

Motor Trends, fuel efficiency

R Mofidi

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Are manual cars more fuel efficient than automatic cars? If so by how much?

Introduction

The age-old question about whether a manual or automatic transmission is best for fuel efficiency has been around for over half a century. As petrol prices change and with global warming becoming an issue the argument gets more intense. The supporters of automatic cars will swear by their wonderful gas-efficiency while the manual drivers will argue the other way. To be sure driving automatic transmission is easier and more ergonomic. Fuel efficiency is related to multiple factors including the number of cylinders, the size of the engine and the weight of the car amongst other variables. This is a problem ideally suited to multivariate regression analysis, if only there was a suitable database available to perform such an analysis.

The data was extracted from the 1974 Motor Trend US magazine (1). It comprises fuel consumption and 10 aspects of automobile design and performance for 32 automobiles (1973–74 models). The data is historical however it is the only data set we have. The aim of the study is to perform the following assessments:

- 1- Is an automatic or manual transmission better for MPG?
- 2- Quantify the MPG difference between automatic and manual transmissions?

The dataset

```
library(datasets)
```

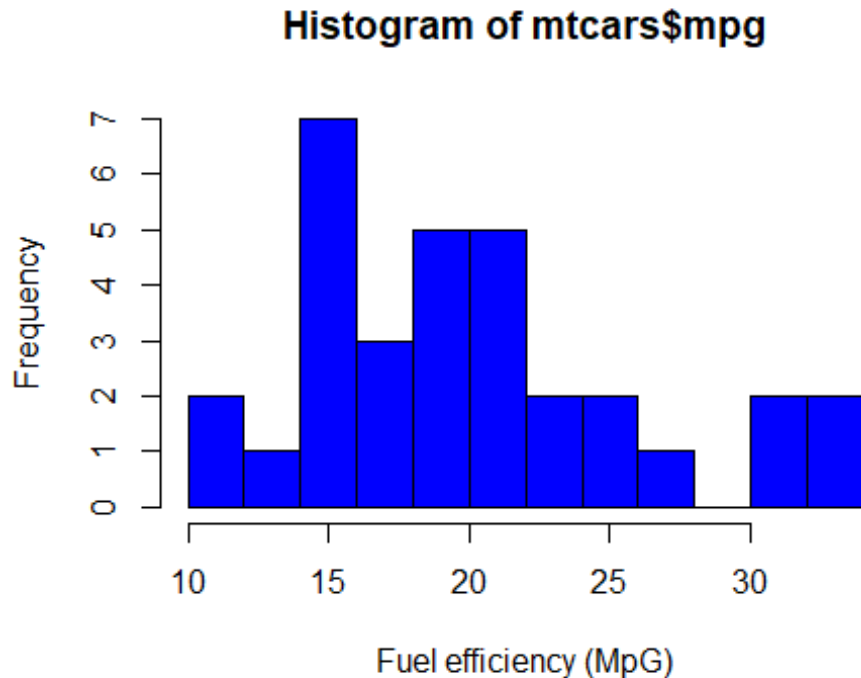
```
head(mtcars)
```

##	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
## Hornet 4 Drive	21.4	6	258	110	3.08	3.215	19.44	1	0	3	1
## Hornet Sportabout	18.7	8	360	175	3.15	3.440	17.02	0	0	3	2
## Valiant	18.1	6	225	105	2.76	3.460	20.22	1	0	3	1

```
summary(mtcars)
```

```
