneous model of Task 2 is -3149.2321. The change in log likelihood is $-2(-3149.2321+3023.3871)= 251.69$. The sampling distribution of this test statistic is chi-square with 7 df. Under the null hypothesis the interaction effects of educ with year take the value 0. The test statistic is clearly significant, suggesting that these interaction effects are present in the model. However, this inference is not supported by the fixed effect model of Task 2.

The fact that the estimates from the homogenous and fixed effects models of Task 3 are different, suggests that incidental parameters are present. The common covariate parameter estimates from the fixed effect model from Task 2 and Task 3 are very similar, and the fixed effects model of Task 3 is more parsimonious. There is no log likelihood that we can use to compare models for the fixed effects estimator.

Task 4. Re-estimate the fixed effects model of Task 2 using adaptive quadrature with mass 12. Compare the fixed and random effect model inferences. What do you find?

Result/Discussion

Log likelihood = -2943.6408 on 4341 residual degrees of freedom

Parameter	Estimate	Std. Err.
expersq	-0.22011E-02	0.84074E-03
union	0.11906	0.19420E-01
married	0.77160E-01	0.18343E-01
d81	0.76501E-01	0.14475
d82	0.14187	0.14836
d83	0.20791	0.15482
d84	0.33558	0.16434
d85	0.36988	0.17689
d86	0.45310	0.19274
d87	0.54148	0.21175
edd81	0.11842E-01	0.12115E-01
edd82	0.12442E-01	0.12244E-01
edd83	0.12459E-01	0.12441E-01
edd84	0.96787E-02	0.12704E-01
edd85	0.13763E-01	0.13023E-01
edd86	0.14902E-01	0.13398E-01
edd87	0.15852E-01	0.13828E-01
sigma	0.35294	0.41047E-02
scale	1.3442	0.45440E-01

The log likelihood of the random effects model is -2943.6408 and log likelihood of the homogeneous model is -3023.3871. The change in log likelihood is $-2(-3023.3871+2943.6408)=159.49$. The sampling distribution of this test statistic is not chi-square with 1 df. Under the null hypothesis `scale` has the value 0, it can only take values >0 under the alternative. The correct p value for this test statistics is obtained by dividing the naive p value of 159.49 for 1 degree of freedom by $1/2$, and so its clearly significant.

There are some differences between the parameter estimates of the fixed effect and random effect versions of the same model, but these differences are not large, e.g. both models find no evidence for an interaction between `educ` and `year`. Perhaps the assumption of independence between the random effects and the included covariates holds, but further analysis is needed to confirm this.

30.2 Batch Script: FE2.R

```
# save the log file
sink("FE2.log")

# use the sabreR library
library(sabreR)

# read the data
wagepan2 <- read.table("wagepan2.tab")
attach(wagepan2)

# look at the 1st 10 lines and columns
wagepan2[1:10,1:10]
```

```

# estimate the 1st FE model
sabre.model.1 <- sabre(lwage~expersq+union+married+d81+d82+d83+d84+
                      d85+d86+d87+educ:(d81+d82+d83+d84+d85+d86+
                      d87)-1,case=nr,first.family="gaussian",
                      fixed.effects=TRUE)

# show the results
sabre.model.1

# estimate the 2nd FE model
sabre.model.2 <- sabre(lwage~expersq+union+married+d81+d82+d83+d84+
                      d85+d86+d87-1,case=nr,first.family="gaussian",
                      fixed.effects=TRUE)

# show the results
sabre.model.2

# estimate the 1st RE model
sabre.model.3 <- sabre(lwage~expersq+union+married+d81+d82+d83+d84+
                      d85+d86+d87+educ:(d81+d82+d83+d84+d85+d86+
                      d87)-1,case=nr,first.family="gaussian",
                      adaptive.quad=TRUE)

# show the results
sabre.model.3

# remove the created objects
detach(wagepan2)
rm(wagepan2,sabre.model.1,sabre.model.2,sabre.model.3)

# close the log file
sink()

```