

Is an automatic or manual transmission better for MPG?

Executive Summary

Fuel consumption is often an important factor to consider when deciding an economic car to purchase. It has always been recommended that buyers opt for a manual transmission for an improvement in fuel consumption. Is statement justified? A study was done on 32 cars models from 1973 and 1974, 13 of which had manual transmissions with the rest automatic. After controlling for a number of variables such as weight of the car and engine power, it was concluded cars with manual transmission indeed showed a better fuel consumption (**+0.5056** miles per gallon) than those with automatic transmission. However, it may not be an important factor of fuel consumption compared to the other variables.

Data

The data was obtained from the `datasets` R package ([documentation](#)). According to the documentation, it was extracted from the 1974 Motor Trend US magazine. It comprised of fuel consumption and 10 aspects of automobile design and performance for 32 automobiles from 1973 and 1974; 13 of them had manual transmission compared to 19 on automatic.

The variables included were: fuel consumption in miles per US gallon (MPG) (`mpg`), number of cylinders (`cyl`), iengine displacement in cubic inches (`disp`), gross horsepower(`hp`), real axle ratio(`drat`), weight in 1000 pounds (`wt`), quarter mile time in seconds (`qsec`), engine configuration (`vs`), transmission (`am`), number of forward gears (`gears`) and number of carburetors (`carb`).

Exploratory Data Analysis

The comparison between the fuel consumption of cars with manual and automatic transmission can be easily done through through a boxplot which was shown in the appendix.

It was evident from the boxplots that cars with manual transmission had higher MPG. The ANOVA comparing the fuel consumption against different transmission showed that the cars with manual transmission was associated with **7.2449** increase in MPG. However, such an analysis did not take into account controlling other variables which might have affected MPG, hence the conclusion could not be taken at face value.

The pairs scatterplots in the appendix gave us a brief idea of how some of the continuous variables were related to MPG and each other. It could be observed that mpg appeared to be highly correlated with all the variables except rear axle ratio and transmission, but showed some correlation with those nonetheless.

Analysis

It would be easy to simply include all the variables into a single regression model and obtain the coefficient for the transimission variable for the difference in MPG between manual and automatic cars. However, such a model would be unnecessarily complex, difficult to interpret and include insignificant variables. Nevertheless, it would be a model based on which the subsequent models would be constructed. The P-values of the coefficients of this model were as followed.

| | | | | | | |
|----|---------|----------|---------|-----------|---------|-------------|
| ## | wt | ammanua1 | qsec | hp | disp | (Intercept) |
| ## | 0.06325 | 0.23399 | 0.27394 | 0.33496 | 0.46349 | 0.51812 |
| ## | drat | gear | carb | vsIengine | cyl | |
| ## | 0.63528 | 0.66521 | 0.81218 | 0.88142 | 0.91609 | |

By ranking the P-value of the coefficients in the ascending order, I removed the variables corresponding to those coefficients. The variable for quarter mile time was also removed since it was not a manufacturer specification and, hence, the coefficient would be difficult to interpret.

```
## (Intercept)          hp          wt    ammanual          drat          disp
## 0.0002817    0.0077548    0.0166362    0.4710325    0.5190745    0.6052971
##          gear
## 0.7491696
```

From the table of coefficients of the resulting model, engine power (P-value of 0.654) and car weight (P-value of 0.5191) were the only 2 significant variables. Transmission would also be included since the coefficient was of interest.

To ensure that variables were not rejected carelessly, the ANOVA was conducted between the final model and the previous model. With a large P-value (0.857), the final model was not rejected for the alternative model with 3 more variables. Hence, it was a valid model.

```
## Analysis of Variance Table
##
## Model 1: mpg ~ hp + wt + am
## Model 2: mpg ~ disp + hp + drat + wt + am + gear
##   Res.Df RSS Df Sum of Sq    F Pr(>F)
## 1      28 180
## 2      25 175   3      5.35 0.26   0.86
```

It would also be necessary to check the diagnostic plots to check for the model fit and outliers. From the diagnostic plots in the appendix, the points for Chrysler Imperial, Fiat 128 and Toyota Corolla appeared to be a significant outliers and was removed from subsequent analysis. The diagnostic plots were more satisfactory after their removal.

Results

The final model and its coefficients were as followed:

```
##           Estimate Std. Error t value Pr(>|t|)
## (Intercept) 35.47152    2.071991 17.1195 2.556e-15
## hp          -0.02802    0.007148  -3.9203 6.079e-04
## wt          -3.75030    0.712337  -5.2648 1.881e-05
## ammanual    0.50558    1.039672   0.4863 6.310e-01
```

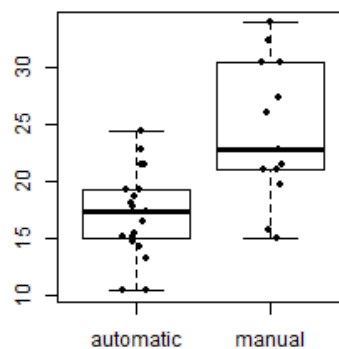
Therefore, controlling for engine power and car weight, cars with manual transmission have a better fuel consumption of **0.5056** increase in MPG. The 95% confidence interval for the increase in MPG was **(-1.554, 2.5651)**. Since the confidence interval contained 0, it meant that the difference in fuel consumption between cars with manual and automatic transmission was not significant. Other factors such as engine power and car weight were more important factors affecting fuel consumption.

