5–Comparing_groups_tests.R

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```
# R code snippets from slides for Chapman & Feit 2015
# Slide file: Chapter6/Chapter6-ChapmanFeit

# All code is (c) 2015, Springer. http://r-marketing.r-forge.r-project.org/

# ==========


# Load the data (same as Chapter 5)
# ==========
seg.df <- read.csv("http://goo.gl/qw303p")
summary(seg.df)
```

```
##       age           gender              income            kids     
##  Min.   :19.26   Length:300         Min.   : -5183   Min.   :0.00  
##  1st Qu.:33.01   Class :character   1st Qu.: 39656   1st Qu.:0.00  
##  Median :39.49   Mode  :character   Median : 52014   Median :1.00  
##  Mean   :41.20                      Mean   : 50937   Mean   :1.27  
##  3rd Qu.:47.90                      3rd Qu.: 61403   3rd Qu.:2.00  
##  Max.   :80.49                      Max.   :114278   Max.   :7.00  
##    ownHome           subscribe           Segment         
##  Length:300         Length:300         Length:300        
##  Class :character   Class :character   Class :character  
##  Mode  :character   Mode  :character   Mode  :character  
##                                                          
##                                                          
##
```

```
# Chi-square test
# ==========
tmp.tab <- table(rep(c(1:4), times=c(25,25,25,20)))
tmp.tab
```

```
## 
##  1  2  3  4 
## 25 25 25 20
```

```
chisq.test(tmp.tab)
```

```
## 
##  Chi-squared test for given probabilities
## 
## data:  tmp.tab
## X-squared = 0.78947, df = 3, p-value = 0.852
```

```r
# chisq.test "significant" and "not significant"
# ==========
tmp.tab <- table(rep(c(1:4), times=c(25,25,25,20)))
chisq.test(tmp.tab)
```

```
##
##  Chi-squared test for given probabilities
##
## data:  tmp.tab
## X-squared = 0.78947, df = 3, p-value = 0.852
```

```r
tmp.tab <- table(rep(c(1:4), times=c(25,25,25,10)))
tmp.tab
```

```
##
##  1  2  3  4
## 25 25 25 10
```

```r
chisq.test(tmp.tab)
```

```
##
##  Chi-squared test for given probabilities
##
## data:  tmp.tab
## X-squared = 7.9412, df = 3, p-value = 0.04724
```

```r
# chisq.test with segment data
# ==========
table(seg.df$Segment)
```

```
##
##  Moving up Suburb mix  Travelers  Urban hip
##         70        100         80         50
```

```r
chisq.test(table(seg.df$Segment))
```

```
##
##  Chi-squared test for given probabilities
##
## data:  table(seg.df$Segment)
## X-squared = 17.333, df = 3, p-value = 0.0006035
```

```r
# chisq.test with segment data
# ==========
table(seg.df$subscribe, seg.df$ownHome)
```

```
##
##          ownNo ownYes
##   subNo    137    123
##   subYes    22     18
```

```r
chisq.test(table(seg.df$subscribe, seg.df$ownHome))
```

```
##
##  Pearson's Chi-squared test with Yates' continuity correction
##
## data:  table(seg.df$subscribe, seg.df$ownHome)
## X-squared = 0.010422, df = 1, p-value = 0.9187
```

```r
chisq.test(table(seg.df$subscribe, seg.df$ownHome), correct=FALSE)
```

```
##
##  Pearson's Chi-squared test
##
## data:  table(seg.df$subscribe, seg.df$ownHome)
## X-squared = 0.074113, df = 1, p-value = 0.7854
```

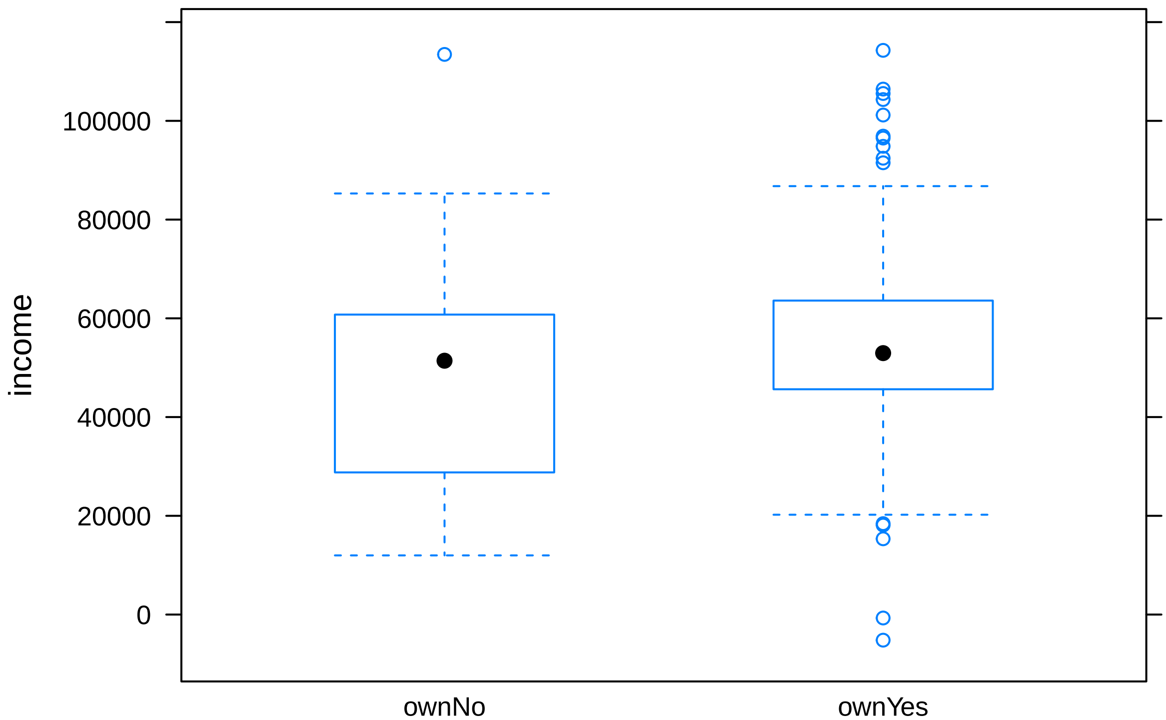
```r
# Proportions: binomial test
# ==========
binom.test(12, 20, p=0.5)
```

