Executive Summary

The purpose of this report is to analyze `mtcars` data set to explore the relationship between a set of variables and miles per gallon (MPG). The data comes from the 1974 *Motor Trend* US magazine, and containsfuel consumption and 10 aspects of automobile design and performance for 32 automobiles (197374 models). I will use regression models and exploratory data analysis to explore if *MPG* is impacted by automatic or manula trasnmisison feature.

Performing t-test shows there is performance difference between cars with automatic and manual transmission of approximately 7 MPG more for cars with manual transmission than those with automatic transmission. Several linear regression models are fitted and I selected the one with highest Adjusted R-squared value. If weight and 1/4 mile time are held constant, manual transmitted cars are 14.079 + (-4.141)*weight more MPG (miles per gallon) on average better than automatic transmitted cars. The summary of this report is that lghter cars with a manual transmission and heavier cars with an automatic transmission will have higher MPG values.

Exploratory Data Analysis

Load the data set `mtcars` and change some variables from `numeric` class to `factor` class.

```
library(ggplot2)
data(mtcars)
mtcars[1:3, ] # Test Data
```

```
##                mpg cyl disp  hp drat    wt  qsec vs am gear carb
## Mazda RX4     21.0   6  160 110 3.90 2.620 16.46  0  1    4    4
## Mazda RX4 Wag 21.0   6  160 110 3.90 2.875 17.02  0  1    4    4
## Datsun 710    22.8   4  108  93 3.85 2.320 18.61  1  1    4    1
```

```
dim(mtcars)
```

```
## [1] 32 11
```

```
mtcars$cyl <- as.factor(mtcars$cyl)
mtcars$vs <- as.factor(mtcars$vs)
mtcars$am <- factor(mtcars$am)
mtcars$gear <- factor(mtcars$gear)
mtcars$carb <- factor(mtcars$carb)
attach(mtcars)
```

```
## The following objects are masked from mtcars (pos = 3):
##
##     am, carb, cyl, disp, drat, gear, hp, mpg, qsec, vs, wt
##
## The following objects are masked from mtcars (pos = 4):
##
##     am, carb, cyl, disp, drat, gear, hp, mpg, qsec, vs, wt
##
## The following object is masked from package:ggplot2:
##
##     mpg
```

Let’s start some xploratory data analysis. Plots are at the end of this report **Plots** . The Box plot tells us thatt manual transmission yields higher values of MPG in general. The pair graph shows some highe correlations between variables like “wt”, “disp”, “cyl” and “hp”.

Inference

Our null hypothesis is that MPG of the automatic and manual transmissions are from the same population (assuming the MPG has a normal distribution). We use the two sample T-test to test it.

```
result <- t.test(mpg ~ am)
result$p.value
```

```
## [1] 0.001373638
```

```
result$estimate
```

```
## mean in group 0 mean in group 1
##        17.14737        24.39231
```

Since the p-value is 0.00137, we reject our null hypothesis. Therefore the automatic and manual transmissions are from different populations. And the mean for MPG of manual transmitted cars is about 7 more than that of automatic transmitted cars.

Regression Analysis

We fit the full model as the following.

```
fullModel <- lm(mpg ~ ., data=mtcars)
summary(fullModel) # results hidden
```

This model has the Residual standard error as 2.833 on 15 degrees of freedom. And the Adjusted R-squared value is 0.779, which means that the model can explain about 78% of the variance of the MPG variable. However, none of the coefficients are significant at 0.05 significant level.

Then, we use backward selection to select some statistically significant variables.

```
stepModel <- step(fullModel, k=log(nrow(mtcars)))
summary(stepModel) # results hidden
```

This model is “mpg ~ wt + qsec + am”. It has the Residual standard error as 2.459 on 28 degrees of freedom. And the Adjusted R-squared value is 0.8336, which means that the model can explain about 83% of the variance of the MPG variable. All of the coefficients are significant at 0.05 significant level.

