A comparative analysis of manual vs. automatic transmission in cars

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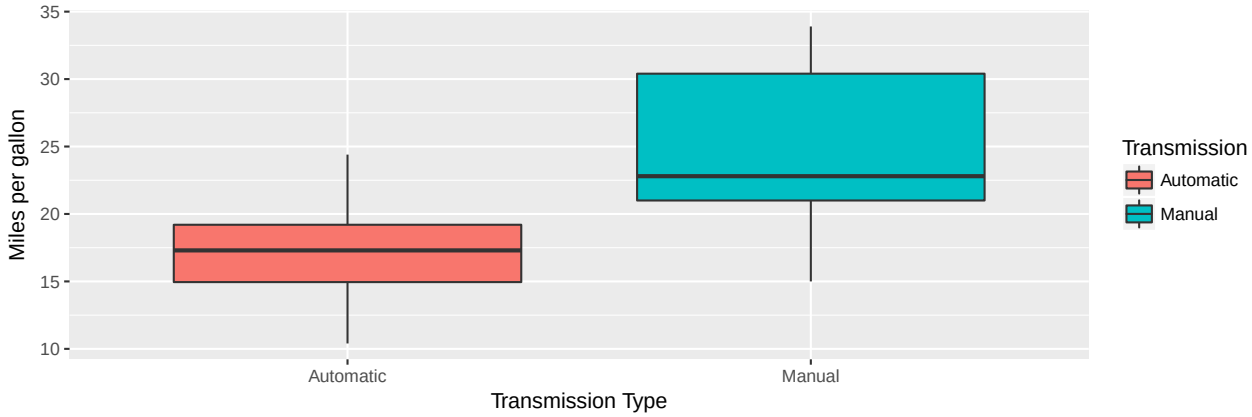
Executive Summary

Recently, Motor Trend comissioned an analysis of automatic vs. manual transmission for cars. We were interested in answering the following two questions: -

- Is an automatic or manual transmission better for MPG? - We find that manual transmission is generally better for car mileage, holding all other variables constant (see Appendix 2 for a zone between 2500-3500 lbs where automatic transmission sometimes performs better than manual transmission).
- What is the MPG difference between automatic and manual transmissions? - Miles per gallon difference between automatic and manual trasmission is about 1.21 mpg holding all other variables constant, with 95% confidence interval as (-5.70, 8.06). Given the interval crosses 0, we cannot reject the null hypothesis, that transmission type has no impact on miles per gallon.

Effect of transmission type on miles per gallon

The data used below is extracted from the 1974 Motor Trend US magazine, and comprises fuel consumption and 10 aspects of automobile design and performance for 32 automobiles (1973–74 models). Their transmission systems and their MPG are shown in Appendix 1. Plotting the MPG vs. Transmission type would suggest that Manual transmission seems to go further in miles per gallon, than Automatic transmission.



Simple linear regression of mpg vs. transmission type

Fitting a linear model with mpg as the outcome, and transmission (am in the dataset mtcars) as the predictor, mpg = b0 + b1 * am, shows that mpg is strongly correlated to transmission.

```
##             Estimate Std. Error   t value     Pr(>|t|)
## (Intercept) 17.147368   1.124603 15.247492 1.133983e-15
## am1          7.244939   1.764422  4.106127 2.850207e-04
```

Digging deeper

We need to understand whether one or many of othe variables have a correlation to miles per gallon, and are confounding this analysis. Fitting a linear model including all variables shows the following: -