```
##
##  Exact binomial test
##
## data:  12 and 20
## number of successes = 12, number of trials = 20, p-value = 0.5034
## alternative hypothesis: true probability of success is not equal to 0.5
## 95 percent confidence interval:
##  0.3605426 0.8088099
## sample estimates:
## probability of success
##                    0.6
```

```r
# Proportions: binomial test continued
# ==========
# binom.test(12, 20, p=0.5)
binom.test(120, 200, p=0.5)
```

```
##
##  Exact binomial test
##
## data:  120 and 200
## number of successes = 120, number of trials = 200, p-value = 0.005685
## alternative hypothesis: true probability of success is not equal to 0.5
## 95 percent confidence interval:
##  0.5285357 0.6684537
## sample estimates:
## probability of success
##                    0.6
```

```r
# t-tests
# ==========
library(lattice)
bwplot(income ~ ownHome, data=seg.df)
```




```
# t.test()
# ==========
t.test(income ~ ownHome, data=seg.df)
```

```
##
##  Welch Two Sample t-test
##
## data:  income by ownHome
## t = -3.2731, df = 285.25, p-value = 0.001195
## alternative hypothesis: true difference in means between group ownNo and group ownYes is not equal to
## 95 percent confidence interval:
##  -12080.155  -3007.193
## sample estimates:
##  mean in group ownNo mean in group ownYes
##             47391.01             54934.68
```

```
# t.test() for a subset() of data
# ==========
t.test(income ~ ownHome, data=subset(seg.df, Segment=="Travelers"))
```

```
##
##  Welch Two Sample t-test
##
## data:  income by ownHome
## t = 0.26561, df = 53.833, p-value = 0.7916
## alternative hypothesis: true difference in means between group ownNo and group ownYes is not equal to
## 95 percent confidence interval:
##  -8508.993 11107.604
## sample estimates:
##  mean in group ownNo mean in group ownYes
##             63188.42             61889.12
```

```r
# ANOVA basics
# ==========
seg.aov.own <- aov(income ~ ownHome, data=seg.df)
anova(seg.aov.own)
```

```
## Analysis of Variance Table
##
## Response: income
##            Df     Sum Sq    Mean Sq F value   Pr(>F)
## ownHome     1 4.2527e+09 4252661211  10.832 0.001118 **
## Residuals 298 1.1700e+11  392611030
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

```r
# ANOVA: Multiple groups
# ==========
aggregate(income ~ Segment, mean, data=seg.df)
```

```
##      Segment   income
## 1  Moving up 53090.97
## 2 Suburb mix 55033.82
## 3  Travelers 62213.94
## 4  Urban hip 21681.93
```

```r
seg.aov.seg <- aov(income ~ Segment, data=seg.df)
anova(seg.aov.seg)
```

```
## Analysis of Variance Table
##
## Response: income
##            Df     Sum Sq    Mean Sq F value    Pr(>F)
## Segment     3 5.4970e+10 1.8323e+10  81.828 < 2.2e-16 ***
## Residuals 296 6.6281e+10 2.2392e+08
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

```r
# ANOVA with Segment + Ownership
# ==========
anova(aov(income ~ Segment + ownHome, data=seg.df))
```

```
## Analysis of Variance Table
##
## Response: income
##            Df     Sum Sq    Mean Sq F value Pr(>F)
## Segment     3 5.4970e+10 1.8323e+10 81.6381 <2e-16 ***
## ownHome     1 6.9918e+07 6.9918e+07  0.3115 0.5772
## Residuals 295 6.6211e+10 2.2444e+08
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

```r
anova(aov(income ~ ownHome, data=seg.df))
```

```
## Analysis of Variance Table
##
## Response: income
##            Df     Sum Sq    Mean Sq F value   Pr(>F)
## ownHome     1 4.2527e+09 4252661211  10.832 0.001118 **
```

```
## Residuals 298 1.1700e+11  392611030
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

```r
# ANOVA with interaction
# ==========
anova(aov(income ~ Segment * ownHome, data=seg.df))
```