Please refer to the **Plots** section for the plots again. According to the scatter plot, it indicates that there appear to be an interaction term between “wt” variable and “am” variable, since automatic cars tend to weigh heavier than manual cars. Thus, we have the following model including the interaction term:

```
amIntWtModel<-lm(mpg ~ wt + qsec + am + wt:am, data=mtcars)
summary(amIntWtModel) # results hidden
```

This model has the Residual standard error as 2.084 on 27 degrees of freedom. And the Adjusted R-squared value is 0.8804, which means that the model can explain about 88% of the variance of the MPG variable. All of the coefficients are significant at 0.05 significant level. This is a pretty good one.

Next, we fit the simple model with MPG as the outcome variable and Transmission as the predictor variable.

```
amModel<-lm(mpg ~ am, data=mtcars)
summary(amModel) # results hidden
```

It shows that on average, a car has 17.147 mpg with automatic transmission, and if it is manual transmission, 7.245 mpg is increased. This model has the Residual standard error as 4.902 on 30 degrees of freedom. And the Adjusted R-squared value is 0.3385, which means that the model can explain about 34% of the variance of the MPG variable. The low Adjusted R-squared value also indicates that we need to add other variables to the model.

Finally, we select the final model.

```
anova(amModel, stepModel, fullModel, amIntWtModel)
confint(amIntWtModel) # results hidden
```

We end up selecting the model with the highest Adjusted R-squared value, “mpg ~ wt + qsec + am + wt:am”.

```
summary(amIntWtModel)$coef
```

```
##               Estimate Std. Error   t value     Pr(>|t|)
## (Intercept)  9.723053  5.8990407  1.648243 0.1108925394
## wt          -2.936531  0.6660253 -4.409038 0.0001488947
## qsec         1.016974  0.2520152  4.035366 0.0004030165
## am1         14.079428  3.4352512  4.098515 0.0003408693
## wt:am1      -4.141376  1.1968119 -3.460340 0.0018085763
```

Thus, the result shows that when “wt” (weight lb/1000) and “qsec” (1/4 mile time) remain constant, cars with manual transmission add 14.079 + (-4.141)*wt more MPG (miles per gallon) on average than cars with automatic transmission. That is, a manual transmitted car that weighs 2000 lbs have 5.797 more MPG than an automatic transmitted car that has both the same weight and 1/4 mile time.

Residual Analysis and Diagnostics

Please refer to the **Plots** section for the plots. According to the residual plots, we can verify the following underlying assumptions:
1. The Residuals vs. Fitted plot shows no consistent pattern, supporting the accuracy of the independence assumption.
2. The Normal Q-Q plot indicates that the residuals are normally distributed because the points lie closely to the line.
3. The Scale-Location plot confirms the constant variance assumption, as the points are randomly distributed.
4. The Residuals vs. Leverage argues that no outliers are present, as all values fall well within the 0.5 bands.

As for the Dfbetas, the measure of how much an observation has effected the estimate of a regression coefficient, we get the following result:

```
sum((abs(dfbetas(amIntWtModel)))>1)
```