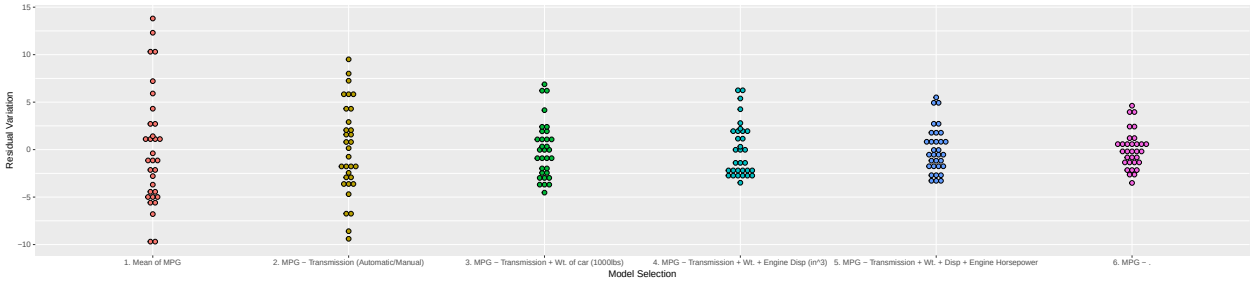
```
##                Estimate  Std. Error     t value   Pr(>|t|)
## (Intercept) 23.87913244 20.06582026  1.19004018 0.25252548
## cyl6        -2.64869528  3.04089041 -0.87102622 0.39746642
## cyl8        -0.33616298  7.15953951 -0.04695316 0.96317000
## disp         0.03554632  0.03189920  1.11433290 0.28267339
## hp          -0.07050683  0.03942556 -1.78835344 0.09393155
## drat         1.18283018  2.48348458  0.47627845 0.64073922
## wt          -4.52977584  2.53874584 -1.78425732 0.09461859
## qsec         0.36784482  0.93539569  0.39325050 0.69966720
## vs           1.93085054  2.87125777  0.67247551 0.51150791
## am1          1.21211570  3.21354514  0.37718957 0.71131573
## gear4        1.11435494  3.79951726  0.29328856 0.77332027
## gear5        2.52839599  3.73635801  0.67670068 0.50889747
## carb2       -0.97935432  2.31797446 -0.42250436 0.67865093
## carb3        2.99963875  4.29354611  0.69863900 0.49546781
## carb4        1.09142288  4.44961992  0.24528452 0.80956031
## carb6        4.47756921  6.38406242  0.70136677 0.49381268
## carb8        7.25041126  8.36056638  0.86721532 0.39948495
```

We see that the effect of manual transmission (am1) on mpg reduces from 7.24 to 1.21 confirming our hypothesis that other variables were confounding the analysis.

Parsimonious model

However, how are we assured that the standard errors are not being inflated, due to throwing in uncorrelated variables into the model? We form a hypthesis that weight of the car, the displacement and horsepower of the engine are covariates in addition to the transmission type in predicting the miles per gallon for the car. We will create 3 additional linear models: -

1. mpg = b0 (showing the variance of the mean of the miles per gallon)
2. mpg = b0 + b1 * am (add transmission type - this is what is shown above)
3. mpg = b0 + b1 * am + b2 * wt (add weight of the car in 1000's of pounds)
4. mpg = b0 + b1 * am + b2 * wt + b3 * disp (add displacement in cubic in.)
5. mpg = b0 + b1 * am + b2 * wt + b3 * disp + b4 * hp (add engine horsepower)
6. mpg ~ . (add all variables as predictors)