##      mpg      cyl      disp      hp
## Min.   :10.40  Min.   :4.000  Min.   : 71.1  Min.   : 52.0
## 1st Qu.:15.43  1st Qu.:4.000  1st Qu.:120.8  1st Qu.: 96.5
## Median :19.20  Median :6.000  Median :196.3  Median :123.0
## Mean   :20.09  Mean   :6.188  Mean   :230.7  Mean   :146.7
## 3rd Qu.:22.80  3rd Qu.:8.000  3rd Qu.:326.0  3rd Qu.:180.0
## Max.   :33.90  Max.   :8.000  Max.   :472.0  Max.   :335.0
##      drat      wt      qsec      vs
## Min.   :2.760  Min.   :1.513  Min.   :14.50  Min.   :0.0000
## 1st Qu.:3.080  1st Qu.:2.581  1st Qu.:16.89  1st Qu.:0.0000
## Median :3.695  Median :3.325  Median :17.71  Median :0.0000
## Mean   :3.597  Mean   :3.217  Mean   :17.85  Mean   :0.4375
## 3rd Qu.:3.920  3rd Qu.:3.610  3rd Qu.:18.90  3rd Qu.:1.0000
## Max.   :4.930  Max.   :5.424  Max.   :22.90  Max.   :1.0000
##      am      gear      carb
## Min.   :0.0000  Min.   :3.000  Min.   :1.000
## 1st Qu.:0.0000  1st Qu.:3.000  1st Qu.:2.000
## Median :0.0000  Median :4.000  Median :2.000
## Mean   :0.4062  Mean   :3.688  Mean   :2.812
## 3rd Qu.:1.0000  3rd Qu.:4.000  3rd Qu.:4.000
## Max.   :1.0000  Max.   :5.000  Max.   :8.000
```

```
hist(mtcars$mpg, breaks = 16, col = "blue", xlab="Fuel efficiency (MpG)")
```



Question-1 Is an automatic or manual transmission better for MPG?

The first question is which one of these 2 methods of transmission is better for fuel efficiency. At face value this is a question of statistical inference i.e. does the difference in fuel efficiency between automatic and manual cars read statistical significance and whether there is any association between fuel efficiency and transmission. The variable relating to the cars fuel efficiency is 'mpg'.

The variable which classifies the cars' transmission is 'am'. Manual cars are recorded as '1' and automatic cars '0'.

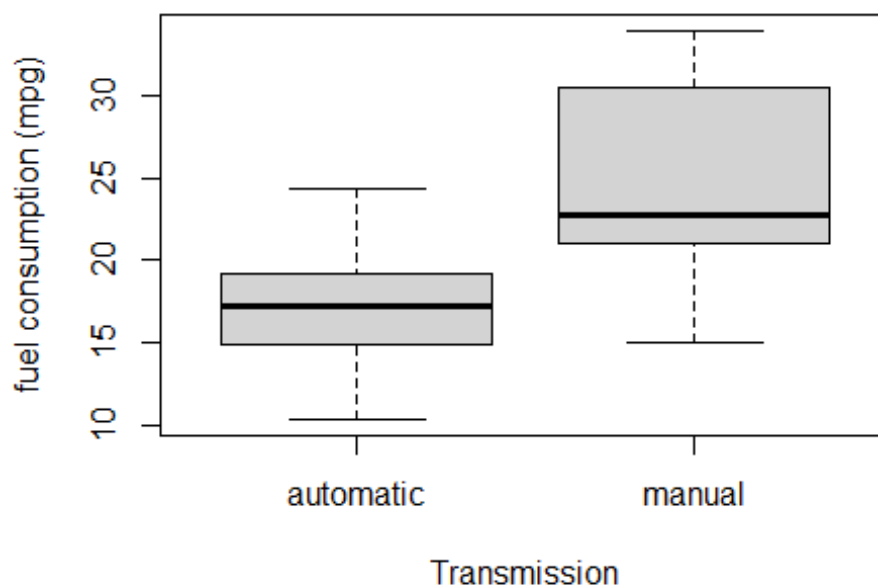
```
MeanMPG_MAN<- mean(mtcars$mpg[mtcars$am=="0"]); StdDevMPH_Man<-  
sd(mtcars$mpg[mtcars$am=="0"])  
MeanMPG_MAN; StdDevMPH_Man  
  
## [1] 17.14737  
## [1] 3.833966  
  
MeanMPG_Aut<- mean(mtcars$mpg[mtcars$am=="1"]); StdDevMPH_Aut<-  
sd(mtcars$mpg[mtcars$am=="1"])  
MeanMPG_Aut; StdDevMPH_Aut  
  
## [1] 24.39231  
## [1] 6.166504  
  
t.test(mtcars$mpg~mtcars$am)$p.value  
  
## [1] 0.001373638
```