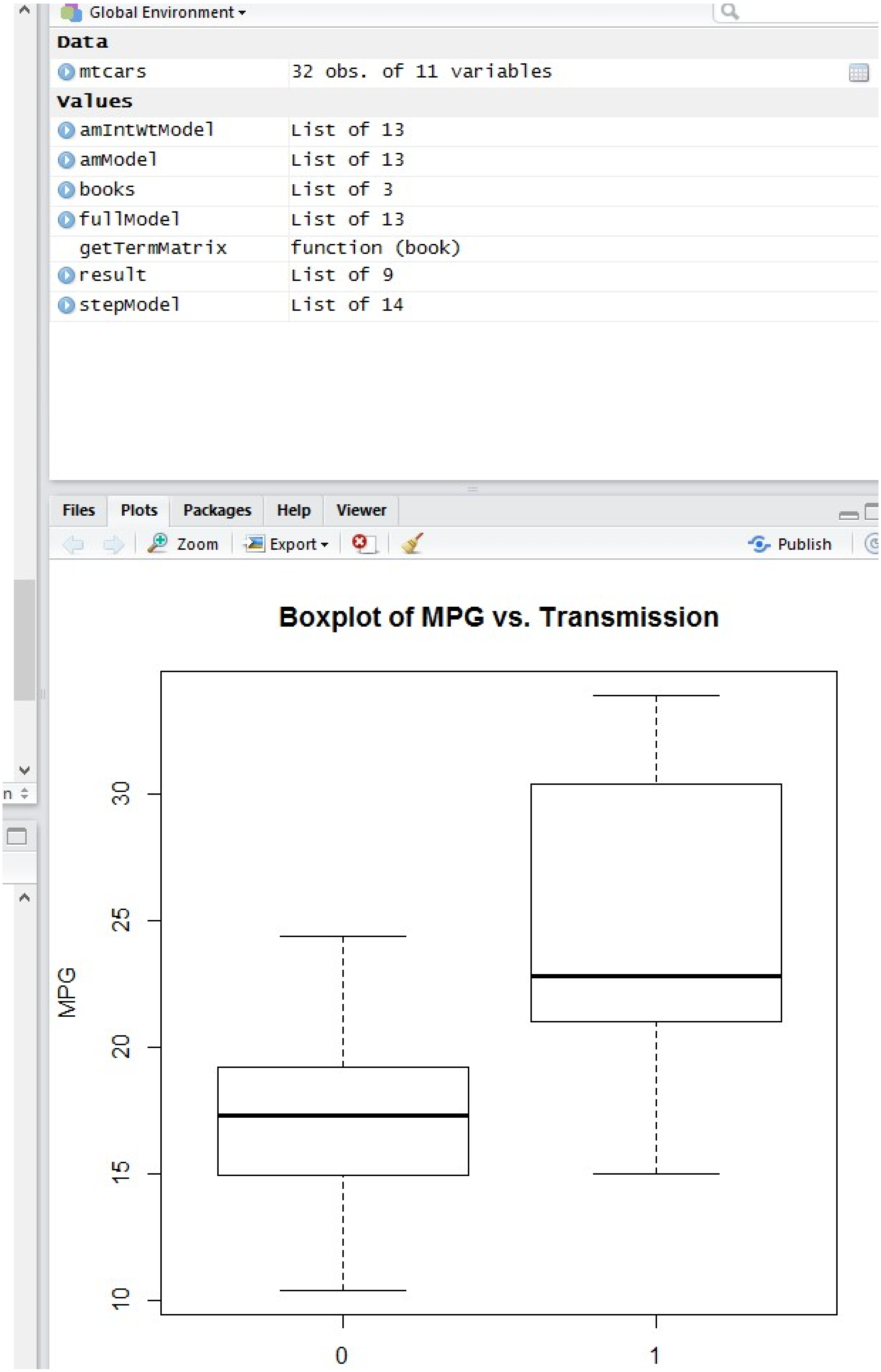
```
## [1] 0
```

Therefore, the above analysismeet all basic assumptions of linear regression and well answer the questions.

