

# Analysis of the Various Factors Influencing the Success of FRC Teams

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Abstract

TODO

# 1 Introduction

FIRST Robotics Competition is a robotics competition in which teams of high schoolers build robots to compete in a game that is different every year.. FIRST is the organization that runs these competitions, and the acronym FIRST stands for “For the Inspiration and Recognition of Science and Technology.” Each year, FIRST reveals a new game in which alliances of 3 industrial-size robots compete against each other on a field to complete various tasks. Teams have limited time after “Kickoff” (the game reveal) to design, build, wire, and program their robot to perform the tasks required for the game. For example, in this year’s game, CHARGED UP, robots must travel across the field to the Substation Area to pick up one game piece (a cube or a cone) at a time and then travel back to their alliance’s Grid and deposit the pieces onto Nodes.

There are many factors that could have an effect on a team’s success. These include general things about the team, such as the team’s age, its budget, and its size, and also things about their robot in a specific season, such as drivetrain type and scoring capability. The goal of this research is to determine which of these factors have the greatest effect on a team’s success.

## 2 Literature Review

There is not much work that has been done on this topic. The most relevant paper that I could find was “An analysis of the Success of FRC Robotics Teams” by Max Tepermeister. Tepermeister found that team age had a small amount of correlation with success, while team budget and team size had no correlation with success. However, Tepermeister used OPR (offensive power rating) rather than win rate to measure a team’s success, which means that his results could be different from mine.

## 3 Method

### 3.1 Analysis of individual variables

I plan to analyze whether several variables have a significant influence on a team’s success. Only qualification matches will be analyzed because the alliances are random and the data only covers scouting matches. **TODO: ADD MORE HERE (HOW IS SUCCESS MEASURED?)**

#### 3.1.1 Drivetrain

A robot’s drivetrain can have a huge influence on how successful it is. FRC games are typically quite fast-paced, so a better drivetrain can make a huge difference. For most games, the playing field is quite flat, with few obstacles to overcome. This is true of both RAPID REACT and CHARGED UP. In games with few obstacles, teams will typically use some sort of “normal” drivetrain (i.e. one without huge wheels or anything like that). The three main types of drivetrain typically found in FRC are:

1. Differential
2. Mecanum
3. Swerve

A differential drive has normal wheels on the left and right sides of the robot. A Mecanum drive uses Mecanum wheels, which are special wheels with diagonal rollers mounted around the circumference. A robot with a mecanum drivetrain can drive forwards and backwards, similar to a differential drivetrain, but it can also drive sideways by driving specific wheels in specific directions. A swerve drive is another type of drivetrain that can drive in any direction, but unlike the Mecanum drivetrain, the swerve drive achieves this by using two motors for each wheel: one to drive the wheel, and another to steer the wheel. This allows each wheel to be steered independently of the others, which allows for complex maneuvers.

These can be grouped into two categories, namely holonomic (Mecanum and swerve) and non-holonomic (differential). The difference between these two categories is that while a non-holonomic drivetrain constrains a robot to only move forwards and backwards such that it must turn to change its direction of motion, a holonomic drivetrain is free of these constraints.

A differential drive is usually the cheapest, since it requires no special parts. The next cheapest of these three is the Mecanum drive because you only need the 4 wheels and a motor for each. However, one major drawback of a Mecanum drivetrain is that the wheels are more prone to slipping. This means that a robot with a Mecanum drivetrain has a lower maximum acceleration before the wheels start to slip. It also means that in FRC, a robot with a Mecanum drivetrain is very easy to play defense against because a robot with a differential drive or a swerve drive can easily shove it around. Finally, the most expensive, but also the most effective is the swerve drive. The swerve drive combines the lack of slip (and by extension, pushing power) of a differential drivetrain with the flexibility of a holonomic drivetrain. The main drawback of swerve drive is that it can at times be prohibitively expensive, with a single swerve module typically costing upwards of \$300 not even including the motors. This is because they are very complex, with lots of gears and custom machined parts.

To analyze the effect of drivetrain on a team's success, I will perform a two sample difference of means  $t$ -test to compare the win rate of teams with holonomic drivetrains to teams without holonomic drivetrains.

### **3.1.2 School budget**

A school's budget can have a huge influence on a team's budget, which can in turn influence the team's success by allowing them to use more complex tools, purchase higher-end parts, and go to more events.

To analyze the effect of budget on a robot's success, I will create a model using school expenditures per pupil to predict win rate and perform a  $t$ -test for slope to see if the relationship is significant.

### 3.1.3 Team age

An older team will likely have more advanced techniques and manufacturing processes at its disposal, while a younger team will typically not have these things. Team number is a good proxy to team age because the team numbers are assigned sequentially.