Appendix

My plots are not showing using `knit2pdf()` for some reason so I saved the html output from `knit2html()` :(

```
data(mtcars)
mtcars2 <- within(mtcars, {
  am <- factor(am, labels = c("automatic", "manual"))
  vs <- factor(vs, labels = c("vengine", "lengine"))
})

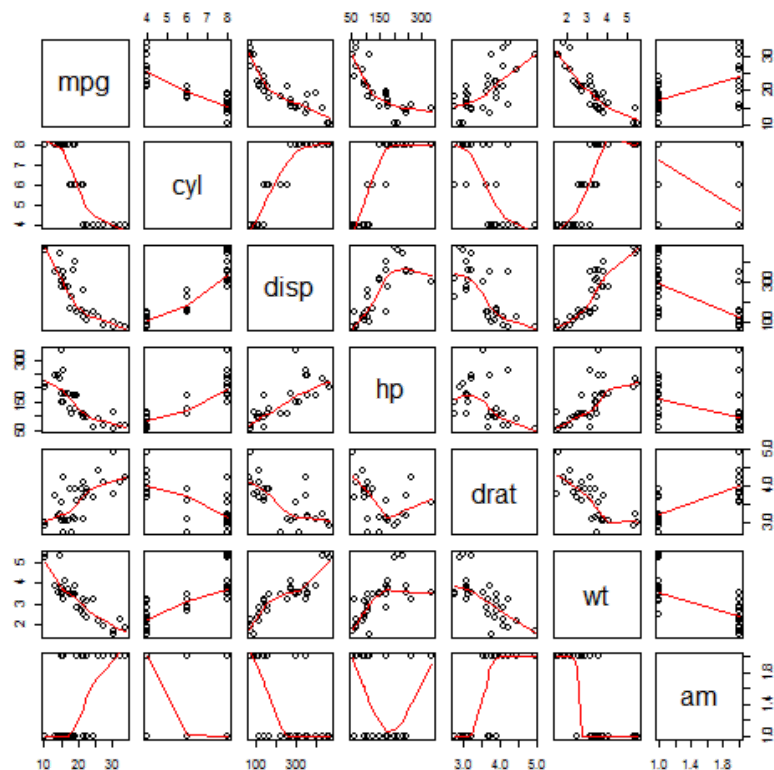
op <- par(mar = c(2,2,1,1))
boxplot(mpg ~ am, data = mtcars2)
stripchart(mpg ~ am, data = mtcars2, vertical = T, method = "jitter", pch = 20, add = T)
par(op)
```



```
fit1 <- lm(mpg ~ am, data = mtcars2)
coef1 <- summary(fit1)$coef
coef1
```

```
##           Estimate Std. Error t value Pr(>|t|)
## (Intercept)   17.147      1.125   15.247 1.134e-15
## ammanual       7.245      1.764    4.106 2.850e-04
```

```
pairs(mtcars2[, c(1:6,9)], panel = panel.smooth)
```



```
fit2 <- lm(mpg ~ ., data = mtcars2)
summary(fit2)$coef
```

| | Estimate | Std. Error | t value | Pr(> t) |
|----------------|----------|------------|---------|----------|
| ## (Intercept) | 12.30337 | 18.71788 | 0.6573 | 0.51812 |
| ## cyl | -0.11144 | 1.04502 | -0.1066 | 0.91609 |
| ## disp | 0.01334 | 0.01786 | 0.7468 | 0.46349 |
| ## hp | -0.02148 | 0.02177 | -0.9868 | 0.33496 |
| ## drat | 0.78711 | 1.63537 | 0.4813 | 0.63528 |
| ## wt | -3.71530 | 1.89441 | -1.9612 | 0.06325 |
| ## qsec | 0.82104 | 0.73084 | 1.1234 | 0.27394 |
| ## vsIengine | 0.31776 | 2.10451 | 0.1510 | 0.88142 |
| ## ammanual | 2.52023 | 2.05665 | 1.2254 | 0.23399 |
| ## gear | 0.65541 | 1.49326 | 0.4389 | 0.66521 |
| ## carb | -0.19942 | 0.82875 | -0.2406 | 0.81218 |

```
fit3 <- lm(mpg ~ disp + hp + drat + wt + am + gear, data = mtcars2)
summary(fit3)$coef
```