Plots

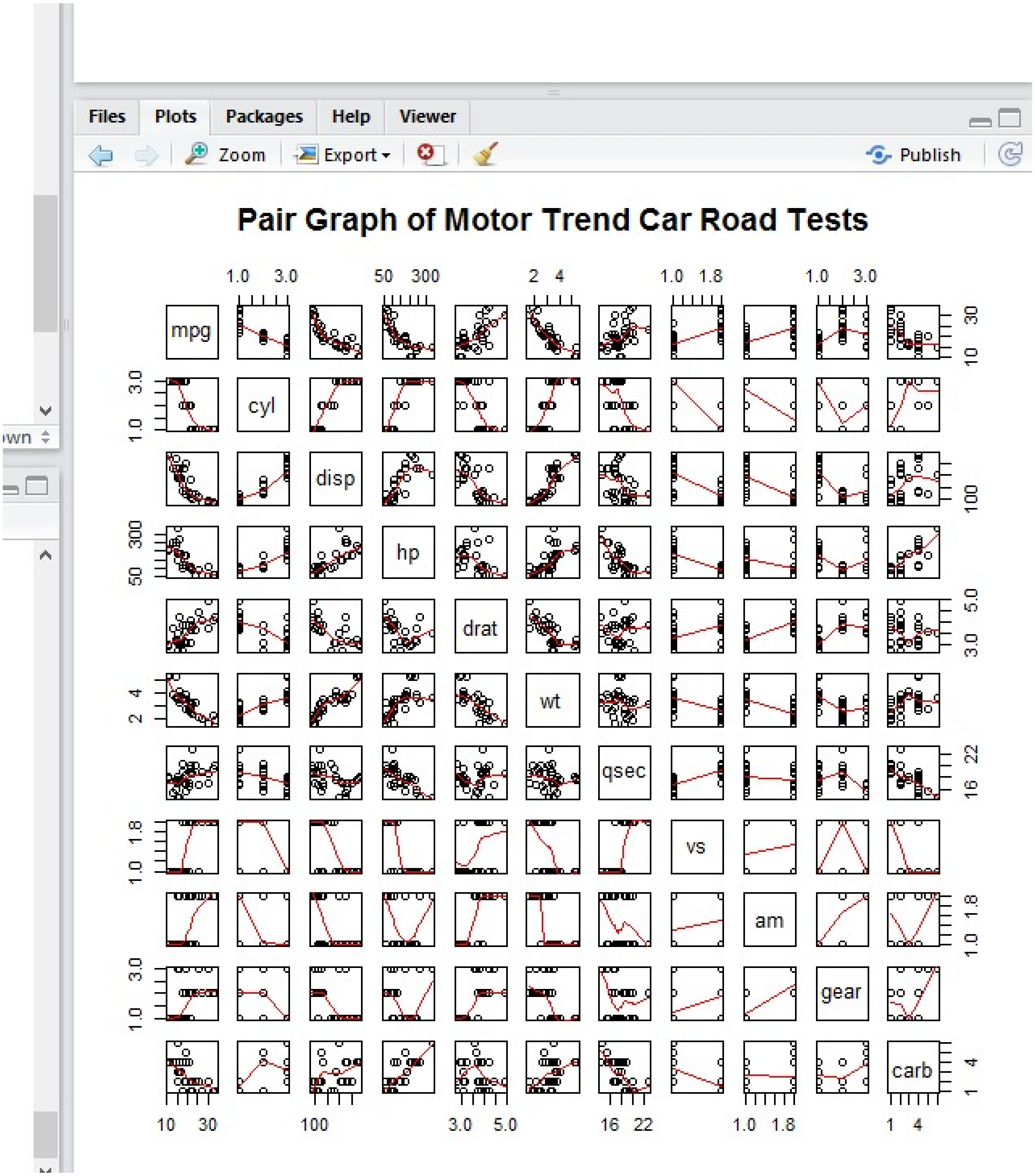
1. Boxplot of MPG vs. Transmission

```
boxplot(mpg ~ am, xlab="Transmission (0 = Automatic, 1 = Manual)", ylab="MPG",
        main="Boxplot of MPG vs. Transmission")
```


Global Environment
Data
mtcars 32 obs. of 11 variables
Values
amIntWtModel List of 13
amModel List of 13
books List of 3
fullModel List of 13
getTermMatrix function (book)
result List of 9
stepModel List of 14
Files Plots Packages Help Viewer
Zoom Export Publish
Boxplot of MPG vs. Transmission
MPG
10
15
20
25
30
0
1

2. Pair Graph of Motor Trend Car Road Tests

```
pairs(mtcars, panel=panel.smooth, main="Pair Graph of Motor Trend Car Road Tests")
```