```
## Analysis of Variance Table
##
## Response: income
##                  Df     Sum Sq    Mean Sq F value Pr(>F)
## Segment           3 5.4970e+10 1.8323e+10 81.1305 <2e-16 ***
## ownHome           1 6.9918e+07 6.9918e+07  0.3096 0.5784
## Segment:ownHome   3 2.6329e+08 8.7762e+07  0.3886 0.7613
## Residuals       292 6.5948e+10 2.2585e+08
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

```r
anova(aov(income ~ Segment + ownHome + Segment:ownHome, data=seg.df))
```

```
## Analysis of Variance Table
##
## Response: income
##                  Df     Sum Sq    Mean Sq F value Pr(>F)
## Segment           3 5.4970e+10 1.8323e+10 81.1305 <2e-16 ***
## ownHome           1 6.9918e+07 6.9918e+07  0.3096 0.5784
## Segment:ownHome   3 2.6329e+08 8.7762e+07  0.3886 0.7613
## Residuals       292 6.5948e+10 2.2585e+08
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

```r
# Model Comparison
# ==========
anova(aov(income ~ Segment,           data=seg.df),
      aov(income ~ Segment + ownHome, data=seg.df))
```

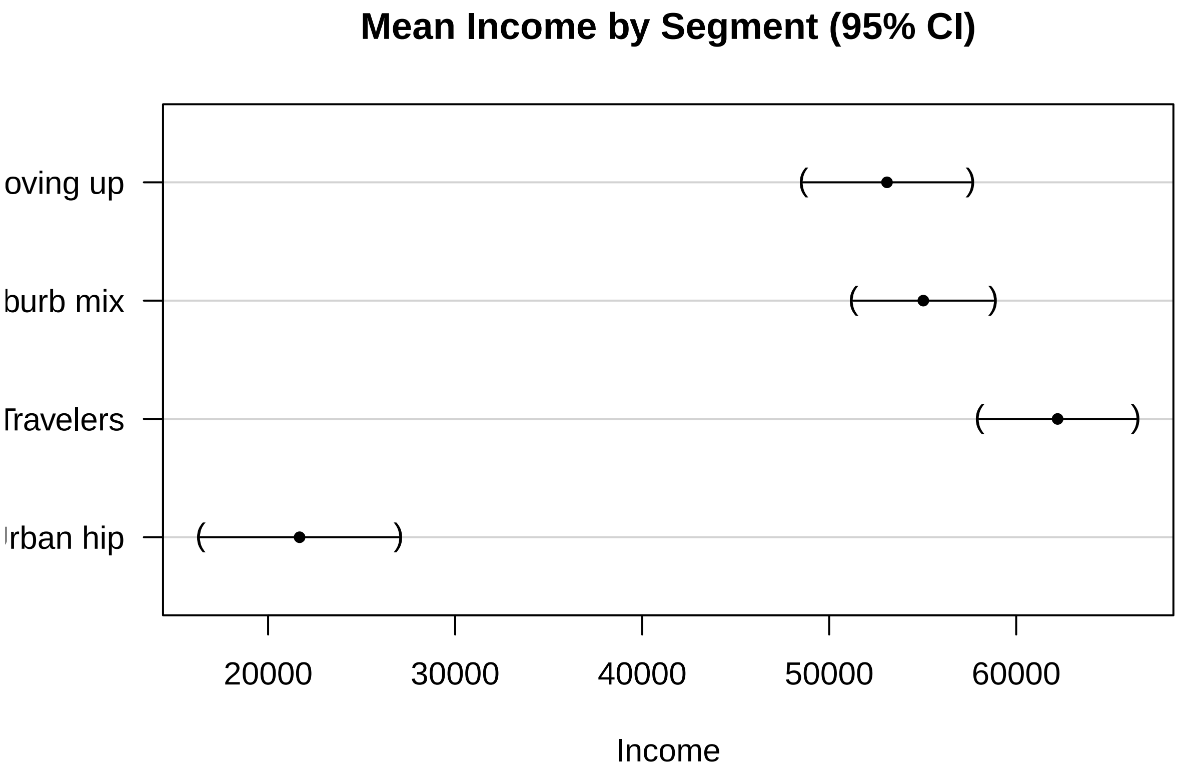
```
## Analysis of Variance Table
##
## Model 1: income ~ Segment
## Model 2: income ~ Segment + ownHome
##   Res.Df        RSS Df Sum of Sq      F Pr(>F)
## 1    296 6.6281e+10
## 2    295 6.6211e+10  1  69918004 0.3115 0.5772
```

```r
# Visualization: ANOVA Group means
# ==========
# install.packages("multcomp")     # if needed
library(multcomp)
```

```
## Loading required package: mvtnorm

## Loading required package: survival

## Loading required package: TH.data

## Loading required package: MASS

##
```

```
## Attaching package: 'TH.data'

## The following object is masked from 'package:MASS':
##
##     geyser
```

```
seg.aov <- aov(income ~ -1 + Segment, data=seg.df)    # model w/o int.
by.seg  <- glht(seg.aov)                              # means and CIs
plot(by.seg, xlab="Income", main="Mean Income by Segment (95% CI)")
```




```
# Exercises (Basic)
# ==========
library(car)     # install.packages("car") if needed
```