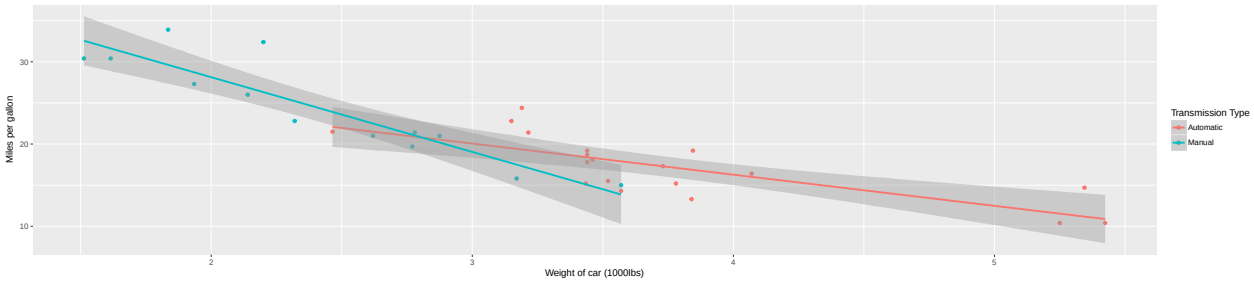
Taking weight, displacement, horsepower, and transmission type into account, we are able to parsimoniously explain the total variation in miles per gallon almost completely, comparing r-squared of model 6 (0.8930749) vs. model 5 (0.8402309). So, in summary, if we hold all other variables constant, moving from automatic to manual transmission type will result in a 1.21 mpg increase in mileage of the car. The confidence interval around this estimate is: -

```
##         2.5 %   97.5 %
## am1 -5.637394 8.061625
```

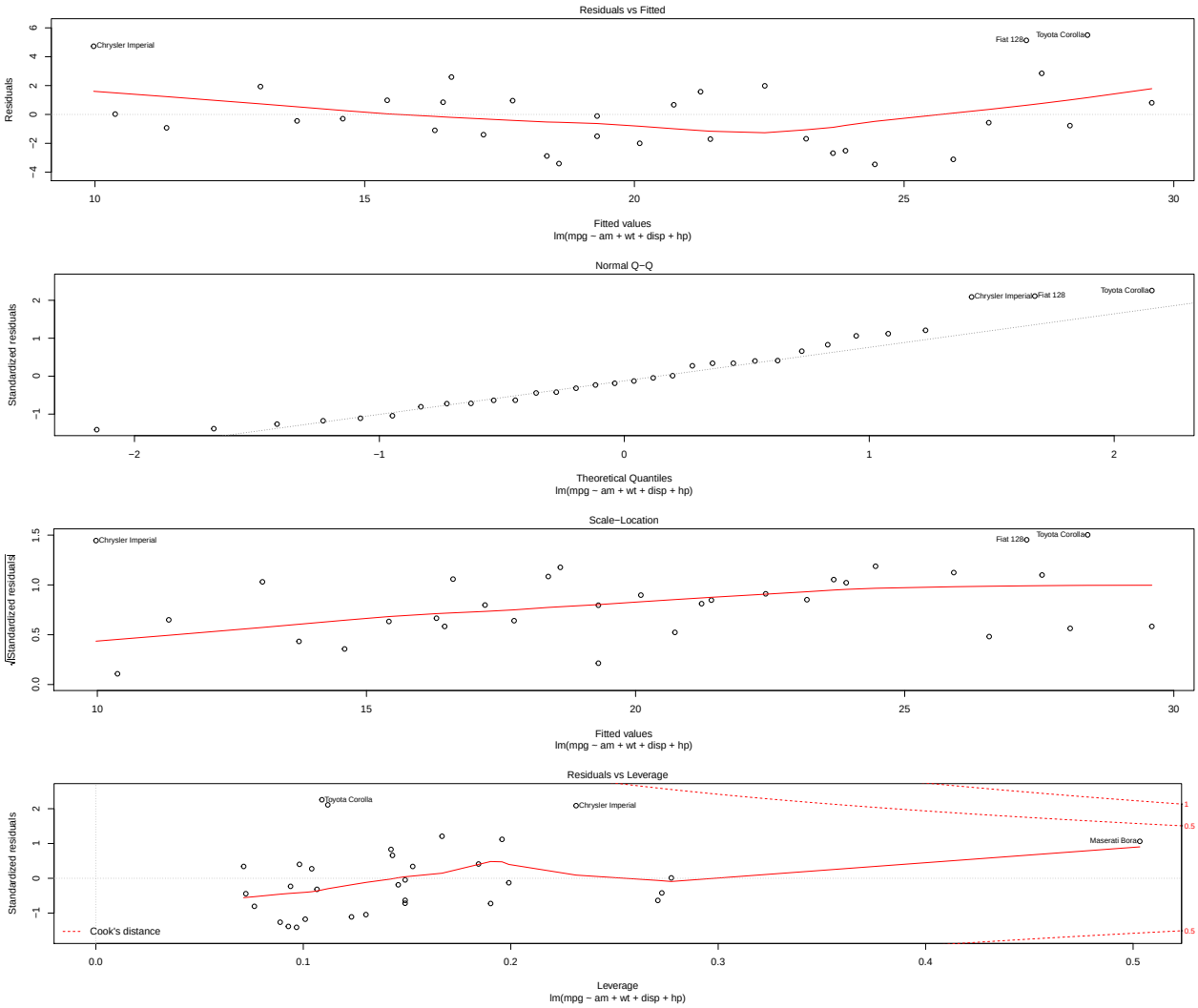
Appendix 1 - Cars in the sample dataset, with transmission type and miles per gallon

```
##                    Car Transmission  MPG
## 1            Mazda RX4       Manual 21.0
## 2        Mazda RX4 Wag       Manual 21.0
## 3           Datsun 710       Manual 22.8
## 4       Hornet 4 Drive    Automatic 21.4
## 5    Hornet Sportabout    Automatic 18.7
## 6              Valiant    Automatic 18.1
## 7           Duster 360    Automatic 14.3
## 8            Merc 240D    