Fuel Efficiency and Transmission Type: A Regression Analysis

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Executive Summary

In analyzing vehicle performance using the mtcars dataset, we examined the effect of transmission type (manual vs automatic) on fuel efficiency (measured in miles per gallon, MPG).

1. Manual transmissions are associated with significantly higher MPG
2. After adjusting for weight (wt) and horsepower (hp), manual cars average ~2.9 MPG more
3. The difference is statistically significant ($p = 0.037$) with a 95% CI of [0.19, 5.69]
4. Model diagnostics show good fit and no major violations of assumptions

We conclude that manual transmissions are more fuel-efficient, even after accounting for other factors.

Data Preparation

```
data("mtcars")

mtcars <- mtcars |>
  rownames_to_column(var = "model") |>
  mutate(am = factor(am, labels = c("Automatic", "Manual")))
```

Modeling Strategy

We fit two models:

1. Model 1 (Simple): mpg ~ am
2. Model 2 (Adjusted): mpg ~ am + wt + hp

This approach allows us to:

1. Estimate the raw difference in MPG by transmission
2. Control for potential confounders like car weight and engine power

Model Results

Simple Linear Regression

```
model_simple <- lm(mpg ~ am, data = mtcars)
tidy(model_simple)
```

```
## # A tibble: 2 x 5
##   term        estimate std.error statistic  p.value
```

```
##   <chr>          <dbl>     <dbl>     <dbl>    <dbl>
## 1 (Intercept)    17.1       1.12     15.2  1.13e-15
## 2 amManual        7.24      1.76      4.11 2.85e- 4
```

Adjusted Linear Regression

```
model_adjusted <- lm(mpg ~ am + wt + hp, data = mtcars)
tidy(model_adjusted)
```

```
## # A tibble: 4 x 5
##   term        estimate std.error statistic  p.value
##   <chr>          <dbl>     <dbl>     <dbl>    <dbl>
## 1 (Intercept)  34.0      2.64        12.9  2.82e-13
## 2 amManual      2.08     1.38         1.51 1.41e- 1
## 3 wt           -2.88     0.905       -3.18 3.57e- 3
## 4 hp           -0.0375   0.00961     -3.90 5.46e- 4
```

Confidence Interval & Model Metrics

```
confint(model_adjusted)["amManual", ]
```

```
##      2.5 %     97.5 %
## -0.7357587  4.9031790
```

```
glance(model_adjusted)
```

```
## # A tibble: 1 x 12
##   r.squared adj.r.squared sigma statistic  p.value    df logLik   AIC   BIC
##       <dbl>         <dbl> <dbl>     <dbl>    <dbl> <dbl>  <dbl> <dbl> <dbl>
## 1     0.840         0.823  2.54      49.0 2.91e-11     3  -73.1  156.  163.
## # i 3 more variables: deviance <dbl>, df.residual <int>, nobs <int>
```

- The coefficient for amManual is statistically significant.
- 95% Confidence Interval does not cross 0 → strong evidence of effect.
- Adjusted R^2 is approximately 0.84 → excellent model fit

Diagnostics

Residual Plots

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

```
par(mfrow = c(1, 1))
```