To analyze the effect of a team's age on its success, I will create a model using team age to predict win rate and perform a  $t$ -test for slope to see if the relationship is significant.

## 3.2 Predictive models

After analyzing individual variables, I will create a multiple linear regression model using a combination of the above variables to predict a team's overall win rate

## 3.3 Data collection and sources

My data comes from three main sources:

1. Evan Kuykendall's 2023 scouting data from Glacier Peak, Auburn, and the Pacific Northwest District Championship
2. Jake Benjamin's 2022 scouting data from Auburn and the Pacific Northwest District Championship
3. The Blue Alliance

The scouting datasets contain information about each robot in every match that was scouted. An example of something that would be included in the data for 2022 would be number of pieces scored in the UPPER HUB while an example of something that would be included in the data for 2023 would be number of pieces scored in HYBRID NODES. The Blue Alliance only has more general data, such as match results (win/loss). However, it also contains information about who was on what alliance for a specific match. This will be useful for gathering data about alliance members to use in the logistic regression model. I also have data from the Department of Education for the inference test with school expenditures.

## 4 Findings

### 4.1 Tests

#### 4.1.1 Win rate vs. drivetrain type

Let  $\mu_h$  = True mean win rate of teams whose robots have holonomic drivetrains

Let  $\mu_{nh}$  = True mean win rate of teams whose robots have non-holonomic drivetrains

$$H_0 : \mu_h = \mu_{nh}$$

$$H_a : \mu_h \neq \mu_{nh}$$

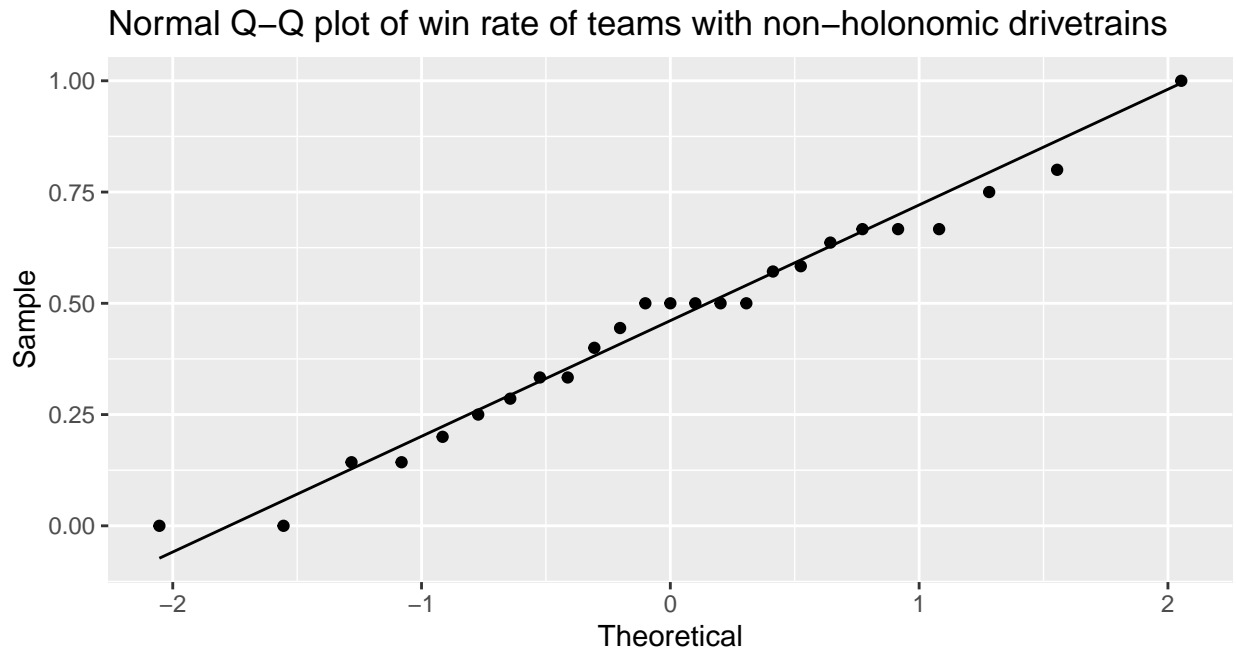
$$\alpha = 0.05$$

## Two-sample difference in means $t$ -test

Random: teams were selected using a simple random sample

Normal:

- $n_h = 34 \Rightarrow$  Central limit theorem states that the distribution of sample means is approximately normal
- $n_{nh} = 25 \Rightarrow$  CLT fails, need normal probability plot



```
##
##  Welch Two Sample t-test
##
## data:  win_rate by dt_type
## t = 1.4802, df = 53.038, p-value = 0.1447
## alternative hypothesis: true difference in means between group h and group nh is not
## 95 percent confidence interval:
##  -0.0354328  0.2350284
## sample estimates:
##  mean in group h mean in group nh
##      0.5547444      0.4549466
```

Normal probability plot is approximately linear  $\Rightarrow$  win rate of teams with non-holonomic drivetrains is approximately normally distributed

Independent:

- $n_h = 34 \not\leq 0.1N_h$ , proceeding with caution

- $n_{nh} = 25 \not\leq 0.1N_{nh}$ , proceeding with caution

$$t = 1.4802$$

$$p = 0.1447 \text{ on } 53.038 \text{ df}$$

Since our  $p$ -value (0.1447) is greater than  $\alpha$  (0.05), we fail to reject our null hypothesis. Therefore, we do not have enough evidence to support the alternative hypothesis.

#### 4.1.2 Win rate vs. school expenditure per pupil

Let  $\beta$  = True mean slope of the relationship between win rate and school expenditure per pupil