```
## Loading required package: carData
```

```
data(Salaries)


# Answers (1)
# ==========
with(Salaries, prop.table(table(discipline, sex), margin=1))
```

```
##           sex
## discipline     Female       Male
##          A 0.09944751 0.90055249
##          B 0.09722222 0.90277778
```

```
with(Salaries, chisq.test(table(discipline, sex)))
```

```
##
##  Pearson's Chi-squared test with Yates' continuity correction
##
```

```
## data:  table(discipline, sex)
## X-squared = 2.0875e-29, df = 1, p-value = 1
```

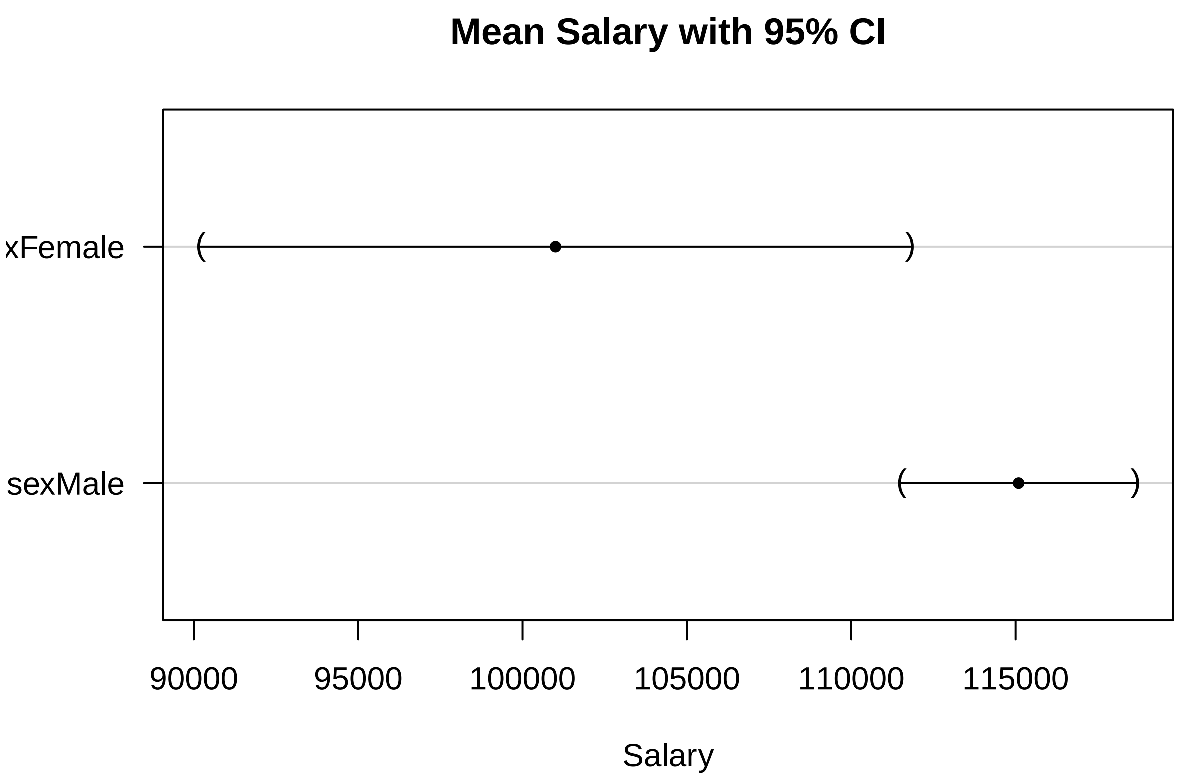
```r
# Answers (2)
# ==========
aggregate(salary ~ sex, data=Salaries, mean)
```