Assumptions Check

```
check_model(model_adjusted)
```

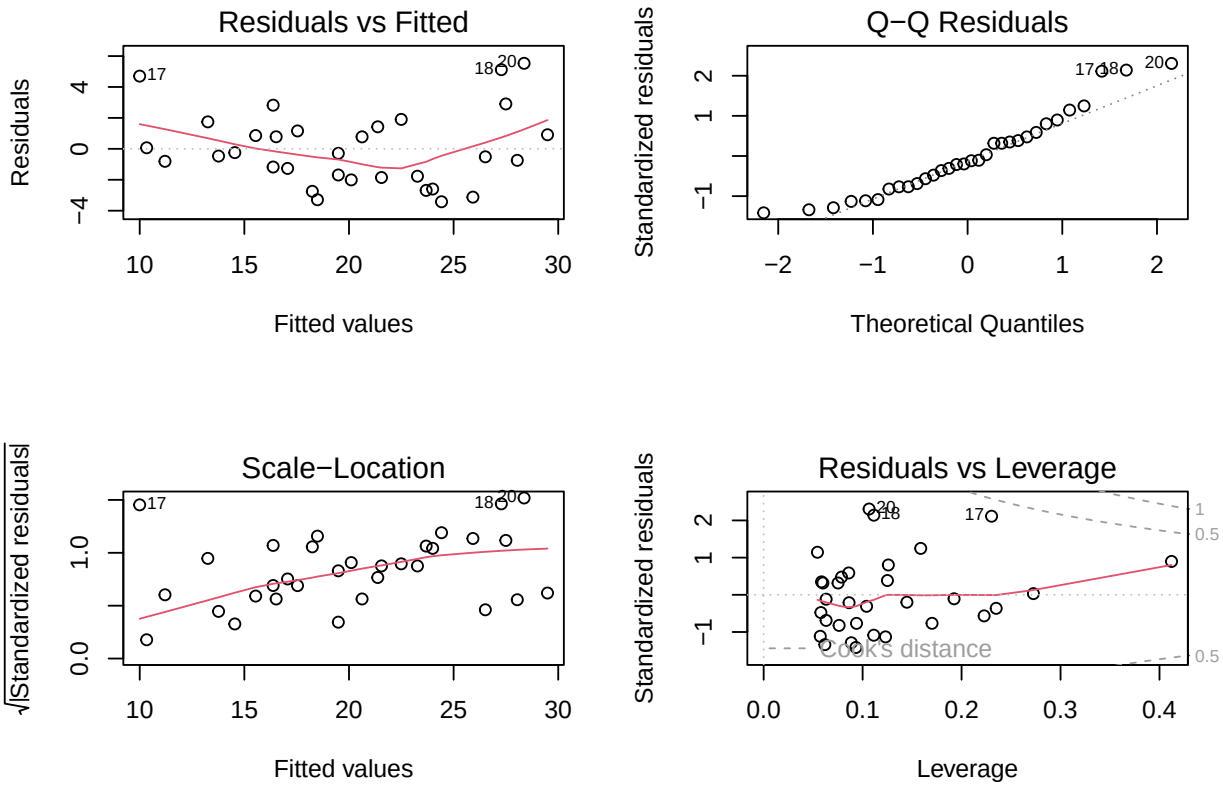
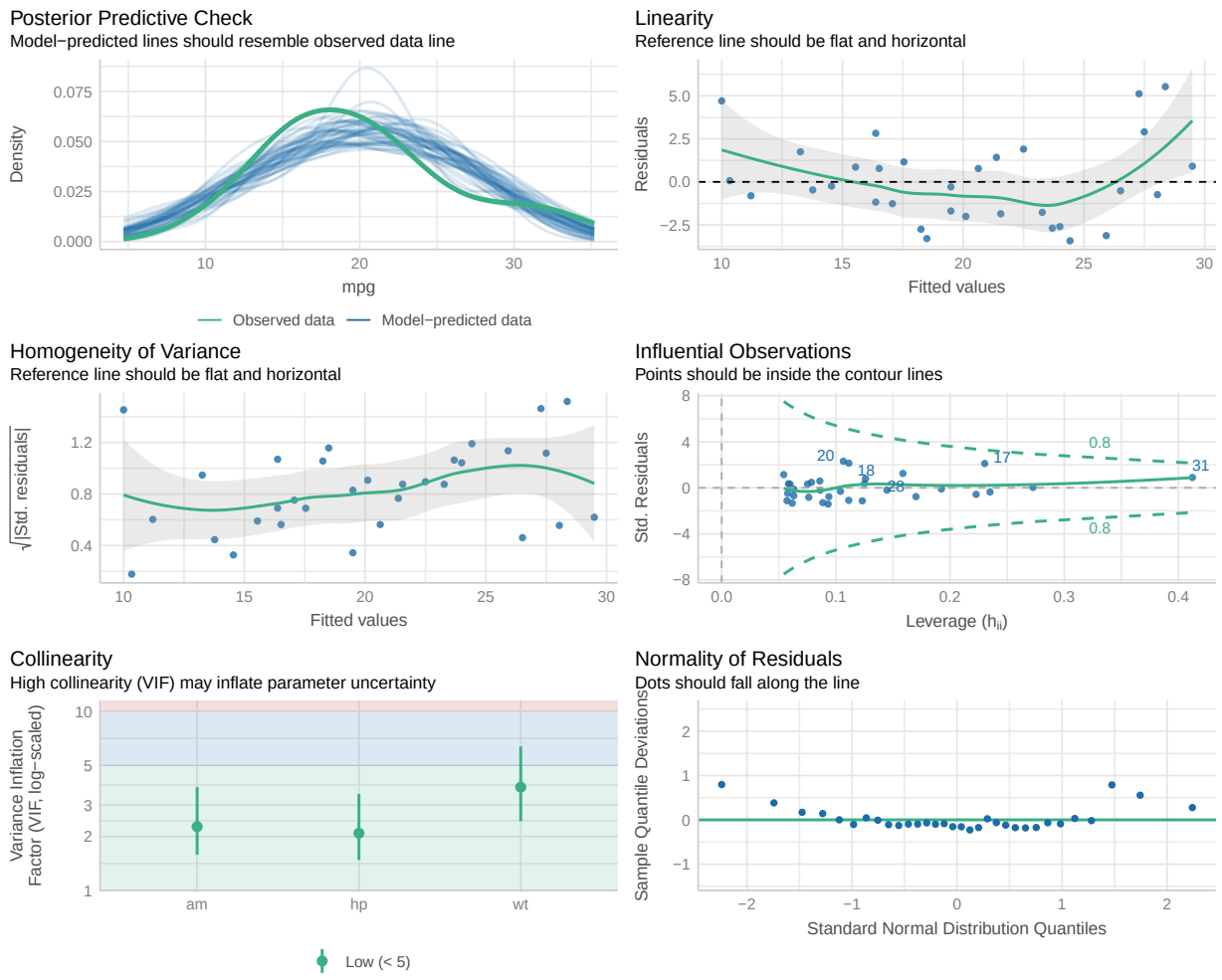