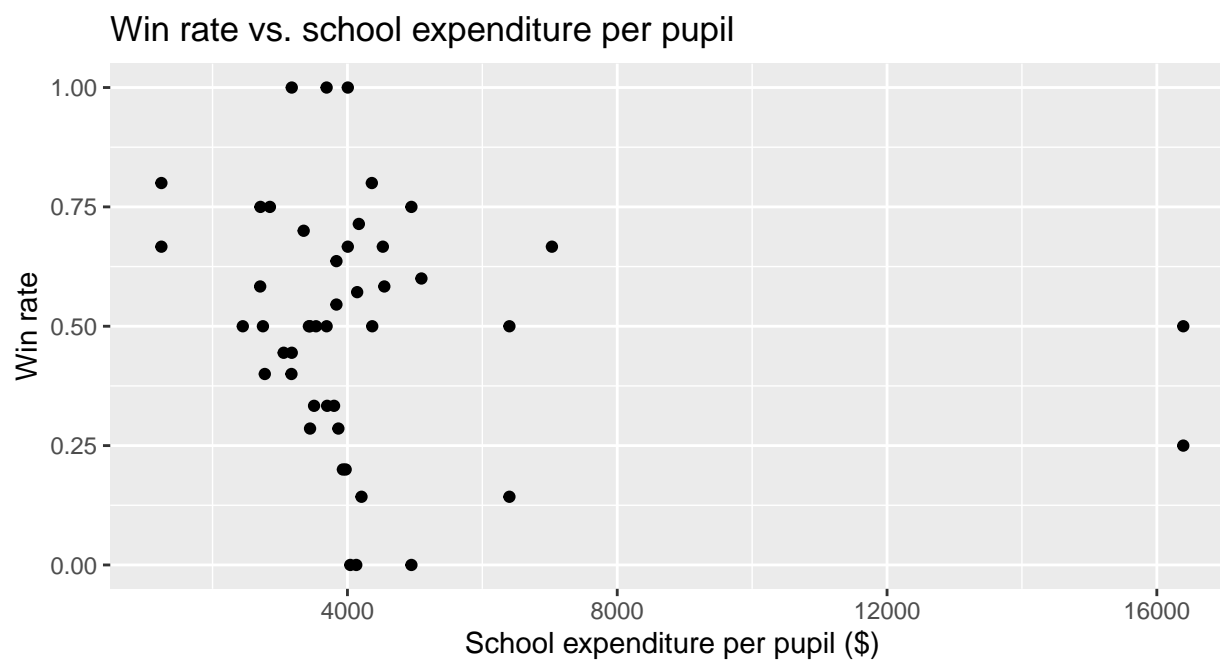
$$H_0 : \beta = 0$$

$$H_a : \beta \neq 0$$

$$\alpha = 0.05$$

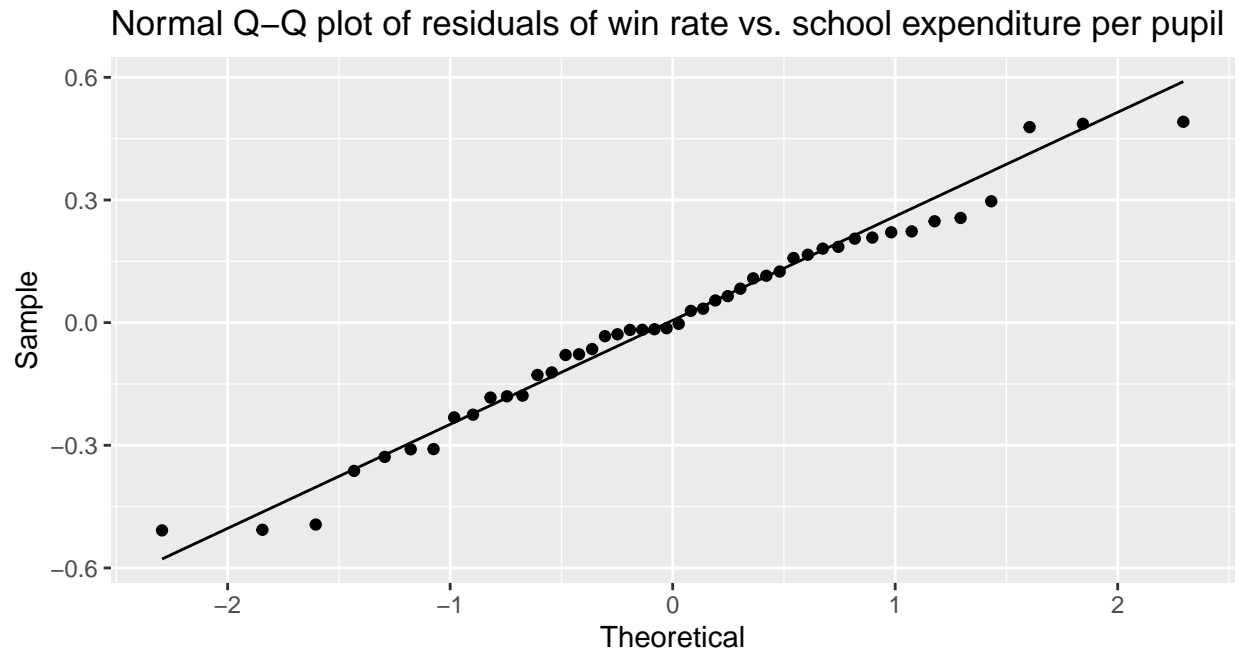
$t$ -test for slope

Linear:



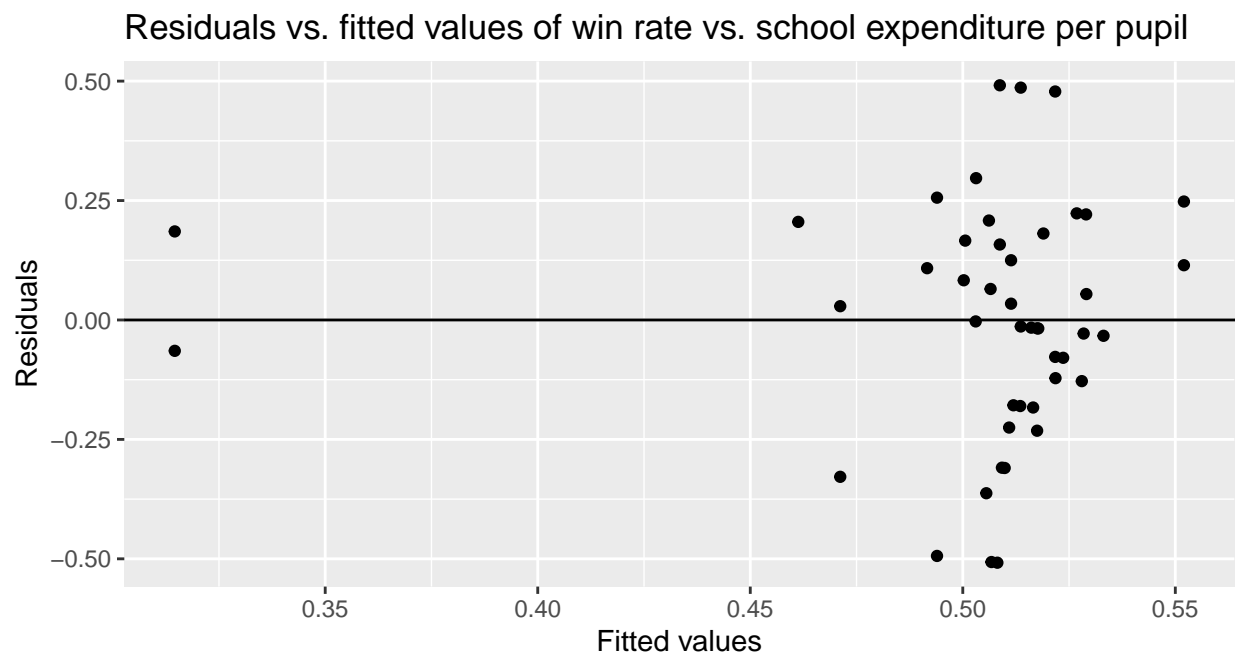
Scatterplot of the data does not appear linear  $\Rightarrow$  proceeding with caution