Mean fuel consumption (efficiency) for Automatic cars is 17.147 mpg (std dev=3.833) and 24.39 mpg (std dev=6.166) for manual cars. This difference is statistically significant (P=0.00137).

```
mtcars$transmission<- factor(mtcars$am, labels=c("automatic", "manual"))  
summary(lm(mpg~transmission, mtcars))  
  
##  
## Call:  
## lm(formula = mpg ~ transmission, data = mtcars)  
##  
## Residuals:  
##      Min       1Q   Median       3Q      Max   
## -9.3923 -3.0923 -0.2974  3.2439  9.5077   
##  
## Coefficients:  
##              Estimate Std. Error t value Pr(>|t|)      
## (Intercept)      17.147      1.125  15.247 1.13e-15 ***  
## transmissionmanual    7.245      1.764   4.106 0.000285 ***  
## ---
```

```
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 4.902 on 30 degrees of freedom
## Multiple R-squared:  0.3598, Adjusted R-squared:  0.3385
## F-statistic: 16.86 on 1 and 30 DF,  p-value: 0.000285
```

Clearly univariate regression analysis suggests that manual transmission is associated with significantly higher miles per gallon (mpg value) and lower fuel consumption (better fuel efficiency).



The next question is whether after account for other variables automatic transmission is still associated with higher fuel consumption (poorer fuel efficiency). For this we perform multivariate regression analysis. For this 'mpg' is selected as the dependent variable, 'am' as the independent variable and 'cyl', 'hp' as well as 'gear' as covariates. The following is a list of what these variables are recorded in a data frame with 32 observations on 11 (numeric) variables (1).