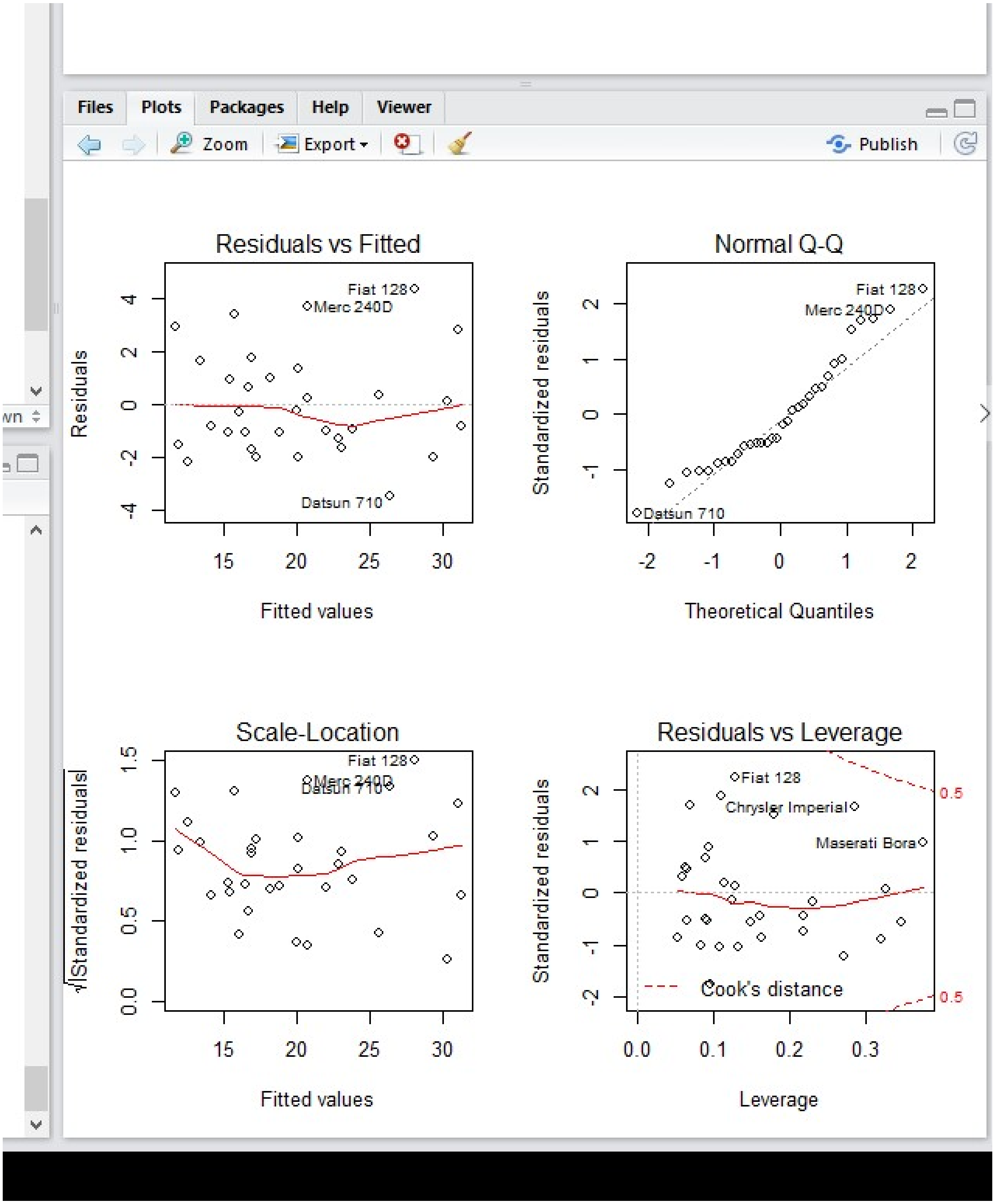


3. Scatter Plot of MPG vs. Weight by Transmission

```
ggplot(mtcars, aes(x=wt, y=mpg, group=am, color=am, height=3, width=3)) + geom_point(
) +
scale_colour_discrete(labels=c("Automatic", "Manual")) +
xlab("weight") + ggtitle("Scatter Plot of MPG vs. Weight by Transmission")
```

4. Residual Plots

```
par(mfrow = c(2, 2))
plot(amIntWtModel)
```


Files
Plots
Packages
Help
Viewer
Zoom
Export
Publish
Residuals vs Fitted
Fiat 128
Merc 240D
Datsun 710
Residuals
Fitted values
Normal Q-Q
Standardized residuals
Theoretical Quantiles
Scale-Location
√|Standardized residuals|
Residuals vs Leverage
Chrysler Imperial
Maserati Bora
Cook's distance
0.5
Leverage