Normal:



Q-Q plot is approximately linear  $\Rightarrow$  residuals are approximately normally distributed

Equal Variance:



Residuals appear to be randomly distributed around 0  $\Rightarrow$  variance is approximately equal

```
##
## Call:
## lm(formula = win_rate ~ eps, data = team_data)
##
```

```
## Coefficients:
## (Intercept)          eps
##    5.715e-01    -1.567e-05
```

$$t = -1.189$$

$$p = 0.241 \text{ on } 44 \text{ df}$$

Since our  $p$ -value (0.241) is greater than  $\alpha$  (0.05), we fail to reject our null hypothesis. Therefore, we do not have enough evidence to support the alternative hypothesis.

### 4.1.3 Win rate vs. team number

Let  $\beta$  = True mean slope of the relationship between win rate and team number

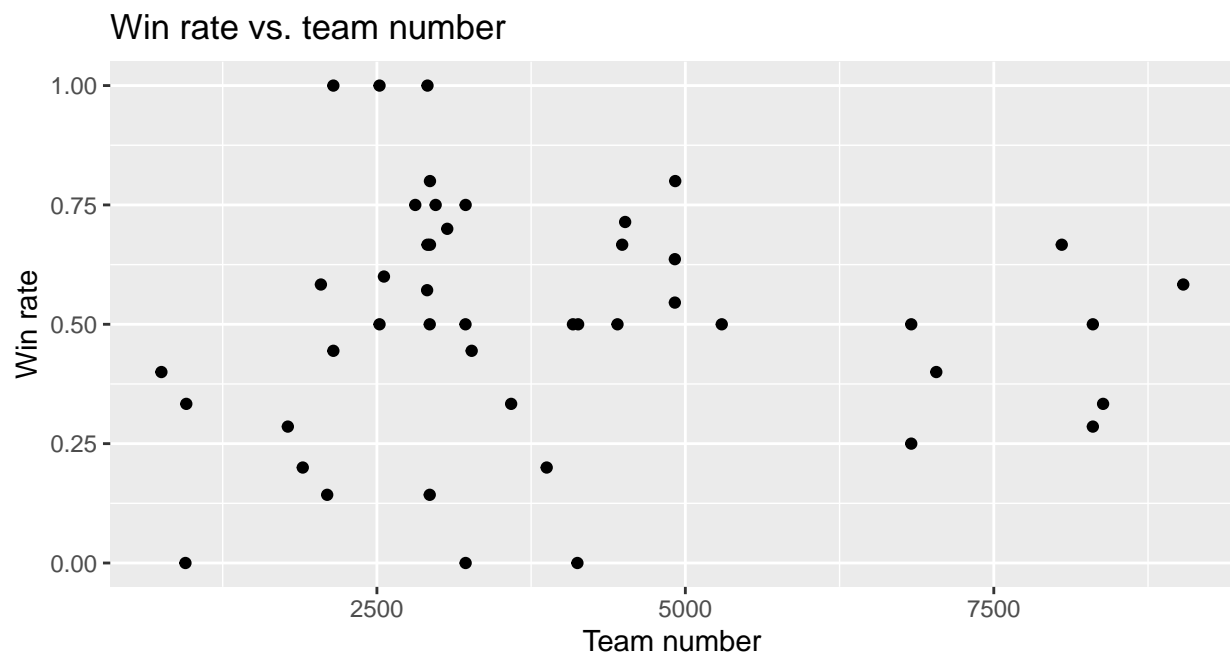
$$H_0 : \beta = 0$$

$$H_a : \beta \neq 0$$

$$\alpha = 0.05$$

$t$ -test for slope

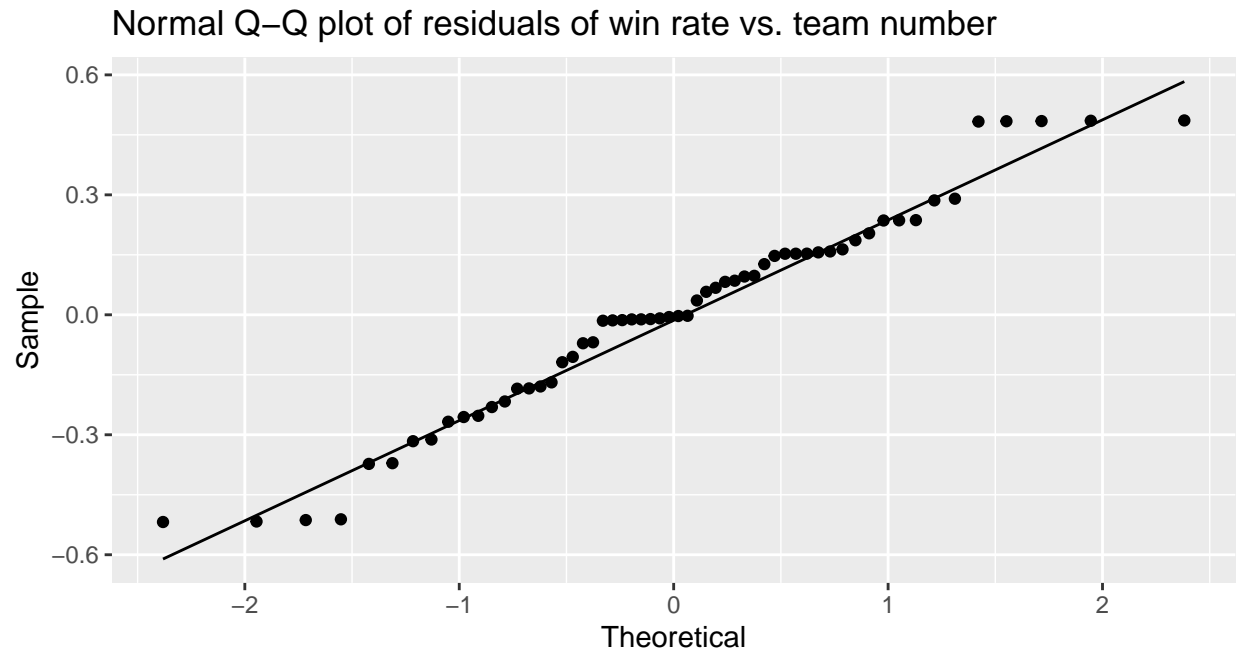
Linear:



Scatterplot of the data does not appear linear  $\Rightarrow$  proceeding with caution

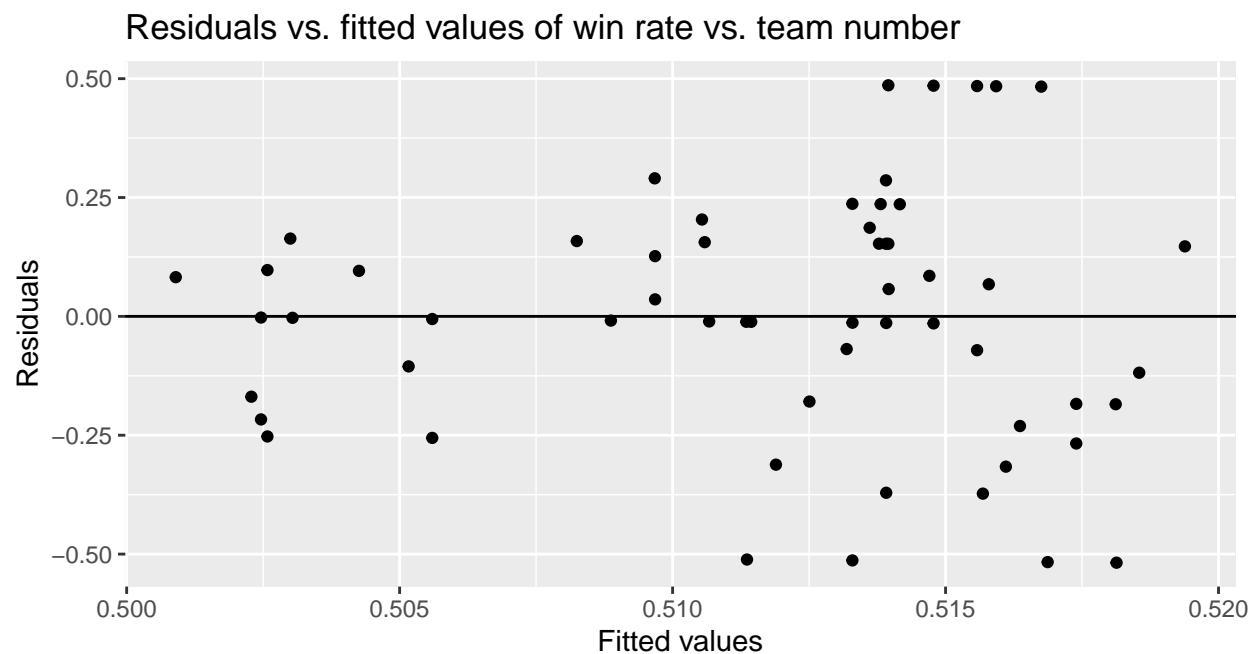
Normal:





Q-Q plot is approximately linear  $\Rightarrow$  residuals are approximately normally distributed

Equal Variance:



Residuals appear to be randomly distributed around 0  $\Rightarrow$  variance is approximately equal

```
##
## Call:
## lm(formula = win_rate ~ team, data = team_data)
##
```

```
## Residuals:
##      Min       1Q   Median       3Q      Max
## -0.51813 -0.18284 -0.00432  0.15528  0.48605
##
## Coefficients:
##              Estimate Std. Error t value Pr(>|t|)
## (Intercept)  5.202e-01  6.760e-02   7.694 2.46e-10 ***
## team        -2.131e-06  1.474e-05  -0.145   0.886
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 0.2608 on 56 degrees of freedom
## (2 observations deleted due to missingness)
## Multiple R-squared:  0.0003729, Adjusted R-squared:  -0.01748
## F-statistic: 0.02089 on 1 and 56 DF,  p-value: 0.8856
```

$$t = -0.145$$

$$p = 0.886 \text{ on } 56 \text{ df}$$

Since our  $p$ -value (0.886) is greater than  $\alpha$  (0.05), we fail to reject our null hypothesis. Therefore, we do not have enough evidence to support the alternative hypothesis.

## 4.2 Predictive Model

### 4.2.1 The model

```
##
## Call:
## lm(formula = win_rate ~ dt_type + eps + dt_type:team + dt_type:eps:team,
##     data = team_data)
##
## Residuals:
##      Min       1Q   Median       3Q      Max
## -0.59818 -0.13468 -0.00769  0.12050  0.47397
##
## Coefficients:
##              Estimate Std. Error t value Pr(>|t|)
## (Intercept)    8.246e-01  2.814e-01   2.931  0.00563 **
## dt_typenh       5.356e-02  1.926e-01   0.278  0.78240
## eps            -1.228e-04  6.972e-05  -1.761  0.08608 .
## dt_typeh:team    1.326e-05  6.450e-05   0.206  0.83814
## dt_typenh:team   -8.224e-05  6.452e-05  -1.275  0.20998
## dt_typeh:eps:team 1.327e-08  1.085e-08   1.223  0.22853
## dt_typenh:eps:team 2.331e-08  1.399e-08   1.667  0.10352
```

```
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 0.2403 on 39 degrees of freedom
## (14 observations deleted due to missingness)
## Multiple R-squared:  0.1991, Adjusted R-squared:  0.0759
## F-statistic: 1.616 on 6 and 39 DF,  p-value: 0.1687
```

$$\hat{y} = 0.8246 + 0.05356x_1 - 0.0001228x_3 + 0.00001326x_2x_4 - 0.00008224x_1x_4 + 0.00000001327x_2x_3x_4 + 0.00000002$$

where  $x_1 = 1$  if team has a non-holonomic drivetrain, 0 if team has a holonomic drivetrain

$x_2 = 1$  if team has a holonomic drivetrain, 0 if team has a holonomic drivetrain