```
##      sex   salary
## 1 Female 101002.4
## 2   Male 115090.4
```

```r
anova(aov(salary ~ sex, data=Salaries))
```

```
## Analysis of Variance Table
##
## Response: salary
##            Df     Sum Sq    Mean Sq F value   Pr(>F)
## sex         1 6.9800e+09 6980014930  7.7377 0.005667 **
## Residuals 395 3.5632e+11  902077538
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

```r
# Answers (3)
# ==========
# install.packages("multcomp")     # if needed
library(multcomp)
salary.aov <- aov(salary ~ -1 + sex, data=Salaries)
by.sex  <- glht(salary.aov)
plot(by.sex, xlab="Salary", main="Mean Salary with 95% CI")
```




```r
# Optional: Stepwise ANOVA
# ==========
```

```r
seg.aov.step <- step(aov(income ~ ., data=seg.df))
```

```
## Start:  AIC=5779.17
## income ~ age + gender + kids + ownHome + subscribe + Segment
##
##             Df  Sum of Sq        RSS    AIC
## - age        1 4.7669e+06 6.5661e+10 5777.2
## - ownHome    1 1.0337e+08 6.5759e+10 5777.6
## - kids       1 1.3408e+08 6.5790e+10 5777.8
## - subscribe  1 1.5970e+08 6.5816e+10 5777.9
## - gender     1 2.6894e+08 6.5925e+10 5778.4
## <none>                    6.5656e+10 5779.2
## - Segment    3 1.9303e+10 8.4959e+10 5850.5
##
## Step:  AIC=5777.19
## income ~ gender + kids + ownHome + subscribe + Segment
##
##             Df  Sum of Sq        RSS    AIC
## - ownHome    1 1.0159e+08 6.5762e+10 5775.7
## - kids       1 1.3205e+08 6.5793e+10 5775.8
## - subscribe  1 1.5794e+08 6.5819e+10 5775.9
## - gender     1 2.7009e+08 6.5931e+10 5776.4
## <none>                    6.5661e+10 5777.2
## - Segment    3 4.9044e+10 1.1470e+11 5938.6
##
## Step:  AIC=5775.66
## income ~ gender + kids + subscribe + Segment
##
##             Df  Sum of Sq        RSS    AIC
## - kids       1 1.0707e+08 6.5869e+10 5774.1
## - subscribe  1 1.6370e+08 6.5926e+10 5774.4
## - gender     1 2.5520e+08 6.6017e+10 5774.8
## <none>                    6.5762e+10 5775.7
## - Segment    3 5.2897e+10 1.1866e+11 5946.7
##
## Step:  AIC=5774.15
## income ~ gender + subscribe + Segment
##
##             Df  Sum of Sq        RSS    AIC
## - subscribe  1 1.6226e+08 6.6032e+10 5772.9
## - gender     1 2.4390e+08 6.6113e+10 5773.3
## <none>                    6.5869e+10 5774.1
## - Segment    3 5.3005e+10 1.1887e+11 5945.3
##
## Step:  AIC=5772.88
## income ~ gender + Segment
##
##           Df  Sum of Sq        RSS    AIC
## - gender   1 2.4949e+08 6.6281e+10 5772.0
## <none>                  6.6032e+10 5772.9
## - Segment  3 5.4001e+10 1.2003e+11 5946.2
##
## Step:  AIC=5772.02
## income ~ Segment
```

```
##
##           Df Sum of Sq        RSS    AIC
## <none>                  6.6281e+10 5772.0
## - Segment  3 5.497e+10 1.2125e+11 5947.2
```

```r
# Stepwise ANOVA: Result
# ==========
seg.aov.step <- step(aov(income ~ ., data=seg.df))
```

```
## Start:  AIC=5779.17
## income ~ age + gender + kids + ownHome + subscribe + Segment
##
##             Df  Sum of Sq        RSS    AIC
## - age        1 4.7669e+06 6.5661e+10 5777.2
## - ownHome    1 1.0337e+08 6.5759e+10 5777.6
## - kids       1 1.3408e+08 6.5790e+10 5777.8
## - subscribe  1 1.5970e+08 6.5816e+10 5777.9
## - gender     1 2.6894e+08 6.5925e+10 5778.4
## <none>                    6.5656e+10 5779.2
## - Segment    3 1.9303e+10 8.4959e+10 5850.5
##
## Step:  AIC=5777.19
## income ~ gender + kids + ownHome + subscribe + Segment
##
##             Df  Sum of Sq        RSS    AIC
## - ownHome    1 1.0159e+08 6.5762e+10 5775.7
## - kids       1 1.3205e+08 6.5793e+10 5775.8
## - subscribe  1 1.5794e+08 6.5819e+10 5775.9
## - gender     1 2.7009e+08 6.5931e+10 5776.4
## <none>                    6.5661e+10 5777.2
## - Segment    3 4.9044e+10 1.1470e+11 5938.6
##
## Step:  AIC=5775.66
## income ~ gender + kids + subscribe + Segment
##
##             Df  Sum of Sq        RSS    AIC
## - kids       1 1.0707e+08 6.5869e+10 5774.1
## - subscribe  1 1.6370e+08 6.5926e+10 5774.4
## - gender     1 2.5520e+08 6.6017e+10 5774.8
## <none>                    6.5762e+10 5775.7
## - Segment    3 5.2897e+10 1.1866e+11 5946.7
##
## Step:  AIC=5774.15
## income ~ gender + subscribe + Segment
##
##             Df  Sum of Sq        RSS    AIC
## - subscribe  1 1.6226e+08 6.6032e+10 5772.9
## - gender     1 2.4390e+08 6.6113e+10 5773.3
## <none>                    6.5869e+10 5774.1
## - Segment    3 5.3005e+10 1.1887e+11 5945.3
##
## Step:  AIC=5772.88
## income ~ gender + Segment
##
##           Df  Sum of Sq        RSS    AIC
```

```
## - gender   1 2.4949e+08 6.6281e+10 5772.0
## <none>                  6.6032e+10 5772.9
## - Segment  3 5.4001e+10 1.2003e+11 5946.2
##
## Step:  AIC=5772.02
## income ~ Segment
##
##           Df Sum of Sq        RSS    AIC
## <none>                 6.6281e+10 5772.0
## - Segment  3 5.497e+10 1.2125e+11 5947.2
```

```
anova(seg.aov.step)
```

```
## Analysis of Variance Table
##
## Response: income
##            Df     Sum Sq    Mean Sq F value    Pr(>F)
## Segment     3 5.4970e+10 1.8323e+10  81.828 < 2.2e-16 ***
## Residuals 296 6.6281e+10 2.2392e+08
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