Automatic 24.4
## 9             Merc 230    Automatic 22.8
## 10            Merc 280    Automatic 19.2
## 11           Merc 280C    Automatic 17.8
## 12          Merc 450SE    Automatic 16.4
## 13          Merc 450SL    Automatic 17.3
## 14         Merc 450SLC    Automatic 15.2
## 15  Cadillac Fleetwood    Automatic 10.4
## 16 Lincoln Continental    Automatic 10.4
## 17   Chrysler Imperial    Automatic 14.7
## 18            Fiat 128       Manual 32.4
## 19         Honda Civic       Manual 30.4
## 20      Toyota Corolla       Manual 33.9
## 21       Toyota Corona    Automatic 21.5
## 22    Dodge Challenger    Automatic 15.5
## 23         AMC Javelin    Automatic 15.2
## 24          Camaro Z28    Automatic 13.3
## 25    Pontiac Firebird    Automatic 19.2
## 26           Fiat X1-9       Manual 27.3
## 27       Porsche 914-2       Manual 26.0
## 28        Lotus Europa       Manual 30.4
## 29      Ford Pantera L       Manual 15.8
## 30        Ferrari Dino       Manual 19.7
## 31       Maserati Bora       Manual 15.0
## 32          Volvo 142E       Manual 21.4
```