$x_3$  = school expenditure per pupil

$x_4$  = team number

$\hat{y}$  = predicted win rate

#### 4.2.2 *F*-test for model utility

$$H_0 : \beta_1 = \beta_2 = \beta_3 = 0$$

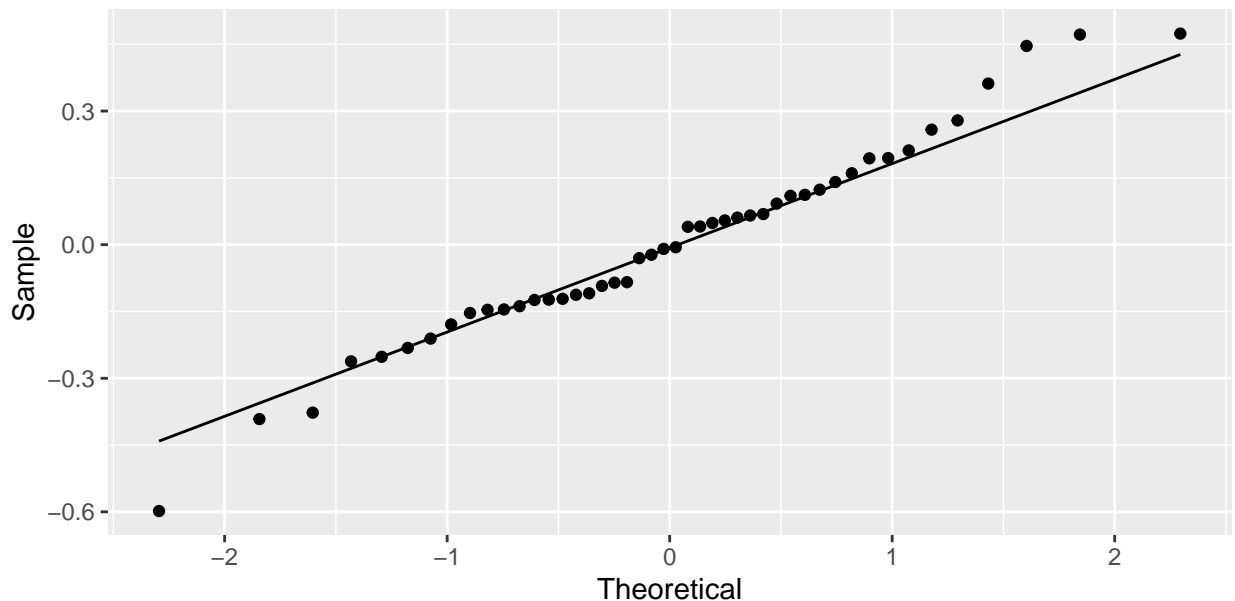
$$H_a : \sum_{i=1}^3 \beta_i^2 > 0$$

$$\alpha = 0.05$$

*F*-test for model utility

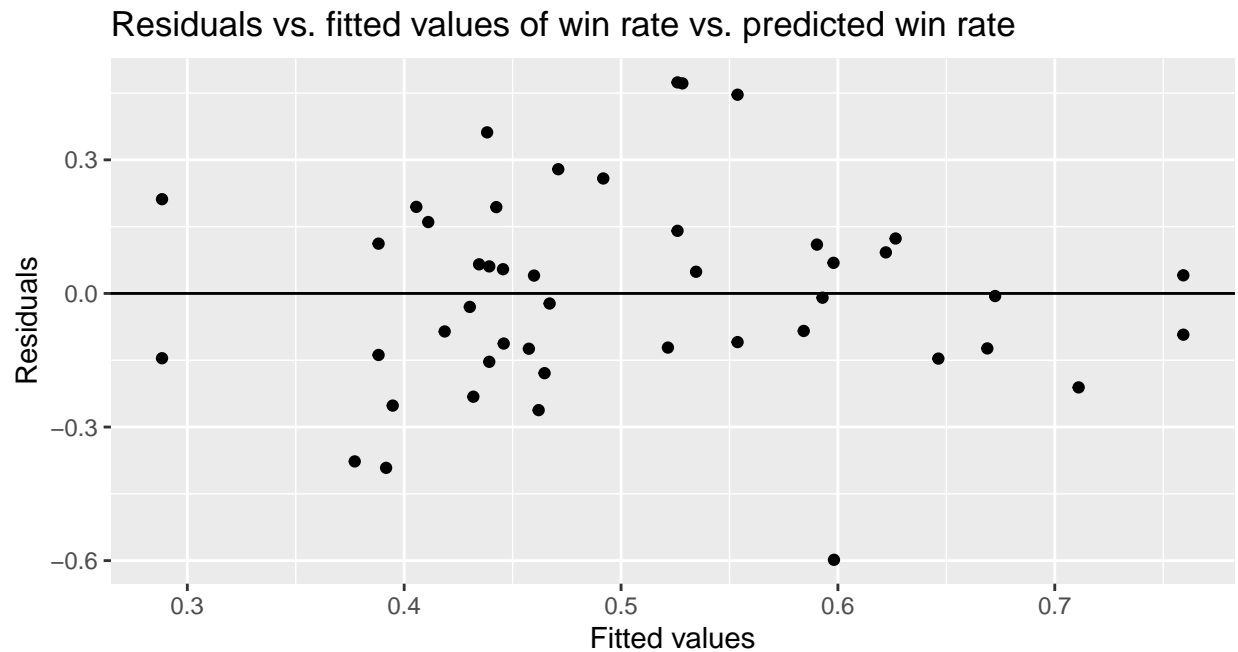
Normal:

Normal Q–Q plot of residuals of win rate vs. predicted win rate



Q-Q plot is approximately linear  $\Rightarrow$  residuals are approximately normally distributed

Equal Variance:



Residuals appear to be randomly distributed around 0  $\Rightarrow$  variance is approximately equal

$$F = 1.616$$

$$p = 0.1687 \text{ on } 6 \text{ and } 39 \text{ df}$$

Since our  $p$ -value (0.1687) is greater than  $\alpha$  (0.05), we fail to reject our null hypothesis. Therefore, we do not have enough evidence to support the alternative hypothesis.

## 5 Analysis

## 6 Conclusion

## 7 Bibliography