```
# More Advanced: Bayesian ANOVA
# ==========
# install.packages("BayesFactor")   # if needed
library(BayesFactor)
```

```
## Loading required package: coda

## Loading required package: Matrix

## ************
## Welcome to BayesFactor 0.9.12-4.3. If you have questions, please contact Richard Morey (richarddmorey
##
## Type BFManual() to open the manual.
## ************
```

```
set.seed(96761)                     # optional, for replication
seg.bf1 <- lmBF(income ~ Segment,           data=seg.df)
seg.bf2 <- lmBF(income ~ Segment + ownHome, data=seg.df)

seg.bf1 / seg.bf2
```

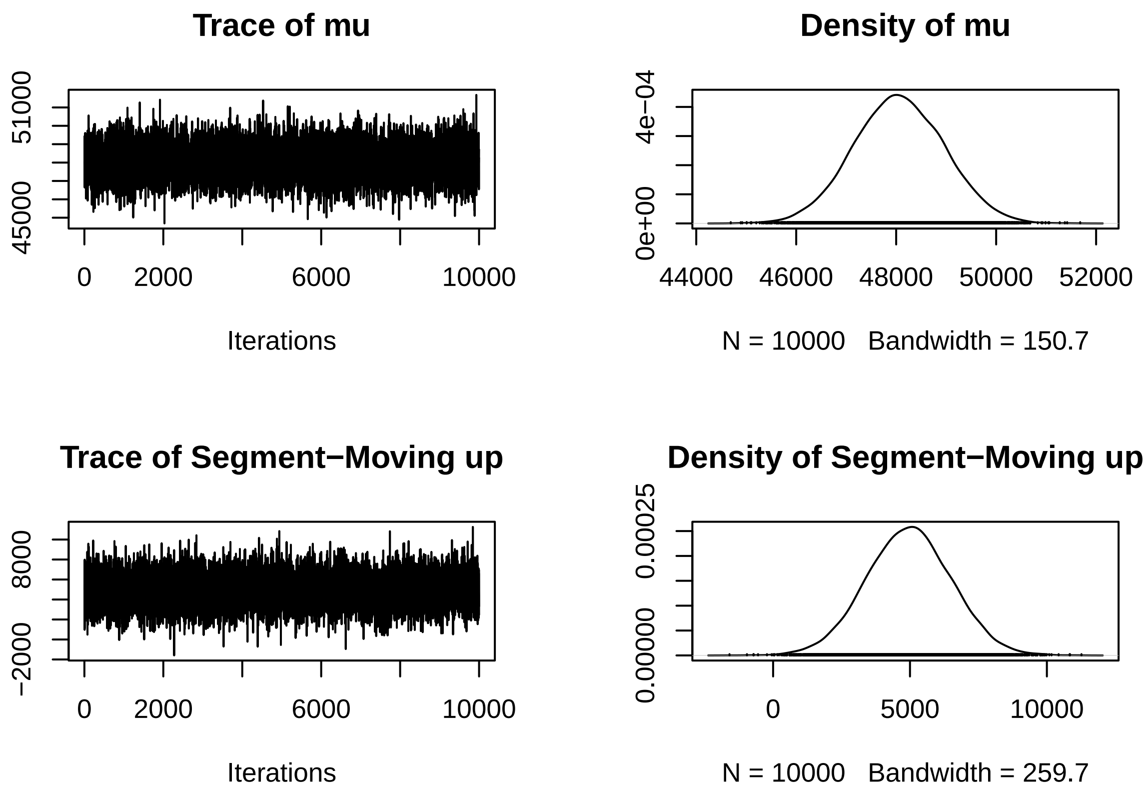
```
## Bayes factor analysis
## --------------
## [1] Segment : 6.579729 ±1.62%
##
## Against denominator:
##   income ~ Segment + ownHome
## ---
## Bayes factor type: BFlinearModel, JZS
```

```
# Bayesian ANOVA: Under the hood
# ==========
seg.bf.chain <- posterior(seg.bf1, 1, iterations = 10000)
head(seg.bf.chain[, 1:4])
```

```
## Markov Chain Monte Carlo (MCMC) output:
```

```
## Start = 1
## End = 7
## Thinning interval = 1
##             mu Segment-Moving up Segment-Suburb mix Segment-Travelers
## [1,] 48055.75          4964.3516           6909.129          13983.40
## [2,] 47706.52          6524.7816           7909.242          12359.19
## [3,] 48361.79          5608.6227           7553.687          14379.18
## [4,] 49396.99          5468.3964           7568.978          12856.49
## [5,] 48176.00          5779.9796           5168.127          13859.16
## [6,] 49446.75           967.5255           8146.482          17934.65
## [7,] 46642.84          3881.8313           7745.062          15994.53
```

```
# Bayesian ANOVA: Plotting the Draws
# ==========
plot(seg.bf.chain[, 1:2])    # overall mean + first segment
```




```
# Bayesian ANOVA: Segment Estimates
# ==========
seg.bf.chain[1:4, 1:4]
```

```
##             mu Segment-Moving up Segment-Suburb mix Segment-Travelers
## [1,] 48055.75           4964.352           6909.129          13983.40
## [2,] 47706.52           6524.782           7909.242          12359.19
## [3,] 48361.79           5608.623           7553.687          14379.18
## [4,] 49396.99           5468.396           7568.978          12856.49
```

