

# Assignment 1

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March 10, 2020

## Task 1

A multiple linear regression model has been estimated to study the relationship between  $Y$  = violent crime rate (per 100,000 people),  $X_1$  = poverty rate (percentage with income below the poverty line) and  $X_2$  = percentage living in urban area. Data are collected in 51 cities in the U.S.

The relevant equations that relate estimate, standard error, T-statistic, R-squared and Sum of Squares of residuals, regression and total are following.

$$\frac{\beta_i}{se(\beta_i)} = T_i \quad R^2 = \frac{SS_{reg}}{SST} = 1 - \frac{SSR}{SST} \quad SST = SS_{reg} + SSR$$

Using these we just plug in the corresponding information that is already provided and compute the missing values.

```
a <- -498.683 / 140.988
b <- 4.885 * 6.677
c <- 9.112 / 6.900
d <- 1841257.15 / (1 - 0.5708)
e <- d - 1841257.15
```

The table below reports the output with filled in missing information.

	Est.	s.e.	t-value	p-value
Intercept	-498.683	140.988	<sup>a</sup> -3.537	0.009
$X_1$	<sup>b</sup> 32.617	6.677	4.885	0.001
$X_2$	9.112	<sup>c</sup> 1.321	6.900	0.001
$R^2$	0.5708			
$SS_{reg}$	<sup>e</sup> 2448718			
$SSR$	1841257.15			
$SS_{Total}$	<sup>d</sup> 4289975			

The coefficient of determination  $R^2$  is 0.5708. This value measures the proportion of the variance in  $Y$  explained by the model. Hence, 57.08 % of the sample variability of  $Y$  can be explained by the linear combination of  $X_i$ 's given the sample data.

To compute the overall F-test we use the equation below and the statistic then follows an F distribution with corresponding degrees of freedom.

$$F = \frac{SS_{reg} / p}{SSR / (n - (p + 1))} \sim F_{p, n - (p + 1)}$$

The data are collected in 51 cities, so  $n = 51$  and we have 2 predictors, so  $p = 2$ . Other values we can easily obtain from the filled table above.

```
(f = (e / 2) / (181257.15 / (51-(2+1))) )
## [1] 324.2312
```

Hence, the F-statistic has a value of 324.2311914. To interpret this, the global F-test, tests a null hypothesis that all regression coefficients are simultaneously 0. In a mathematical notation  $H_0 : \beta_1 = \beta_2 = 0$ . To evaluate the test, we can compute its p-value. It is a quantile of the corresponding F-distribution for the given statistic or mass under the distribution.

```
(p = pf(f,2,48,lower.tail = FALSE))
## [1] 1.319003e-28
```

The p-value is  $1.3190029 \times 10^{-28}$ , which is very low and therefore there is a significant evidence against the null hypothesis that all regression coefficients are simultaneously zero. Hence, the p-value of a given sample is small and it suggests that the model with all the covariates is better than the one with just intercept coefficient. This test therefore determines if the linear model is at least suitable to explain some of the variance in the outcome variable. Which in this case it does.

## Task 2

The table below shows the scores of the first test (maximum score 10 points) in a beginning German course. Students in the course are grouped as follows:

- Group A: Never studied foreign language before, but have good English skills
- Group B: Never studied foreign language before, have poor English skills
- Group C: Studied other foreign language

Group A	Group B	Group C
4	1	9
6	5	10
8		5

Two-sample t-test is usual method for comparing mean scores of two groups. The one-way analysis of variance (ANOVA), also known as one-factor ANOVA, is an extension of independent two-samples t-test for comparing means in a situation where there are more than two groups. This corresponds to our situation.

The Hypothesis test in ANOVA is following:

- Null hypothesis: the means of the different groups are the same
- Alternative hypothesis: At least one sample mean is not equal to the others

The Assumptions of ANOVA are following:

- The observations are obtained independently and randomly from the population defined by the groups of factor levels.
- The data of each factor level are normally distributed.
- These normal populations have a common variance.