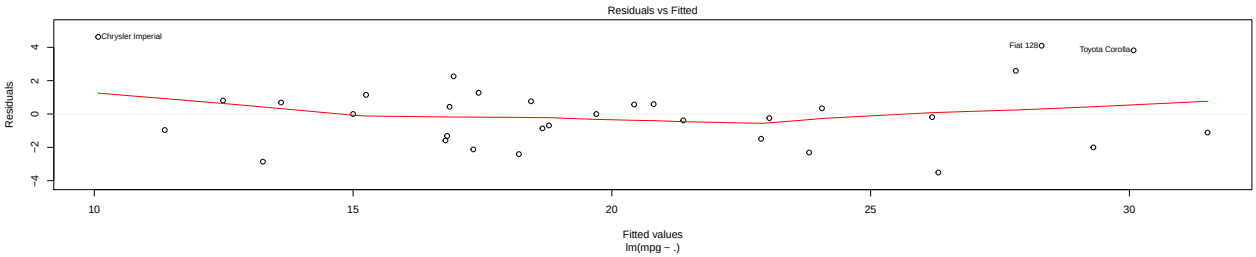
Appendix 2 - Miles per gallon vs. weight of the car, coloured by transmission type

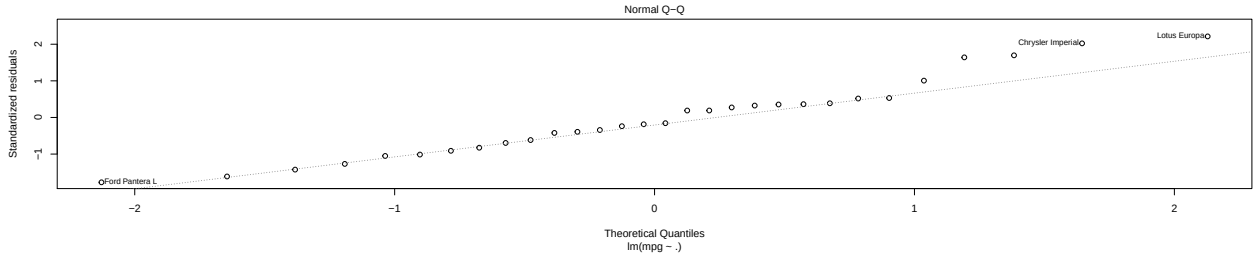


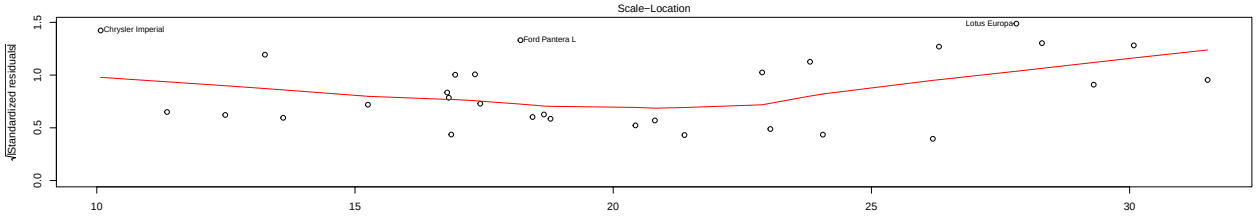
Appendix 3 - Plot of the mpg against transmission type, displacement, horsepower and wt

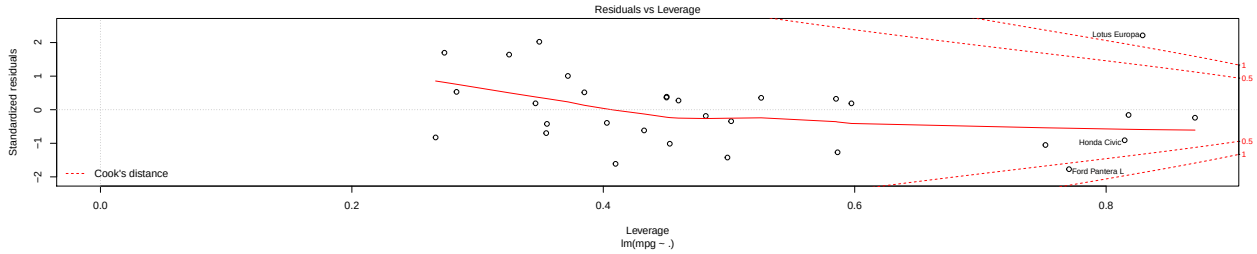


Appendix 4 - Plot of the mpg against all regressors




Normal Q−Q
Standardized residuals
Theoretical Quantiles
lm(mpg ~ .)
Chrysler Imperial
Lotus Europa
Ford Pantera L


Scale−Location
√|Standardized residuals|
Fitted values
lm(mpg ~ .)
Chrysler Imperial
Ford Pantera L
Lotus Europa


Residuals vs Leverage
Standardized residuals
Leverage
lm(mpg ~ .)
Cook's distance
Lotus Europa
Honda Civic
Ford Pantera L