[, 1] mpg Miles/(US) gallon [, 2] cyl Number of cylinders [, 3] disp Displacement (cu.in.) [, 4] hp Gross horsepower [, 5] drat Rear axle ratio [, 6] wt Weight (1000 lbs) [, 7] qsec 1/4 mile time [, 8] vs Engine (0 = V-shaped, 1 = straight) [, 9] am Transmission (0 = automatic, 1 = manual) [,10] gear Number of forward gears

```

univar <- lm(mpg ~ am, data = mtcars)
multivar<- lm(mpg~am+cyl+hp+gear, mtcars)
summary(multivar)

##
## Call:
## lm(formula = mpg ~ am + cyl + hp + gear, data = mtcars)
##
## Residuals:
##      Min       1Q   Median       3Q      Max
## -4.7608 -1.9415 -0.2465  1.5457  6.0684
##
## Coefficients:
##              Estimate Std. Error t value Pr(>|t|)
## (Intercept) 30.13671     6.08447   4.953 3.46e-05 ***
## am           3.74434     1.74774   2.142  0.0413 *
## cyl          -1.07827     0.73460  -1.468  0.1537
## hp           -0.03797     0.01674  -2.269  0.0315 *
## gear          0.18297     1.31060   0.140  0.8900
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 2.857 on 27 degrees of freedom
## Multiple R-squared:  0.8043, Adjusted R-squared:  0.7753
## F-statistic: 27.74 on 4 and 27 DF, p-value: 3.245e-09

anova(univar, multivar)

## Analysis of Variance Table
##
## Model 1: mpg ~ am
## Model 2: mpg ~ am + cyl + hp + gear
##   Res.Df    RSS Df Sum of Sq    F    Pr(>F)
## 1       30 720.90
## 2       27 220.39  3     500.5 20.439 4.06e-07 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

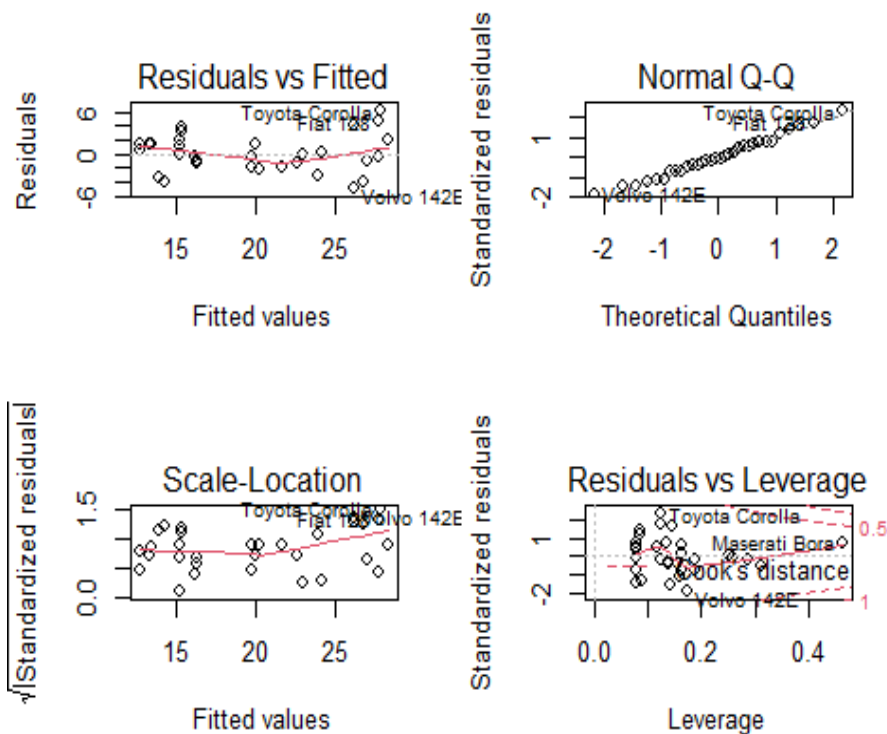
```

After accounting for these variables the association between transmission and fuel consumption (mpg) is less significant (P=0.0413).

```

par(mfrow = c(2,2))
plot(multivar)

```



Quantify the MPG difference between automatic and manual transmissions?

This question is also answered using linear regression analysis:

```
mtcars$transmission<- factor(mtcars$am, labels=c("automatic", "manual"))
summary(lm(mpg~transmission, mtcars))

##
## Call:
## lm(formula = mpg ~ transmission, data = mtcars)
##
## Residuals:
##      Min       1Q   Median       3Q      Max
## -9.3923 -3.0923 -0.2974  3.2439  9.5077
##
## Coefficients:
##              Estimate Std. Error t value Pr(>|t|)
## (Intercept)      17.147      1.125  15.247 1.13e-15 ***
## transmissionmanual    7.245      1.764   4.106 0.000285 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 4.902 on 30 degrees of freedom
## Multiple R-squared:  0.3598, Adjusted R-squared:  0.3385
## F-statistic: 16.86 on 1 and 30 DF, p-value: 0.000285
```

Bearing in mind that the variable 'am' is a binary variable, the estimated coefficient (7.245) also represents the difference in mpg between automatic and manual transmissions.

Conclusions

Based on the analysis of the mtcars database which is a little dated now, manual cars have significantly higher mpg values i.e are significantly more fuel efficient. Fuel efficiency is a complex variable being dependent on multiple variables such as the number of forward gears, engine power in horse power and number of cylinders amongst other variables and once these variables are assigned as co-variates the association between transmission (am) and fuel efficiency 'mpg' becomes less significant.

Manual transmission cars have fuel efficiency which is higher by 7.245 mpg.

Reference

- (1) R-core R-core@R-project.org. Mt cars dataset in R.
<https://www.rdocumentation.org/packages/datasets/versions/3.6.2/topics/mtcars>
(accessed 20/06/2020)