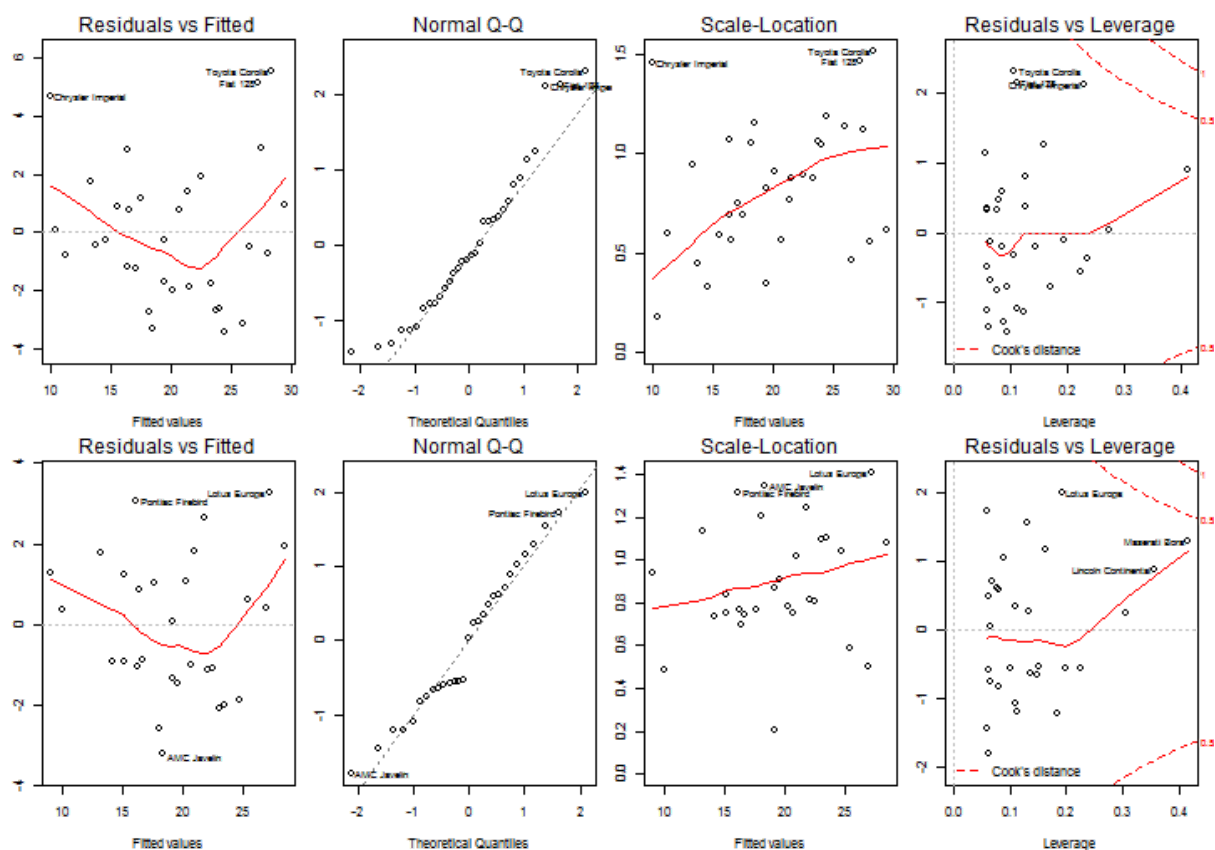
| | Estimate | Std. Error | t value | Pr(> t) |
|----------------|-----------|------------|---------|-----------|
| ## (Intercept) | 28.962452 | 6.86448 | 4.2192 | 0.0002817 |
| ## disp | 0.006283 | 0.01200 | 0.5234 | 0.6052971 |
| ## hp | -0.041919 | 0.01448 | -2.8952 | 0.0077548 |
| ## drat | 1.006269 | 1.53861 | 0.6540 | 0.5190745 |
| ## wt | -3.065995 | 1.19449 | -2.5668 | 0.0166362 |
| ## ammanual | 1.349766 | 1.84418 | 0.7319 | 0.4710325 |
| ## gear | 0.413313 | 1.27849 | 0.3233 | 0.7491696 |

```
fit4 <- lm(mpg ~ hp + wt + am, data = mtcars2)
anova(fit4, fit3)
```

```
## Analysis of Variance Table
##
## Model 1: mpg ~ hp + wt + am
## Model 2: mpg ~ disp + hp + drat + wt + am + gear
##   Res.Df RSS Df Sum of Sq   F Pr(>F)
## 1      28 180
## 2      25 175   3      5.35 0.26  0.86
```

```
outliers <- c("Chrysler Imperial", "Fiat 128", "Toyota Corolla")
mtcars3 <- mtcars2[!is.element(rownames(mtcars2), outliers), ]
fit5 <- lm(mpg ~ hp + wt + am, data = mtcars3)
```

```
op <- par(mfrow = c(2,4), mar = c(4,2,2,1))
plot(fit4)
plot(fit5)
par(op)
```



```
coef5 <- summary(fit5)$coef
coef5
```

```
##           Estimate Std. Error t value Pr(>|t|)
## (Intercept) 35.47152   2.071991 17.1195 2.556e-15
## hp          -0.02802   0.007148  -3.9203 6.079e-04
## wt          -3.75030   0.712337  -5.2648 1.881e-05
## ammanual    0.50558    1.039672   0.4863 6.310e-01
```

```
CI <- coef5[4, 1] + c(-1, 1) * qt(0.975, df = fit5$df)
CI
```

```
## [1] -1.554  2.565
```