```
seg.bf.chain[1:4, 2:4] + seg.bf.chain[1:4, 1]
```

```
##      Segment-Moving up Segment-Suburb mix Segment-Travelers
## [1,]          53020.10           54964.87          62039.15
## [2,]          54231.30           55615.76          60065.71
```

```
## [3,]            53970.41            55915.48            62740.98
## [4,]            54865.39            56965.97            62253.49
```

```r
# Bayesian ANOVA: Segment CIs
# ==========
seg.bf.chain.total <- seg.bf.chain[, 2:5] + seg.bf.chain[, 1]
seg.bf.chain.total[1:4, 1:3]
```

```
##      Segment-Moving up Segment-Suburb mix Segment-Travelers
## [1,]          53020.10           54964.87          62039.15
## [2,]          54231.30           55615.76          60065.71
## [3,]          53970.41           55915.48          62740.98
## [4,]          54865.39           56965.97          62253.49
```

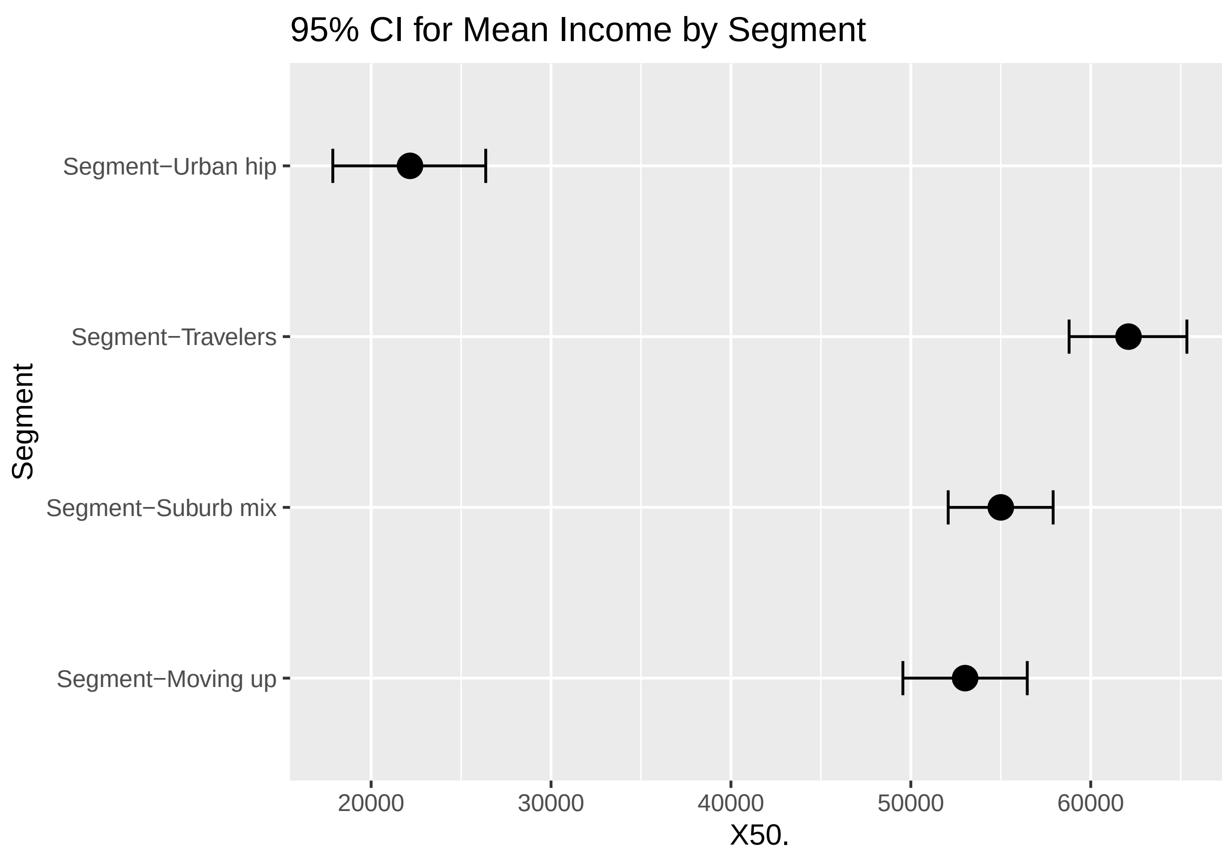
```r
seg.bf.ci <- t(apply(seg.bf.chain.total, 2,
                     quantile, pr=c(0.025, 0.5, 0.975)))
seg.bf.ci
```

```
##                        2.5%      50%    97.5%
## Segment-Moving up  49558.48 53017.70 56472.80
## Segment-Suburb mix 52077.24 55001.33 57911.31
## Segment-Travelers  58798.46 62101.16 65345.16
## Segment-Urban hip  17868.25 22161.13 26370.48
```

```r
# Bayesian ANOVA: Plot the CIs
# ==========
seg.bf.df <- data.frame(seg.bf.ci)
seg.bf.df$Segment <- rownames(seg.bf.df)

library(ggplot2)
```

```
## Warning in register(): Can't find generic `scale_type` in package ggplot2 to
## register S3 method.
```

```r
# basic plot object with CIs on Y axis by Segment on X
p <- ggplot(seg.bf.df, aes(x=Segment,
                           y=X50., ymax=X97.5., ymin=X2.5.))