The F-test is used for comparing the factors of the total deviation. In ANOVA, F-statistic is computed as the ratio of the variance between groups and variance within groups. The F-statistic is then compared to the F-distribution with  $I - 1$  and  $n - I$  degrees of freedom, where  $I$  = total number of groups and  $n$  = total number of observations. Note that, a lower ratio (ratio < 1) indicates that there are no significant difference between the means of the samples being compared. However, a higher ratio implies that the variation among group means are significant.

The process of ANOVA testing is following:

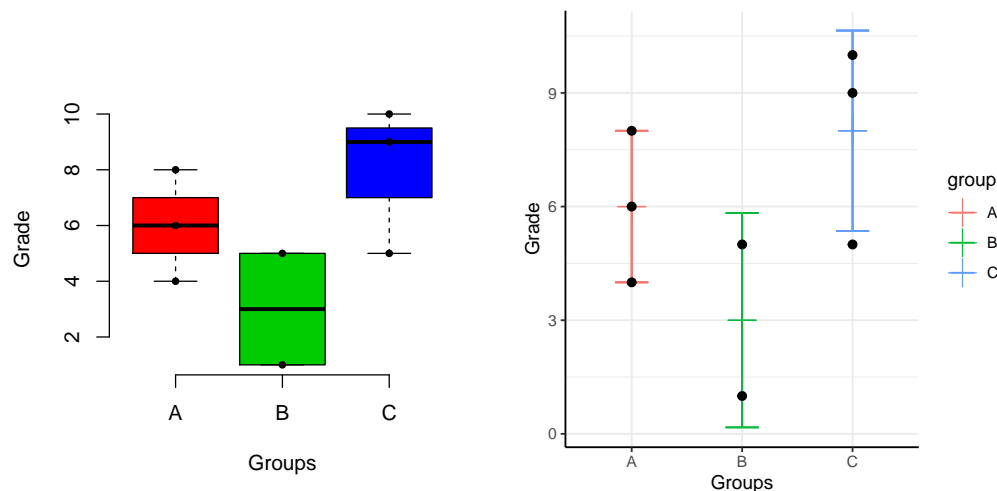
- Compute the common variance, which is called variance within samples  $S^2_{\text{within}}$  or residual variance.
- Compute the variance between sample means, by first computing the mean of each group and then computing the variance between sample means.
- Produce F-statistic as the ratio of  $F = S^2_{\text{between}} / S^2_{\text{within}}$ .

With the code below, we specify the data and compute common statistics for each group.

```
X <- data.frame("grade" = c(4,6,8,1,5,9,10,5),
               "group" = c("A","A","A","B","B","C","C","C"))
library(dplyr)
data.frame(group_by(X, group) %>%
  summarise( count = n(), mean = mean(grade), var = var(grade), sd = sd(grade)))
```

##	group	count	mean	var	sd
## 1	A	3	6	4	2.000000
## 2	B	2	3	8	2.828427
## 3	C	3	8	7	2.645751

These can be easily visualised with a boxplot (left) or a group means plot with errorbars signifying one standard deviation (right). The main observation we conclude from these plot is the large variance within groups caused mainly by having just few observations.



Finally, below we compute the ANOVA tests with our data using the function `aov()`.

```
fit <- aov(grade ~ group, data = X)
summary(fit)
```

##		Df	Sum Sq	Mean Sq	F value	Pr(>F)
##	group	2	30	15	2.5	0.177
##	Residuals	5	30	6		

The F-statistics has value of 2.5, which is above 1 which signifies some differences in group means. However the p-value is 0.177, which is not significant under the 5 % significance level and therefore we cannot reject the null hypothesis of the group means being different.

Case: Suppose that the first observation in the second group was actually 9, not 1. Then, the standard deviations are the same, but the sample means are 6, 7 and 8, rather than 6, 3 and 8.

In this situation, we would expect the

**Task 3**

**Task 4**