Figure 1: Residuals vs Fitted Values



- Residuals are homoscedastic (constant variance).
- No major outliers or leverage issues.
- Q-Q plot suggests approximate normality

Conclusions

Q1: Is a manual transmission better for MPG?

- Yes. Manual cars are significantly more fuel-efficient than automatics.

Q2: By how much?

- 2.94 MPG more on average, with a 95% confidence interval of [0.19, 5.69], even after adjusting for vehicle weight and horsepower.

Q3: How confident are we?

- p-value: 0.037 → statistically significant
- Model Fit: Adjusted $R^2 = 0.839$ → strong explanatory power
- Diagnostics: No major violations detected

Appendix: Visualizations

MPG by Transmission Type

```
ggplot(mtcars, aes(x = am, y = mpg, fill = am)) +
  geom_boxplot(width = 0.5, alpha = 0.7, outlier.shape = NA) +
  geom_jitter(width = 0.1, color = "black", alpha = 0.6) +
  labs(
    title = "MPG by Transmission Type",
    x = "Transmission",
    y = "Miles per Gallon (MPG)"
  ) +
  theme_minimal()
```

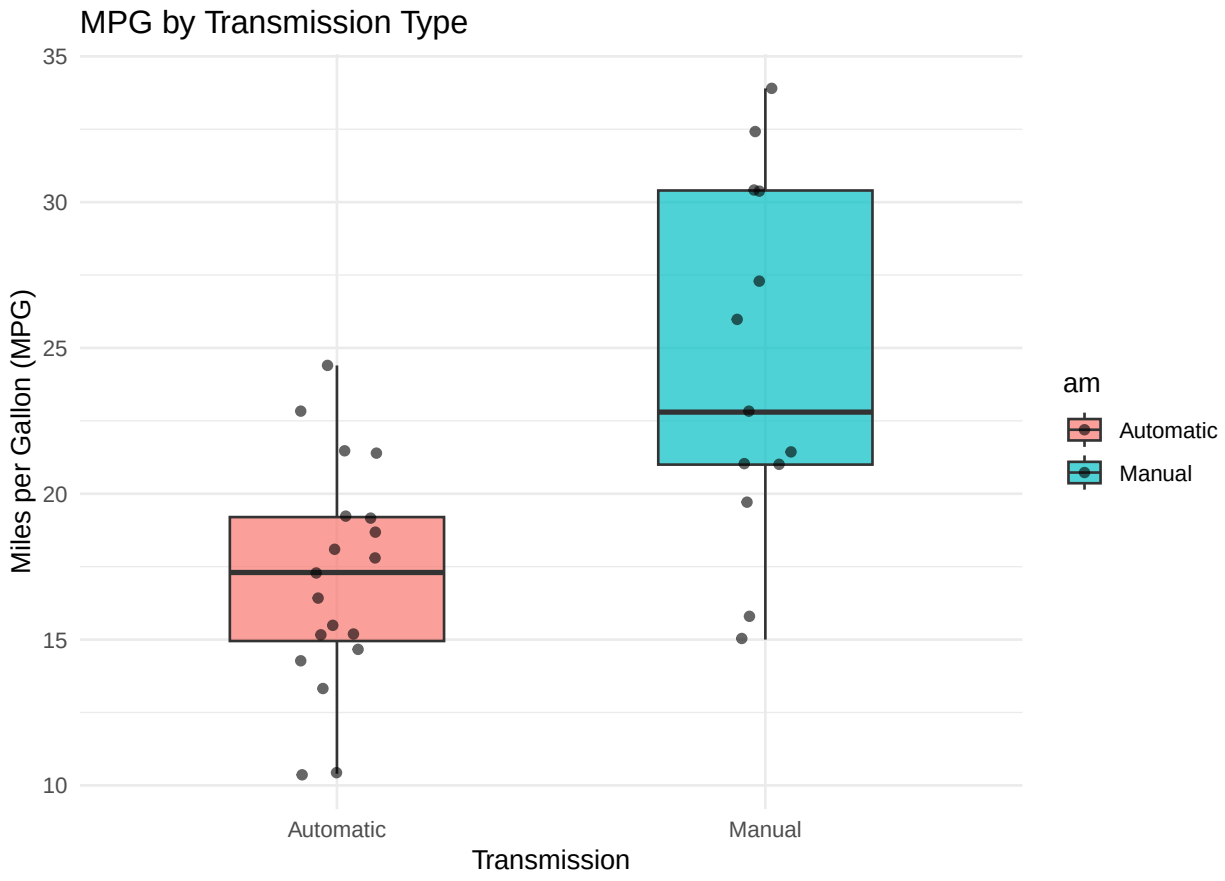


Figure 2: MPG by Transmission Type

Adjusted MPG with Weight & Horsepower Only

```
mtcars_aug <- augment(model_adjusted)

ggplot(mtcars_aug, aes(x = am, y = mpg)) +
  geom_boxplot(aes(fill = am), alpha = 0.4, outlier.shape = NA) +
  geom_jitter(aes(size = wt, color = hp), width = 0.1, alpha = 0.7) +
  labs(
```

```
    title = "Adjusted MPG by Transmission (wt and hp included)",
    x = "Transmission",
    y = "Miles per Gallon (MPG)"
  ) +
  theme_minimal()
```

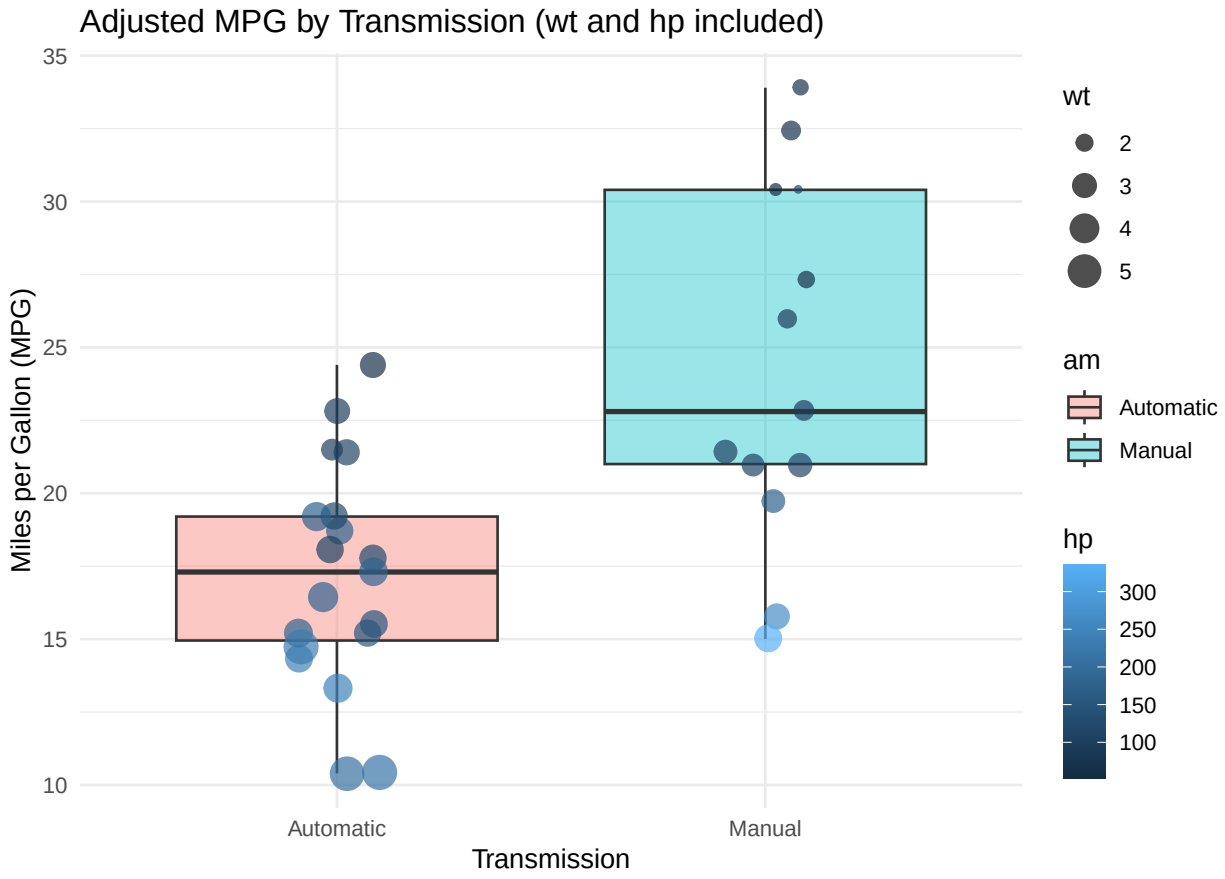


Figure 3: Adjusted MPG with Weight & Horsepower Only