# add points for the Y var and error bars for ymax, ymin
p <- p + geom_point(size=4) + geom_errorbar(width=0.2)

# add a title and rotate the plot to horizontal
p <- p +
  ggtitle("95% CI for Mean Income by Segment") + coord_flip()


# Plot it
# ==========
p
```




```r
# Exercises (Advanced)
# ==========
library(car)    # install.packages("car") if needed
data(Salaries)


# Answers (Advanced, 1)
# ==========
salary.step <- step(aov(salary ~ ., data=Salaries))   # output hidden
```

```
## Start:  AIC=7965.19
## salary ~ rank + discipline + yrs.since.phd + yrs.service + sex
##
##                 Df  Sum of Sq        RSS    AIC
## - sex            1 7.8068e+08 1.9890e+11 7964.8
## <none>                        1.9812e+11 7965.2
## - yrs.since.phd  1 2.5041e+09 2.0062e+11 7968.2
## - yrs.service    1 2.7100e+09 2.0083e+11 7968.6
## - discipline     1 1.9237e+10 2.1735e+11 8000.0
## - rank           2 6.9508e+10 2.6762e+11 8080.6
##
## Step:  AIC=7964.75
## salary ~ rank + discipline + yrs.since.phd + yrs.service
##
##                 Df  Sum of Sq        RSS    AIC
## <none>                        1.9890e+11 7964.8
## - yrs.since.phd  1 2.5001e+09 2.0140e+11 7967.7
```

```
## - yrs.service    1 2.5763e+09 2.0147e+11 7967.9
## - discipline     1 1.9489e+10 2.1839e+11 7999.9
## - rank           2 7.0679e+10 2.6958e+11 8081.5
```

```r
anova(salary.step)
```

```
## Analysis of Variance Table
##
## Response: salary
##                 Df     Sum Sq    Mean Sq  F value    Pr(>F)
## rank             2 1.4323e+11 7.1616e+10 140.7855 < 2.2e-16 ***
## discipline       1 1.8430e+10 1.8430e+10  36.2303 4.039e-09 ***
## yrs.since.phd    1 1.6565e+08 1.6565e+08   0.3256   0.56857
## yrs.service      1 2.5763e+09 2.5763e+09   5.0646   0.02497 *
## Residuals      391 1.9890e+11 5.0869e+08
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

```r
# Answers (Advanced, 2)
# ==========
library(BayesFactor)
set.seed(96761)                    # optional for replication

salary.b  <- lmBF(salary ~ rank + discipline + yrs.service,
                  data=Salaries)
salary.mc <- posterior(salary.b, 1, iterations=10000)

t(apply(salary.mc[, 1:7], 2, quantile, pr=c(0.025, 0.5, 0.975)))
```

```
##                               2.5%         50%       97.5%
## mu                      96140.5552  99183.0465 102160.5734
## rank-AsstProf          -25606.7816 -20875.8574 -16296.1832
## rank-AssocProf         -10971.6824  -6811.8484  -2680.7953
## rank-Prof               23840.8543  27721.1831  31590.4752
## discipline-A            -8918.5337  -6635.0952  -4386.1522
## discipline-B             4386.1522   6635.0952   8918.5337
## yrs.service-yrs.service   -273.9851    -60.5864    147.7961
```

```r
# Answers (Advanced, 3)
# ==========
salary.b2 <- lmBF(salary ~ rank + discipline + yrs.service + sex,
                  data=Salaries)

salary.b2 / salary.b
```

```
## Bayes factor analysis
## --------------
## [1] rank + discipline + yrs.service + sex : 0.3426499 ±8.08%
##
## Against denominator:
##   salary ~ rank + discipline + yrs.service
## ---
## Bayes factor type: BFlinearModel, JZS
```

```r
# Answers (Advanced, 4)
# ==========
```

```
aov1 <- aov(salary ~ rank + discipline + yrs.service,
            data=Salaries)
aov2 <- aov(salary ~ rank + discipline + yrs.service + sex,
            data=Salaries)
anova(aov1, aov2)
```

```
## Analysis of Variance Table
##
## Model 1: salary ~ rank + discipline + yrs.service
## Model 2: salary ~ rank + discipline + yrs.service + sex
##   Res.Df        RSS Df Sum of Sq      F Pr(>F)
## 1    392 2.0140e+11
## 2    391 2.0062e+11  1 776686259 1.5137 0.2193
```

```
# Answers (Advanced, 5)
# ==========
salary.cidf <- data.frame(t(apply(salary.mc[, 2:4] + salary.mc[ , 1], 2,
                                  quantile, pr=c(0.025, 0.5, 0.975))))
salary.cidf$rank <- rownames(salary.cidf)
library(ggplot2)
p <- ggplot(salary.cidf, aes(x=rank,
                             y=X50., ymax=X97.5., ymin=X2.5.))
p <- p + geom_point(size=4) + geom_errorbar(width=0.2)
p + ggtitle("95% Credible Intervals for Mean Salary by Rank") +
  coord_flip()
```